ATTITUDES, BEHAVIOUR AND PRACTICES IN THE USE OF EDUCATIONAL TECHNOLOGY IN MATHEMATICS TEACHING AND LEARNING

by

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Abstract

This study explored teachers' and learners' use of educational technology in mathematics teaching and learning environments. Mathematics is classified as one of the scarce skills subjects in South Africa. Any endeavour to try and improve the teaching and learning of mathematics is seen as a positive contribution towards mathematics education. Technologies are tools that offer possibilities for new approaches to teaching and learning as well as encouraging and sustaining learners' attention in mathematics.

The research focused on the influence of teachers' pedagogical practices and competence in mathematics on their use of educational technology in their classrooms. The research further established factors that influence learners' use of educational technology in mathematics. A mixed method research approach was conducted to understand teachers' and learners' attitudes, behaviour, and practices in the use of educational technology in mathematics. Two schools participated in the study. From school A, one teacher and 43 learners were involved in the study. The second teacher withdrew during the study. From school B, three teachers and 36 learners participated in the study. Data were collected through questionnaires, interviews, and class observations

A Technological Pedagogical Content Knowledge (TPACK) framework and social capital theory were used to help explain the influence of teachers' pedagogical practices and competence in mathematics on their use of educational technology and the factors affecting learners' use of educational technology in mathematics learning. The findings demonstrated that social capital, pedagogical practices, and the school's socio-economic status contribute to teachers' use of educational technology in mathematics. The teachers used desktop computers and laptops in mathematics mainly to present mathematics concepts and carry out the administrative tasks. The findings also showed that learners' use of technology in mathematics is consistent with their teachers' use of technology. Based on these findings it is suggested that teachers' school-based professional development is key to fostering technology integration in the schools. Also, schools should develop guidelines that exert pressure on teachers to use technology in their classrooms.

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Dedications

To my late father who was always proud of me. To my mother for being there for me. To the two men in my life, Larry and Seshoka. I am handing the baton over to you, my sons.

Declarations

I declare that this thesis is my own original work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

Mathomo M. Moila

09 June 2022

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Abbreviations and acronyms

ACE	Advanced Certificate in Education
ACOT	Apple Classroom of Tomorrow
AMESA	Association for Mathematics Educators in South Africa
ANA	The Annual National Assessments
CAPS	Curriculum and Assessment Policy Statement
CAS	Computer Algebra System
CBAM	Concerns Based Adoption Model
CDE	Centre for Development and Enterprise
CERI	Centre for Educational Research and Innovation
CK	Content Knowledge
CSIR	Council for Scientific and Industrial Research
CWOA	Commonwealth of Australia
DBE	Department of Basic Education
DGS	Dynamic Geometry System
DHET	Department of Higher Education and Training
DoE	Department of Education
EEA	Employment of Educators' Act
ELRC	Education Labour Relations Council
FET	Further Education and Training
GDE	Gauteng Department of Education
GET	General Education and Training
GNP	Gross National Product
GTTPD–ICT	Guidelines for Teacher Training and Professional Development in ICT
HOD	Head of Department
ICT	Information and Communication Technology

ICT-CFT	ICT Competence Framework for Teachers
ICT4RED	ICT for Rural Education Development
IDT	Innovation and Diffusion Theory
ISTE	International Society for Technology in Education
IT	Information Technology
LAN	Local Area Network
LoU	Level of Use
LPDoE	Limpopo Provincial Department of Education
MM	Motivational Model
MPCU	Model of PC
NCS	National Curriculum Statement
NEIMS	National Education Infrastructure Management System
OECD	Organisation for Economic Cooperation and Development
PC	Personal Computer
PCK	Pedagogical Content Knowledge
PIL	Partnerships In Learning
PK	Pedagogical Knowledge
RNCS	Revised National Curriculum Statement
SABC	South African Broadcasting Corporation
SACE	South African Council for Educators
SA-SAMS	South African School and Administration Management System
SCT	Social Cognitive Theory
SGB	School Governing Body
SITES	Second Information Technology in Education Study
SMT	School Management Team
SNSA	Schoolnet South Africa
SoC	Stages of Concern

SP	Spreadsheet Programme
SPTD	Senior Primary Teacher's Diploma
TAM	Technology Acceptance Model
TCK	Technological Content Knowledge
TK	Technical Knowledge
TLI	Teacher Laptop Initiative
TPACK	Technological Pedagogical Content Knowledge
TPB	Theory of Planned Behaviour
TPK	Technological Pedagogical Knowledge
TRA	Theory of Reasoned Action
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USA	United States of America
UTAUT	Universal Technology Adoption and Use Theory

Contents

Chapter 1

Introduction and the study overview

1.1 Introduction

Information and Communication Technology (ICT) tools are changing the world (Christie, 2008). These tools have a profound effect on how we live and work, creating what is referred to as a “knowledge–based society” (Anderson, 2008; Eftimie, 2012; Kozma, 2003; Punie, 2007). ICT tools enable us to collaborate in the creation of knowledge and to distribute and benefit from knowledge creation (Loveless & Dore, 2002; Tondeur, Cooper & Newhouse, 2010). Thus, it is important for teachers to have the knowledge and skills to facilitate in this kind of an environment. Teachers’ skills and knowledge are essential in ensuring that ICT tools are used in the classroom environment. Demetriadis et al. (2003) indicate that ICTs support educational reform by transforming learners into knowledge constructors. Thus, learners are enabled to take control of their learning. This has implications for pedagogy. A change in pedagogy effects the role of the teacher in the teaching and learning process. Depending on the teacher’s pedagogical orientation, these tools require the teacher to assume a facilitative role. Christie (2008), Selwyn (2004) and Wade (2002) see ICTs as a solution to developmental problems. ICT tools are not in themselves change agents for education, but when used as tools that are integrated with the curriculum, they could make a difference in education (Muir–Herzig, 2004).

Schools are also trying to keep up with changes that are taking place globally so that they can develop citizens that can function in some knowledge–based society. Schools are part of the society; their operations thus reflect societal factors. Therefore, schools are meant to reproduce and uphold the culture of society (Christie, 2008). Schools fulfil these purposes by providing an environment where teaching and learning can take place, preparing people for the world of work beyond the school, fostering nation building and citizenship, teaching the values of society to children and young adults and developing a whole individual (Christie, 2008). To fulfil these roles, schools need to be responsive to social demands and challenges, including the challenge of coping with a technology-driven global economy.

Internationally most countries are employing ICTs in teaching and learning to improve the quality of education (Belland, 2009; Kozma, 2003; Player-Koro, 2012) and increase educational gains on the part of learners (Pelgrum & Voogt, 2009). This is because ICT tools have interactive capabilities, empowering learners to learn independently and enabling them to access more learning resources (Jourbert, 2013). Despite the mentioned benefits of these tools, there are difficult conditions that affect the successful integration of ICT into teaching and learning. Bingimlas (2009) called these conditions barriers. He grouped the barriers into the following categories:

- Teacher level barriers, which include lack of confidence among teachers, lack of competence in ICTs, resistance to change and attitudes towards the use of ICTs.
- School level barriers, which include lack of time, lack of effective training, lack of access and lack of technical support.

Schools find themselves in a dilemma when preparing learners for the world of work. They need to choose between teaching in the old ways and imparting new skills and competences to the learners. To impart new skills and competences, schools can provide learning opportunities that incorporate ICT for their learners. On the other hand, the use of ICT continues to create pedagogical and didactical challenges for teachers in schools worldwide (Hodgkinson-Williams, 2005, as cited in Naicker, 2010). Challenges include the development of effective teaching and learning strategies that incorporate the use of ICT in teaching and learning by teachers (Hartley, Treagust & Ogunniyi, 2008). Hartley et al. (2008) indicate that it is important for teachers to understand the different ways in which ICT tools could facilitate learning and the types of learning these tools support. This will enable schools to consider their contexts and ensure that skills and competences are developed based on these contexts (Ertmer & Ottenbreit-Leftwich, 2010).

South Africa has its own fair share of challenges in the use of technology in its schooling system. Despite having had a democratic government for more than two decades, the schooling socio-economic inequalities of the previous dispensation are still clearly visible. These inequalities have implications for the availability and accessibility of technological resources. However, the South African government has made a commitment to improve the ICT skills of its people and bridge the digital divide by targeting previously disadvantaged groups (Department of Education (DoE), 2004). This is done by providing technological tools to schools in these groups. It is therefore important to understand the impact these tools will have and whether they will afford an effective teaching and learning environment.

Despite countries' endeavours to try to use ICTs in teaching and learning, usage is still low, particularly in Africa (Hennessy, Harrison & Wamakote, 2010). This is largely attributed to factors such as lack of technology and software in schools, limited expertise on the part of teachers regarding ICT usage, and teachers' beliefs and knowledge about how to use ICT tools in teaching and learning (Bingimlas, 2009; Ertmer, 2005; Hennessy et al., 2010). Belland (2009) indicates that with the ubiquity of ICT tools and the intensity of teachers' trainings in the United States of America (USA), Europe and a few Asian countries, educational technology usage in teaching and learning should have had an impact on how teaching and learning is taking place in those contexts. The most important single factor contributing to change of practice where ICTs are utilised is the teacher (Belland, 2009). Thus, for effective technology usage, the teacher plays a significant role in ensuring that technological tools are implemented effectively.

Drijvers, Doorman, Boon, Reed and Gravemeijer (2010) emphasise the importance of the role of the teacher in effective technology usage in a mathematics learning environment. They argue that technology cannot and never will be a substitute for the teacher. Therefore, there is a need to investigate how teachers can better use technologies in their classrooms. (Shulman, 1986, as cited in Koehler et al., 2014) proposed a special type of knowledge for effective teaching, which he called Pedagogical Content Knowledge (PCK). This is explained as an understanding of the subject matter together with the development of appropriate instructional strategies and skills appropriate for teaching and learning. Mishra and Koehler (2006) extended PCK to Technological Pedagogic Content Knowledge (TPACK). This extension considers the role that technology knowledge can play in effective teaching and learning. In this study, TPACK was used to establish the relationship between teachers' pedagogical practices and their use of technology in mathematics teaching.

In most South African high schools ICT resources are acquired through donations or government and private sector partnerships (Isaacs, 2007; SNSA,2015). Not many studies have been conducted on how these tools are used in mathematics teaching and learning in low a socio-economic context. A study by Moila (2007) found that the availability of ICT tools did not lead to abundant use of these tools in the mathematics teaching and learning environment. The study was conducted in one rural school in Limpopo province. A rural area in this context is explained in terms of communal land tenure, villages, or scattered groups of dwellings, typically located in one of the former homelands, with the presence of one or two small towns in the area (Palmer & Sender, 2006, as cited in Atkinson, 2014). In this kind of settlement there are very few economic activities. A similar study was conducted by Mogodi (2013) in another rural school in Limpopo province. Mogodi (2013) found that mathematics teachers were using laptops loaded with mathematics software programs. These two studies revealed that in instances where ICT tools were used, they were used by the teachers and for low level learning. In both schools the ICT resources had been acquired through donations. Knowledge of how ICT resources are used in mathematics could assist schools that are using these tools with strategies on how to use ICT effectively to enhance mathematics teaching and learning.

This study investigated the influence of teachers' pedagogical practices and mathematics competence on their use of educational technology in mathematics teaching and learning, and the factors that affect learners' use of technology in mathematics. Competence and pedagogical practices are important in understanding the reasons for use or non-use of technologies by both teachers and learners, the ways in which they are used and their effect on the teaching and learning of mathematics.

1.2 Aim of the Study

Educational technology tools were found to contribute towards the social and economic development of countries like China, Malaysia, and Singapore (Kozma, 2008). The aim of this study is to investigate the influence of teachers' pedagogical practices and mathematics competence on their use of educational technology in a mathematics teaching and learning environment, and the factors affecting learners' use of technology in mathematics in two secondary schools in Mopani District in the Limpopo Province in South Africa. This study therefore sought to gain a deeper understanding of the relationship among ICT usage, competence, and practices in mathematics. This understanding helped to explain the influence of attitudes, behaviour, and practices in the use of ICT on mathematics teaching and learning in the investigated schools; it also helped in developing pragmatic solutions to challenges related to attitudes, behaviour, and practices in the use of ICT in mathematics.

1.3 Rationale for and contribution of the study

In most South African schools, teachers and learners have little or no say in the acquisition of educational technology resources. Usually, the responsibility for purchasing these resources lies with the School Governing Bodies (SGBs) and the School Management Teams (SMTs). Owing to this limited involvement of teachers, or lack thereof, they do not have a sense of ownership of these tools. Furthermore, decisions taken regarding the acquisition of technology are rarely based on any research findings on technology integration into the teaching and learning environment (Baylor & Richie, 2002). The success of any educational reform is measured by the extent to which it is adopted by teachers (Yusuf et al., 2012).

The South African government has made commitments to the use of technology in teaching and learning. This investigation has helped shed light on factors that enhance and constrain teachers' adoption and use of technology in teaching mathematics at secondary school level. The main contribution of this study is that it sheds light on how best teachers steeped in the traditional teacher–centred pedagogy could improve their use of technology in the teaching and learning of mathematics. Traditional pedagogy does not promote creativity, problem solving and collaboration, which are prominent skills required for meaningful mathematics learning. The study generated useful insights into teacher training programmes. The findings will act as a guideline to the responsible South African officials to take appropriate actions that will enhance the use of technology in mathematics.

Most studies conducted in disadvantaged South African schools have focused on the general use of ICT tools (Beyers & Hlala, 2015; Hodgkinson-Williams, Siebörger & Terzoli, 2007; Madida, Naidoo & Rugbeer, 2019; Makgato, 2014; Mathevula & Uwizeyimana, 2014). A few studies focused on mathematics teaching and learning targeted at using a specific ICT tool in teaching mathematics (Mokotjo & Makgalwa, 2021; Roberts & Vänskä, 2011; Tachie, 2019). These studies showed that the use of ICT in mathematics remains a challenge in South African schools. This study has made several significant contributions to the existing body of knowledge on the appropriate use of technology in mathematics teaching and learning in secondary schools.

Also, the study made a theoretical contribution by showing that learners' use of educational technology is influenced by teacher attributes and classroom practices. Most studies focused on factors such as gender, attitudes, resources, and contextual factors. Learners' competence in the use of technology is important, as they need technological competence to navigate their studies in higher education.

Lastly, the study enhances the literature regarding the application of the TPACK framework in an empirical study by investigating the use of technology in mathematics teaching in secondary schools. TPACK context is described from the schools' physical location. However, this study has shown that physical location together with social trust, access to expertise and social pressure can enhance the use of TPACK framework in empirical research.

1.4 Statement of the Problem

Mathematics teaching plays an important role in the curriculum. It is through mathematics that higher order thinking skills are developed for the achievement of relevant pedagogical outcomes (Gonzalez & Herbst, 2009). These pedagogical outcomes include, among others, conceptualisation, abstraction, generalisation, problem solving and information processing (Niewoudt & Golightly, 2006, as cited in Leendertz et al., 2013). In South Africa, mathematics is classified as one of the scarce skills subjects. Scarce skills subjects are those subjects that open a plethora of opportunities for the learners but do not have enough human resources within the country for teaching. In most instances, foreign nationals are used in our schools to teach these subjects. Mathematics is also used more than any other subject to filter career options. South Africa is still significantly underperforming in mathematics education (The Centre for Development and Enterprise (CDE), 2013). Schools are faced with the daunting task of trying to get more learners to register for pure mathematics in grade 10 and thus, very few learners register for pure mathematics in grade 12. Mathematics is not compulsory in grades 10, 11 and 12. Learners have a choice between pure mathematics, and mathematics and mathematical literacy. Many learners opt for mathematics and mathematical literacy.

Furthermore, most of the learners who register for mathematics do not perform well in the subject. This poor performance was seen in the analysis of mathematics results in the Annual National Assessment (ANA) tests in grades 3, 6, and 9 and the grade 12 final year results. In 2011 when ANA was introduced, the national average scores of learners in grades 3 and 6 were 28% and 30% respectively (Department of Basic Education (DBE), 2011a). In 2012 ANA was also introduced in grade 9. Table 1.1 below shows the performance of learners who achieved at least 50% in the ANA tests in grades 3, 6 and 9 in 2012, 2013 and 2014 (DBE, 2014).

Table 1.1:

Percentage of learners achieving at least 50% in mathematics in the ANA tests

Grade	Percentage of learners achieving 50% or more		
	2012	2013	2014
3	36	59	65
6	11	27	35
9	2	2	3

Source: Department of Basic Education, 2014, p. 10

From Table 1.1 it is evident that the results of grade 3 learners are better than those of grades 6 and 9, and grade 6 learners perform better than those in grade 9. To address this problem, concerted efforts to improve the situation need to be made, and strategies to remediate the situation must be developed. However, the ANA tests have since been suspended owing to dissatisfaction from the teachers’ unions.

Looking at Grade 12 national mathematics results for the same period as above, table 1. 2 below gives a picture of learners' performance.

Table 1.2:

Grade 12 learners' performance in mathematics: 2012 - 2014

2012			2013			2014		
No. Wrote	Achieved at 30% & above	% achieved	No. Wrote	Achieved at 30% & above	% achieved	No. Wrote	Achieved at 30% & above	% achieved
225874	121970	54	241501	142666	59.1	225458	120523	53.5

Source: Department of Basic Education, 2015, p.7

Tables 1.1 and 1.2 paint a picture of mathematics performance in primary and secondary schools. Performance in mathematics remains generally poor in the schooling system. As a mathematics teacher I am eager to explore different strategies that could assist in improving learners' performance in mathematics.

Technologies are tools that offer possibilities for new approaches to teaching and learning as well as encouraging and sustaining learners' attention in mathematics. In mathematics, technologies provide learners with opportunities to simulate various complex scenarios, processes, and phenomena; generate visualisation and explorations of mathematical content; and connect dynamic notations, link representations and operations with symbols (Baya'a & Daher, 2013; Thorvaldsen, Vavik & Salomon, 2012). Technologies also have the potential to allow students to explore and reach an understanding of mathematics concepts (Ittison & Zewe, 2003, in Agyei & Voogt, 2011). Noor-Ul-Amin (2013) further indicated that the appropriate use of technologies in teaching and learning of mathematics supports conceptual development in mathematics, enables mathematical investigations by learners and teachers, influences how mathematics is taught and enables interaction of teachers with learners, parents, peers, colleagues, and the global society. These approaches promote higher order thinking skills, and better problem-solving strategies, which are the skills needed in mathematics teaching and learning.

These benefits are only realisable if teachers can appreciate that the meaningful use of technology requires new competencies and appropriate approaches to pedagogy. Thus, teachers' competencies in the use of technologies and their effective use of technologies in teaching and learning, are some of the important factors that shape technology-mediated teaching and learning. Technology-mediated teaching is related to teachers' technological knowledge, content knowledge and pedagogical knowledge. These three knowledge domains are what Mishra and Koehler (2006) developed into the TPACK framework. TPACK is the knowledge that teachers need in order to use technology effectively in their classrooms. The TPACK framework is discussed in Chapter 3 of this study. However, TPACK is not the only technology framework model that can be used. Other models and their inappropriateness for this study are explained in Chapter 3 of this study.

This study sought to establish the role the above-mentioned factors played in the use of educational technology in the teaching and learning of mathematics in grades 10 to 12 at two schools in Limpopo Province, South Africa. The following key research questions were addressed in the study:

How do teachers' pedagogical practices and competence in mathematics influence their use of educational technologies in mathematics teaching and learning?

What factors influence learners' use of educational technology in mathematics learning?

The following sub-questions formed part of the main question:

1. What do teachers and learners do with technology in mathematics instruction?
2. What benefits do teachers and learners appreciate in using educational technology in mathematics?
3. What are teachers' and learners' attitudes towards the use of educational technology in mathematics?
4. How does teachers' pedagogy affect their use of educational technology?

1.5 Delimitation of the Study

In this study, two secondary schools in Mopani District of Limpopo Province were chosen. The study used a mixed methods approach with a questionnaire, lesson observations, and both individual and focus group interviews to gain a deeper understanding of teachers' and learners' uses of educational technologies in mathematics teaching and learning environment. The schools are referred to as school A and school B. In school A, one mathematics teacher and 43 learners participated in the study. In school B, three mathematics educators and 36 learners participated in the study. The field work was conducted during the first term of the 2018 school calendar year. Questionnaires were distributed outside the normal school hours. Interviews were also conducted outside the normal school hours.

1.6 Structure of the Research Report

Chapter 1 gives an outline of the study. It describes the aim of the study, the purpose of the study, the statement problem and the delimitations of the study.

Chapter 2 locates the study in the South African context. The significance of e-education is discussed together with its implementation in South African schools. The chapter gives the context in which educational technologies in the South African education system are used and the challenges that are faced in their usage. This helped in contextualising the data analysis and interpretation presented later in the study.

Chapter 3 provides a review of literature on competence as a concept and its role in mathematics and technology adoption. Different technology adoption models are discussed, and their strengths and weaknesses highlighted. The chapter further discusses ICT and pedagogical practices considering the technology adoption models. Gaps that need to be addressed by this study are also outlined.

Chapter 4 gives a framework of the philosophical considerations that form the lens through which my study was conducted. The chapter focuses on the TPACK framework and social learning theories, specifically social capital theory.

Chapter 5 outlines the research methodology adopted in the study. In this chapter I argue that a mixed method approach was the most appropriate design for this study. I also justify the selection of the data collection strategies adopted and data analysis procedures followed by considering the challenges in mixed method research, specifically reliability and validity, credibility as ‘communicative validity’ and ‘trustworthiness’, generalisability, and the issue of coding, a process of data analysis.

Chapter 6 provides an analysis and discussion of the two schools. The chapter reports on teachers’ competence in mathematics and the use of educational technology in mathematics teaching. The chapter further describes teachers' pedagogical practices. The chapter continues by detailing learners' use of educational technology in mathematics learning and the influence of teachers on learners' use of educational technology in mathematics learning.

Chapter 7 presents a summary and conclusion of the entire study. The chapter also outlines some implications and recommendations for further research and closes with a final reflection on the study.

1.7 Chapter Summary

This chapter provided the framework of this study. The chapter included the aim of the study, the rationale, the purpose of the study, a statement of the problem, and the limitations of the study. The chapter also included an account of the structure of the thesis by briefly describing the contents of each chapter.

In the next chapter, I provide a background of ICT in education in the South African context.

Chapter 2

South Africa's ICT in Education Context

2.1 Introduction

South Africa, like any other country, wants to stay competitive and continue to develop socially and economically. Education is seen as one of the factors that will contribute to the country's social and economic competitiveness. Countries that have moved from being developing countries to emerging economies have done so through transforming their education systems. China, Singapore, and Taiwan are examples of such countries (Kozma, 2008). Education has helped them to break the cycle of poverty and has contributed to their economic and social development (United Nations Educational, Scientific and Cultural Organisation (UNESCO), 2004). One of the drivers of educational transformation is the use of ICT in teaching and learning, as these tools have the potential to deliver education to learners across space and time, enable collaboration and cooperation among stakeholders in education and share resources among themselves (Kozma, 2005; Kozma, 2008).

The South African landscape changed after 1994. Post-1994, all sectors of government started advocating for transformation to address the imbalances of the past. Policies were put in place to address these injustices (Christie, 2008) and a new curriculum was introduced. This happened at the time of emerging globalisation (Christie, 2008). To keep up with the rest of the world, the South African government, in partnership with the private sector, made a significant investment in educational technology resources. However, this investment has done very little to address the imbalances of the past. This is evident from the National Education Infrastructure Management System (NEIMS) report on availability of computer centres in South African government schools (Department of Basic Education (DBE), 2019). The report showed the uneven spread of ICT infrastructure across provinces. Indeed, the legacy of the apartheid era still lingers and the gap between the rich and poor is ever widening. The spread of computers into South African schools is illustrated in table 2.1.

Table 2.1:

Computer Penetration into South African Schools, 2019

Province Name	Number of Schools	With Computer Centre	% With Computer Centre	Without Computer Centre	% Without Computer Centre
Eastern Cape	4234	528	12.47	3691	87.18
Free State	852	420	49.3	432	50.7
Gauteng	1975	1597	80.86	378	19.14
Kwazulu Natal	5031	1837	36.51	3194	63.49
Limpopo	3390	549	16.19	2841	83.81
Mpumalanga	1518	653	43.02	865	56.98
North West	1204	589	48.92	615	51.08
Northern Cape	415	255	61.45	160	38.55
Western Cape	1203	792	65.84	411	34.16

Source: DBE, 2019, p. 4

Table 2.1 shows that provinces do not have equal resources. The reason for this is that the National Department of Education assigned the implementation of the e-education White Paper to individual provinces (DoE, 2004). Provinces are not equally resourced because of the legacy of the past. Provinces that fell largely within the former homeland system are the ones with least resources. They must first address the problems of the shortage of classrooms and toilets before they can contemplate equipping the schools with technology. Despite these provincial challenges, it remains the responsibility of the Department of Basic Education (DBE) to address the social and economic disparities across the provinces and provide access to educational technology tools to all schools in terms of educational technology professional development and infrastructure. However, private sector partnerships with the provinces provide some relief for provincial budgets as most of their technologies are sourced through public-private sector partnership initiatives (Isaacs, 2007). Usually, secondary schools are given donations based on their final grade 12 performance, whereas in other schools governing bodies work hard to raise funds for the purpose of equipping schools with technology infrastructure.

Furthermore, within the same provinces, schools show disparities in terms of infrastructure and teacher development. Independent and former model C schools are better resourced than schools that served the marginalised communities prior to 1994.

Table 2.1 shows that Gauteng, Western Cape, and Northern Cape are the leading provinces in terms of the number of computers for teaching and learning. This is because they incorporated only a small area of the former homeland system. They have fewer socio-economic problems than other provinces. Gauteng is the economic hub of South Africa and can thus afford to provide technology access to all its schools in the province. However, even though these provinces have relatively good access to technology, usage nevertheless remains low (Chigona, Chigona, Kayango & Kausa, 2010; Howie & Blignaut, 2009; Madida, Naidoo & Rugbeer, 2019; Makgato, 2014).

The above discussion illustrates how the South African government responded in relation to ICT in teaching and learning. The discussion shows a significant experience of more than two decades of the use of ICT in teaching and learning (Isaacs, 2007; Lundall & Howell, 2000). However, despite this experience, many schools in disadvantaged communities have yet to fully experience the use of ICT in teaching and learning. A study conducted by Lundall, and Howell (2000) showed that in the 1990s, primary school computer usage focused mainly on computer literacy, emphasising basic computer principles and word processing, while most high schools focused on computer literacy, computer studies and advanced skills such spreadsheet, file management, database management and computer programming. However, the picture is now changing as more experience is gained in the use of ICT in teaching and learning (Howie & Blignaut, 2009). In this chapter, I chart the path that South Africa has followed in the use of ICT in teaching and learning. Government, private sector, and nongovernmental initiatives are discussed, together with their role in trying to improve teachers' instructional practices for economic and social development of our country, South Africa.

2.2 ICT Initiatives in South Africa

The South African government published the e-education policy as one of the initiatives to promote the use of educational technology in teaching and learning (DoE, 2004). The policy envisaged enhancing teaching and learning with the use of ICT. In addition to the e–education policy, there are other initiatives in place to ensure the employment of educational technologies in teaching and learning. However, some of them do not align to the e–education policy while others have fallen by the wayside (Howie & Blignaut, 2009; Isaacs, 2007). In developing countries, ICT initiatives often focus on creating an ICT presence in schools, while others target capacity building of both learners and teachers (Howie & Blignaut, 2009). ICT initiatives in South Africa focus on different aspects of ICT use. Some focus on the provision of access to infrastructure, others on professional development and training of teachers, content development, or a combination of the above factors. These initiatives involve public-private sector collaboration. A discussion of the different initiatives according to their focus area(s) follows later in this chapter.

South Africa is an unequal society; most of the population live in poverty while a small portion are wealthy. These disparities influence access to ICT in the classroom, presenting the country with a further challenge. Class sizes are greater in rural and peri–urban schools than in urban schools. This has resulted in overcrowding and limited availability of teaching and learning resources in rural and peri-urban schools. Even though the proportion of schools with computers increased from 18 percent in 1998 to 38 percent in 2006 (Pelgrum, 2008, cited in Blignaut et al., 2010), many rural schools still experience electricity and network coverage problems. Thus, in ensuring access to ICT infrastructure, the government is considering digital equity in addressing the country's disparities to bridge the digital divide (DoE, 2004). In the next paragraph, the concepts 'digital divide' and 'digital equity' are discussed.

The digital divide debate has been going on amongst countries and within individual countries for some time and a great deal has been written about it (Light, 2001; Selwyn, 2004; Singh, 2004; Wade, 2002). The digital divide is sometimes understood from the perspective of the uneven distribution of resources, which results in inequality (Light, 2001; Singh, 2004; Wade, 2002). However, Selwyn (2004) suggests that the digital divide incorporates four prominent aspects:

- The meaning of ICTs: These are a range of heterogeneous technologies, types of information and resources which are not necessarily analogous to each other.

- The meaning of access: Access as it refers to making ICTs available to all is ill defined. The definition tends to obscure subtle disparities in the context of ICT access. ICT should be defined in terms of time, cost, quality of technology and the environment in which it is used, as well as more qualitative concerns of privacy and ease of use. In addition, access needs to be defined from an individual's perspective, that is, whether people have access at all and the hierarchy of access amongst those that do. Similarly, access to material without the required knowledge, skills, and support to use the technology is useless.

- The relationship between access to ICTs and use of ICTs: Technological determinism asserts that access to ICTs will lead to ICT usage. Even if the ICTs are used, there is no guarantee that they will be used for meaningful engagement. Engagement with ICTs is concerned about how people develop relationships with ICTs and how they can make use of social resources, which make access useable.

- Consequences of engagement with ICTs: Outcome, impact, and consequences of accessing and using ICTs are very important. Access to information cannot be uniformly available to all. Specialised information needs specialists to engage with it meaningfully. Consequences of meaningful engagement with ICT are seen in terms of the effects on an individual's and on communities' quality of life, that is, the extent to which technology use enables individuals to participate in and be part of society.

On the other hand, Howie and Blignaut (2009) showed that digital equity comprises five components:

- Access to hardware, software, and connectivity to internet;
- Access to content in local language;
- Access to create, share and exchange digital content;
- Access to educators who know how to use tools and knowledge and
- Access to research on the application of technology for leaning.

However, access in Howie and Blignaut's (2009) context referred to making resources available. This is what Selwyn (2004) called the limited explanation of access. Looking at digital equity composition, it is evident that it drives ICT initiatives in South Africa. Initiatives are focusing on changing the status quo and particularly benefiting the disadvantaged groups to increase their access and use. However, in South Africa, the best ICT infrastructure is available in several urban schools, while rural and peri–urban areas have inadequate and primitive ICT infrastructure (Howie & Blignaut, 2009).

Howie and Blignaut (2009), referring to the Second Information Technology in Education (SITES) 2006 secondary study, pointed out that essential conditions necessary to use ICT effectively in mathematics and science in grade 8 were not yet in place in most South African schools. These conditions included access to hardware and software, availability of technology, obstacles to pedagogical goals, location of ICT, provision of staffing and channels for teachers to acquire skills and technology. Looking at these conditions, it is evident that most of them are associated with ICT infrastructure. Howie and Blignaut (2009) indicated further that, in cases where hardware and software were in place, the location of ICT in schools required a great deal of attention. They recommended placing ICTs in classrooms rather than in a computer laboratory, as learners have easier access to classrooms than a computer laboratory. The problem with placing ICTs in a computer laboratory is scheduling to accommodate everybody in the school. However, nothing has changed, as indicated in table 1.2. ICT infrastructure is still reported in terms of computer laboratories that the schools have. Schools might have computer laboratories with computers that are not in operation.

Despite these challenges relating to ICT integration in teaching and learning, table 1.2 indicates a slight improvement in the availability of computer laboratories compared to the year 2009 (DBE, 2009a; DBE, 2019). However, when Howie and Blignaut (2009) compared South Africa' s progress in terms of the use of ICT in teaching to that of countries with similar developing conditions which have a lower gross national product (GNP) per capita but spend a smaller percentage of their budget on education, they concluded that South Africa's progress is slow. This confirms the view that the digital divide cannot always be explained in terms of the 'haves' and the 'have-nots'. For South Africa to achieve digital equity, it should review its norms and standards for funding to resolve its financial challenges posed by the costs of providing access to ICT infrastructure, technical support, maintenance, upgrades, and repairs of ICT infrastructure (Howie & Blignaut, 2009). In addition, public-private sector partnerships are important in this regard to relieve government of some of the cost burden. The section below gives a detailed description of how the South African government is trying to address the digital divide through infrastructure rollout.

2.2.1 Infrastructure Initiatives

ICT infrastructure in this study refers to computer hardware, software, internet access, mobile technology and broadcasting technology that are used in teaching and learning. Different stakeholders provide different types of technological equipment in their endeavour to promote the use of ICT in teaching and learning. One cannot overemphasise the importance of ICT infrastructure in providing an enabling environment for the use of ICT in teaching and learning. Access to ICT infrastructure is one of the key elements supported by the e–education policy framework for the use of ICT in teaching and learning (DoE, 2004).

ICT infrastructure plays a crucial role in technology adoption, which contributes to the culture of technology usage in teaching and learning. The extent to which a country can participate and benefit from ICTs depends on the country's digital divide as well as availability of ICT infrastructure and technical know-how in the country (UNESCO, 2004). ICT infrastructure gives a true picture of the specific operational environment in institutions. A review study conducted by Basak and Govender (2015) found that ICT infrastructure was among the major factors contributing to technology adoption in teaching and learning. The review involved a Google, Google Scholar and Durban University of Technology library database search using the search terms “enhancing adoption in teaching and learning” and “enhancing ICT implementation for teachers”. The aim of their study was to develop a conceptual framework regarding the factors inhibiting teachers’ successful adoption and implementation of ICT in teaching and learning. The ICT infrastructural problems that were identified were: limited resources, the high costs of ICT resources, lack of access to a reliable energy source, and corruption where huge budgets are passed to buy peripherals to improve teaching and learning but little improvement is seen because of corruption (Basak & Govender, 2015).

Mulwa and Kyalo (2011) conducted a survey in Kitui district in Kenya. The survey investigated the influence of ICT infrastructure on readiness to adopt e–learning in secondary schools. They found that ICT infrastructure had a positive and significant influence on schools’ readiness to adopt e–learning. However, they further indicated that ICT infrastructure is dependent on the availability of a reliable source of energy.

As indicated in table 2.1 above DBE is also trying its best to supply the relevant hardware to support e-education. However, the table does not indicate the number of computers stocked per computer laboratory. In addition, the information does not indicate learner-computer ratio. The table indicates the number of schools with computers per province. Schools are also not equal in size. In big schools where the learner population is 800 and above, the model will result in a very high learner-computer ratio that will have implications for access in terms of school timetabling. Also, the model does not consider initiatives that emerged recently like the Gauteng paperless classroom which is explained below.

The National Department of Basic Education also tried to encourage schools to perform better in mathematics and sciences. This was done in secondary schools that include grade 12. Well-performing schools were rewarded by being placed in a category called Dinaledi schools (Taylor, 2007). All Dinaledi schools were equipped with ICT infrastructure and other resources that would enable them to perform at their best in mathematics and science subjects (Taylor, 2007). Despite the provision of this ICT infrastructure, schools are supposed to find funds to maintain and sustain the ICT infrastructure. In addition, not all schools have access to electricity.

According to a National Education Infrastructure Management System (NEIMS) report, seven percent of schools have no access to electricity supply, while three percent have an unreliable electricity supply (DBE, 2019). This model has the potential to create a digital divide in this kind of society.

In addition to supporting schools, there was also an initiative to support educators with ICT infrastructure, called the teacher laptop initiative (TLI) project. This project was an agreement that was reached between the Education Labour Relations Council (ELRC) and teachers' unions (DBE, 2009b). Every school-based educator employed in terms of the Employment of Educators' Act (EEA) and occupying a permanent teaching post, was eligible to participate in this initiative. It involved providing a subsidy for teachers on their laptop purchase, including a subscription to internet access. This project started in July 2009. However, to date, there is no written evidence of the number of teachers who benefited from this project and whether the project was ever kick-started.

At the provincial level, Gauteng province has its own ICT infrastructure initiatives. This can be seen in table 2.1. Gauteng province has the highest number of computer centres. The Gauteng Online project, which was managed by Gauteng province, involved establishing a computer laboratory with 25 workstations and, internet and e-mail access, to be used for curriculum delivery by all Gauteng schools. In 2010, Gauteng online had 1 665 schools with fully functional computer laboratories (Mpehle, 2011). According to Isaacs (2007), Gauteng Online goals were to:

- Contribute towards building the human resources capacity of the province and the country through the provision of quality education;
- Contribute towards stimulating positive economic activity in the country through the creation of a strong local ICT industry that has a capacity for ICT development and innovation;
- Enhance the efficacy of government for improved service delivery and a better life for all;
- Position the province at the cutting edge of change through technological innovation and
- Bridge the digital divide.

To achieve these goals, the Gauteng Department of Education (GDE) sought private partnership collaboration that designed, built, and ran end-to-end solutions for a range of Gauteng schools (DoE, 2006). However, the project dwindled along the way. More recently there has been a tablet initiative project, 'paperless classrooms', initiated by the Education Member of the Executive Council in the same province (Gauteng Province, 2015). As it is still in its initial stage, there is not much research about it.

Another provincial ICT initiative that provided infrastructure was the Khanya project in the Western Cape. Khanya, which means light, started in 2001 and was intended to make education shine in the Western Cape, especially in previously disadvantaged schools. Its aim was to have every educator in every school of the Western Cape empowered to use appropriate and available ICT to deliver curriculum to every learner by 2012 based on the following objectives (Khanya, 2008):

- Increase educator capacity and effectiveness by means of technology;
- Harness the power of technology to deliver the curriculum;
- Enhance the quality of the learning experience in the classroom, providing an opportunity for students to benefit from a variety of learning styles;
- Integrate appropriate and available technology into the curriculum delivery process as different technologies mature;
- Use technology to assist all disabled students to maximise learning;
- Improve Senior Certificate and Further Education and Training (FET) results, as well as student outcomes in all grades, in terms of number of passes and quality of results;
- Increase the number of students taking mathematics and science at the higher grade and those coping successfully;
- Increase the number of students qualified and competent to enter tertiary education institutions after obtaining their Senior Certificates and
- Improve numeracy and literacy in lower grades to build a stronger foundation for future grade 12s.

At the end of 2008, the Khanya report indicated that 1 007 schools had been provided with technology facilities, typically computer laboratories, consisting of between 25 and 40 computers per school (local area network (LAN) and Internet linked). The report further indicated that approximately 39 022 PCs had been deployed in the above schools and a total of 21 500 educators had received basic IT training. This has resulted in benefitting approximately 750 000 learners from using the technology daily. The report also indicated the financial commitment towards the project. The expenditure for 2008/2009 was R93 million and a further R98 million was budgeted for 2009/2010 by the Western Cape Province (Khanya, 2011). The required infrastructure was being prepared at a further 150 schools. The Khanya project won a few awards for its successful achievement (Khanya, 2011). The awards include among others the Silver Award at the Western Cape Premier Services Excellence Awards in 2005 and 2006, the Technology Top 100 (TT100) Leader in Empowerment Award in 2006 and a Gold Award from the Impumelelo Innovation Award Trust in 2007. As indicated above, the project ended in 2012 as planned and achieved almost all its objectives. Despite winning the mentioned awards, schools in disadvantaged communities had encountered challenges and had thus made limited use of ICT in their teaching (Chigona et al., 2010)

Despite the above-mentioned infrastructure initiatives, there is a dearth of studies on the role played by infrastructure in the use of educational technology in mathematics in Limpopo province schools. Furthermore, most of the literature is limited to reports of how technological tools were distributed in the different schooling communities (Beyers & Hlala, 2015; Mathevula & Uwizeyimana, 2014). The next section provides a detailed explanation of professional development category initiatives.

2.2.2 Teacher Professional Development and Training

Teacher professional development and training are extremely important to the success of educational technology within teaching and learning. Teachers' ability to use the technology affect their willingness to integrate them in their classroom. If teachers do not have the knowledge and skills to use the technology in teaching and learning, the likelihood is that they will not use them. However, some teachers, even though they have undergone ICT professional development, still do not use ICT in teaching and learning. Mouza (2011) attributed this to the shortage of high–quality professional development programmes, while Nkula and Krauss (2014) indicated that teachers' beliefs about teaching and learning contribute to their use or non-use of educational technology in teaching and learning.

One of the priority goals for the DBE is to improve the professionalism, teaching skills, subject knowledge, and computer literacy of teachers throughout South Africa (DBE, 2011b). However, teachers do not have time for professional development to ensure the achievement of this priority goal. This is because professional development programmes take place after normal working hours. Teachers have commitments and usually do not attend these programmes. To meet these in-service training challenges, government envisages much greater use of distance education, particularly e-education (DBE, 2011b). In addition, the DBE wanted to create an enabling environment for the formation of local learning communities of practice as part of in-service programmes. According to the DBE (2011b), in many countries more than 30 percent of teachers make use of communities of practices and these have positive effects on teaching and learning. In addition to the challenges of professional development that South Africa is facing, there is also a dearth of information on the implementation of the e–education policy. Thus, teachers' professional development and training on ICT integration cannot be neglected. To this effect, a Guideline for Teacher Training and Professional Development in ICT (GTTPD–ICT) was published (DoE, 2007). It is important that professional development should consider teachers' knowledge of their subject matter, teachers' ability to select appropriate educational technology, and knowledge about how learners learn (Mishra & Koehler, 2006).

Higher education institutions are part of government's initiative to provide professional development for both pre-service and in-service teachers. The programmes differ according to institutions, especially undergraduate programmes. For example, some universities are making use of the Intel® Teach programme to support their pre-service offering, even though the course was designed for in-service teachers (Butcher, 2008; Isaacs, 2007). Isaacs (2007) further indicated that Intel® Teach is one of the official professional development programmes of the South African Council for Educators (SACE). Intel® Teach is in partnership with Schoolnet South Africa (SNSA) and will therefore be discussed under SNSA initiatives that follow in the next section. Most universities offer postgraduate degrees in educational technology in teaching and learning up to doctoral level.

SNSA

SNSA is a non-profit section (21) company which has a record of accomplishment in developing and administering teachers' professional development programmes on the use of ICT in teaching (SNSA, 2015). Its vision is to promote a community of teachers and learners through the effective use of technology (SNSA, 2015). SNSA (2015) indicated that its vision will be realised by:

- Promoting good quality teaching and learning through the effective use of technology that considers the needs of learners and teachers;
- Harnessing the power of technologies to support and enhance the acquisition of knowledge and skills in children, youths, and young adults.

To realise its vision SNSA seeks partnership collaborations with the public and private sectors as well as non-profit organisations (SNSA, 2015). This was done to reduce duplication, promote efficiency and share lessons learnt in working with governments, schools, teachers, and learners. SNSA is not involved in technological solution or software platforms; their professional development is tailored according to their clients' available resources. According to SNSA (2015) professional development comprises of numerous activities like attending meetings and conferences and being exposed to new ideas, but they exclude improving an individual's qualifications. SNSA believes that professional development should engage teachers and school administrators as learners themselves and support them along the way to improve teaching and learning quality. SNSA is offering free professional development to teachers. This is done through webinars on many interesting topics for teachers. Below follows a brief discussion on each of the partners that collaborate with SNSA.

Council for Scientific and Industrial Research (CSIR) – ICT for Rural Education Development (ICT4RED)

This project was initiated by the Department of Science and Technology in collaboration with the DBE, the Eastern Cape Department of Education and the Department of Rural Development and Land Reform. The project involved only 26 schools out of 7406 schools in the Eastern Cape province (Herselman & Botha, 2014). The project's aim was to improve rural education via technology-led innovation in the district of Cofimvaba (Herselman & Botha, 2014). SNSA was responsible for managing the professional development of teachers. This included the development of learning materials and the preparation and monitoring of facilitators (SNSA, 2015). The technologies were provided by the CSIR. The technologies comprised a teacher's Android tablet, a school server housing volume of Curriculum and Assessment Policy Statement (CAPS) related content, a projector, and mobikits and tablets for all learners in each school in the district (Herselman & Botha, 2014). However, SNSA's partnership with the project ended in 2014 when the project came to an end. SNSA trained 160 educators who were awarded their certificates at a graduation ceremony (SNSA, 2015).

Although the project was a success, concerns were raised about the sustainability of the project. The concerns included, among others, provincial commitment to maintaining the tablets, failure to allocate budgets for upgrading of the technology and the context of poverty where parents do not always have the means to buy new tablets for their children (Herselman & Botha, 2014).

Vodacom Foundation's ICT Resource Centres and Vodacom Business

The aim of this project was to improve the quality of instruction in all subjects, with the emphasis on mathematics, mathematics literacy and physical science in grades 10 to 12. Vodacom Foundation provided laptops to schools in the form of donations. Encarta, Microsoft Office, and software for all the school subjects for the South African curriculum were installed on the laptops. The project also established ICT resource centres. These centres were used to train staff members appointed to manage them and teachers and principals of the schools that received the laptops. SNSA was involved to assist in capacity building in the use of laptops for teaching. SNSA was responsible for developing workshops for centre managers, principals, teachers, and trainers in all nine centres in South Africa, with each province having one ICT resource centre. The centre manager was responsible for developing courses for the local community as well as running workshops for teachers in their respective provinces. However, SNSA conducted training for one year only. Training is now provided by the centre managers and provincial trainers in their respective provinces. The centres have also increased from 9 to 92. No study has been conducted to establish whether the project was a success or not.

Intel® Teach

SNSA was the regional training agency for all Intel® Teach program. The program trained teachers in how to incorporate technology effectively in the classroom. The aim of the program was thus to develop teachers to integrate technology into their classrooms. The assumption was that technology integration would promote problem solving, critical thinking and collaboration skills among the learners (SNSA, 2015). The Intel® Teach curriculum has been adapted by SNSA for local interpretations. Teacher training was funded by individual schools or the various provincial departments of education. The main challenge experienced by SNSA in training teachers was the DBE's inability to confirm training dates. SNSA then conducted classroom visits to provide teachers with practical tips for using educational technologies in classroom activities (SNSA,2015). About 400 educators benefited from this program (SNSA,2015). However, to date there is no study conducted to establish whether the Intel® Teach program was successful or not.

Microsoft Partners in Learning

This project involved teacher development and support programmes. It offered training programmes that included basic ICT skills and ICT integration, peer coaching for teachers, and ICT leadership for education managers. SNSA was responsible for quality assuring courseware as well as managing of the Partnerships in Learning (PIL) teachers' forum and PIL network. Microsoft was experimenting with the use of White Space for connectivity in schools in Limpopo province. Training workshops were conducted using Microsoft tablets and a sustained professional development programme for teachers. However, this initiative was implemented in one district only in Limpopo province.

DG Murray Trust – Learning Gains from Play

This project started in 2014. Ten schools in two provinces were encouraged to use Android tablets and Xbox Kinect technology. Learning gains were evaluated following a developmental approach where the project was tracked and documented. The evaluators worked closely with the project team to interpret data as the project progressed. The targeted literacies were visual, oral (English acquisition), and fine and gross motor coordination. Lessons learnt from this project in its second year of implementation included the following:

- There was a close correlation between frequency of use and improved learner performance.
- More learning gains were recorded in schools where teachers support each other and are also supported by management teams, and where 100% attendance was recorded at both cluster and school–based workshops.
- The rigid structure of the curriculum puts pressure on teachers because teachers must cover the curriculum within a specified time and there is thus little time for play.

This initiative has the potential to benefit many rural schools in Limpopo province based on the lessons learnt. The next section gives a detailed description of the last category which is provision of content.

2.2.3 Digital Content Initiatives

Isaacs (2007) indicated that there were a limited number of local projects focusing on digital content development. She further indicated that the model of digital content development was often from an imported curriculum which had been localised and adapted for the South African context. However, there is the South African Broadcasting Corporation (SABC) learning channel which focuses on the South African secondary schools' curriculum using, satellite broadcasting. The DBE in collaboration with provincial departments of education and other stakeholders has also developed a National Education Portal called "Thutong". The aim of the DBE in developing the portal was to provide access to a wide range of curriculum and support materials that are contextually relevant to South African learners, teachers, and education. All SNSA partner projects that have been discussed have their own digital content. Book publishers are also developing digital content that is relevant to the South African context.

Most of the infrastructure and teacher development initiatives discussed above were limited to one or two provinces. It is only the Resource centres and Vodacom Business and Intel® Teach programs that were implemented in all the provinces.

Although digital content can be accessed by most schools in South Africa, there is a dearth of research on how rural schools use this content in their classrooms.

2.3 Chapter Summary

In this chapter I have discussed initiatives that have been put into place to support South Africa in its endeavour to integrate ICT in teaching and learning. The initiatives were categorised into three categories: initiatives that provide infrastructure; those that provide professional development for teachers; and those that provide content development. However, these initiatives are not spread evenly among the provinces. Provinces like Gauteng and the Western Cape enjoy an oversaturation of these initiatives, whereas provinces like Limpopo and Mpumalanga are struggling to attract them. Unfortunately, little is being done by either the provincial or national departments of basic education to remedy the situation. The next chapter gives a review of the literature to this study.

Chapter 3

Literature review

3.1 Introduction

In this chapter, a review of the relevant literature is presented and discussed. This is done to identify the gaps in the literature and to address the relationship between teachers' pedagogical practices, their competence in mathematics and their use of technologies in mathematics, and the factors that contribute to learners' use of educational technologies in mathematics learning. This review is informed by the two main research questions of the study which were:

- How do teachers' pedagogical practices and competence in mathematics influence their use of educational technology in mathematics teaching and learning?
- What factors influence learners' use of educational technologies in mathematics learning?

Developing appropriate mathematics teaching strategies remains a daunting task for South African public schools. This is seen in the low number of learners who are leaving our schools with a pass in mathematics. This in turn has an impact on the number of future mathematics teachers that our country will have. Thus, any strategy to deal with this problem should broaden participation and ensure measurable quality outcomes in mathematics.

Educational technologies can offer learners opportunities to engage constructively and critically with mathematical ideas (Goos, Galbraith, Renshaw & Geiger, 2003). However, equipping our schools with technological tools does not guarantee full exploitation of these opportunities. Different factors contribute to the ability to exploit these opportunities. Teachers' competence in the use of educational technologies in mathematics is important for an understanding of their approach to teaching with such technologies. Understanding the relationship between teachers' pedagogical practices, competence in mathematics and their use of technology in teaching and learning can contribute towards fully exploiting these opportunities. In addition, understanding how teachers' use of technological tools in their classrooms affect learners' use of educational technologies in mathematics can also contribute to learners fully exploiting these opportunities.

The review is organised into eight main sections. Section 3.1 is the introduction of the chapter. Section 3.2 gives a detailed discussion of ICT adoption in schools. Section 3.3 focuses on competence as a concept. Section 3.4 gives details of use of technology by teachers and learners. Section 3.5 discusses the benefits of using technology in the teaching and learning of mathematics. Section 3.6 deals with factors which influence learners' use of technology in learning mathematics. Section 3.7 gives a detailed discussion of attitudes of teachers and learners towards the use of technology in the teaching and learning of mathematics. Section 3.8 provides a summary of the chapter.

3.2 Information Communication Technologies (ICT) Adoption in Schools

Studies have been conducted to establish the potential of educational technologies for teachers who choose to adopt these tools in their classroom practices (Dwyer, 1994; Shambare & Shambare, 2016; Stols, 2007; Tunk & Welle, 2009; Wong, Teo & Russo, 2013). In these studies, different models were used to investigate the extent to which ICT was adopted in the classroom. This has paved the way for countries to invest in educational technology tools with the hope that these tools will help to improve classroom practices. In the South African context, the e-education policy and the GTTPD–ICT guide and direct schooling systems on how educational technologies should be used to improve classroom practice.

Despite these efforts by different countries, studies have shown that teachers' adoption of educational technologies is very slow or has not yet started (Belland, 2009; Ertmer, 2005; Hennessy, Harrison & Wamakote, 2010; Hew & Brush, 2007). That is, ICT resources are used mostly for low level activities like drill and practice, and tutorials (Cuban, 2001). Other studies have found that teachers' adoption of educational technologies takes time and develop through different stages (Dwyer, Ringstaff & Sandholtz, 1991), moving from a lower level to a higher level. Thus, the extent to which educational technologies are used depend on teachers' adoption level. Most of the above-mentioned studies used technology adoption models. These models place ICT in a conceptual framework that helps to explain where ICT fits into the educational context. The models include the concerns-based adoption model (CBAM), the technology acceptance model (TAM) and the universal technology adoption and use theory (UTAUT). TAM and UTAUT originated from a computer science context but were later applied to an educational context. A discussion of each of the models follows below. The discussion helped to shed light on the causes, levels and/or lack of technology adoption by the teachers.

3.2.1 The Concerns-Based Adoption Model (CBAM)

The CBAM shows how an individual's concerns influence their integration of innovation (Straub, 2009). The CBAM was developed by (Hall, 1976, as cited in Straub, 2009) and was based on Fuller's work on teacher change and the classification of teachers' concerns from a developmental perspective (Fuller, 1969; Hall, 1976, as cited in Straub, 2009). CBAM was developed to address teachers' needs when going through change so that change would be more easily facilitated (Hall, 1976, as cited in Straub, 2009). CBAM was developed based on the following six assumptions:

- Change is a process, not an event;
- Change is accomplished by individuals;
- Change is a highly personal experience;
- Change involves developmental growth;
- Change is best understood in operational terms and
- The focus of facilitation should be on individuals, innovations, and context.

These assumptions form the basis of the two components of the CBAM, namely: stages of concern (SoC) and level of use (LoU). These components are discussed below.

Stages of Concern (SoC)

The SoCs describe the concerns teachers have as they progress through the adoption process. In the early stages, concerns revolve around teachers' personal issues. As those concerns are met, they are replaced by concerns about their learners and implementation. Each stage represents a possible necessary developmental progression. Teachers will also show concerns about all stages at any given point during the process. Lastly, progression is not hierarchical, as when teachers move out of one stage, they may still have concerns consistent with previous stages. Table 3.1 shows the SoC.

Table 3.1

Stages and descriptions of SoC

Stage	Name	Description of concerns
0	Awareness	Teachers have awareness of or concerns about a specific innovation. The innovation is seen not to affect them at this stage.
1	Informational	Teachers have a general or vague awareness of an innovation. Teachers may begin seeking additional knowledge about the innovation.
2	Personal	Teachers' concerns are about the personal costs of implementing an innovation–how a specific innovation will change the demands of or conflict with existing understanding of what they currently do.
3	Management	Teachers' concerns will focus around how to integrate the logistics of an individual innovation into their daily jobs.
4	Consequence	Teachers' concerns are primarily on the impact of the innovation on their learners.
5	Collaboration	Teachers begin to have concerns about how they compare to their peers and how they can work with their fellow teachers on an innovation.
6	Refocusing	Teachers' concerns are about how to better implement an innovation.

Source: Straub, 2009, p. 635

Level of Use (LoU)

The LoU provides a framework for understanding how teachers behave when implementing an innovation. It breaks down the actions of teachers into categories, indicating how a teacher acts within these categories, starting from the lowest behavioural implementation that shows teachers not using the innovation, to the highest which indicates teachers transforming and extending the innovation. Table 3.2 shows LoU.

Table 3.2

Stages and description of LoU

Level	Name	Description of use
0	Non-use	A teacher does not use or has no intention of using an innovation.
1	Orientation	A teacher is seeking additional information about an innovation but has not determined whether they will implement it.
2	Preparation	A teacher gets ready to include an innovation (but has not yet implemented it).
3	Mechanical	A teacher begins implementation but generally struggles with the logistics of the innovation.
4A	Routine	A teacher successfully integrates the innovation.
4B	Refinement	A teacher changes the innovation to suit their needs.
5	Integration	A teacher goes beyond their own classroom to share their implementation of an innovation with peers.
6	Renewal	A teacher extends an innovation, transforming the innovation.

Source: Straub, 2009, p. 636

In the literature that uses CBAM as a theoretical framework, the SoC is mostly used to examine teachers' choices associated with pedagogical adoption of technologies (Straub, 2009). Teachers' educational technology usage patterns assist to explain their level of use. However, the levels of use do not consider the schools' contextual factors and the role played by different subjects when educational technology are used in the classroom. Thus, it becomes difficult to understand teachers' competences in the use of technology in the classroom.

3.2.2 The Technology Acceptance Model (TAM)

TAM was adapted from the theory of reasoned action (TRA) proposed by (Fishbein and Azjen 1975, as cited in Davis, 1993). Davis (1993) showed how an individual's perceptions of a technology innovation affected the eventual use of that technology. Davis (1993) identified two perceived characteristics of a technology that predicted its usage. The characteristics were firstly, the perceived ease of use, explained as the degree to which an individual believed that using a specific technological tool would be of minimal effort; and secondly, perceived usefulness, explained as the degree to which an individual believed that using a specific technology would enhance their job performance. Perceived usefulness has been found to be a consistent influence on future individual use of technology (Akinde & Adetimirin, 2017; Hart & Laher, 2015; Straub, 2009). It was also found that perceived usefulness may be linked to how innovative an individual may be (Venkatraman, 1991, as cited in Straub, 2009).

Despite TAM being used in many educational settings to explain the acceptance of technology (Akinde & Adetimirin, 2017; Pan, Gunter, Sivo & Cornell, 2005; Hart & Laher, 2015; Stols, 2007), it does not address the pedagogy involved in the use of ICT in the classroom. In disregarding the pedagogy, it falls short of explaining teachers' professional practices.

3.2.3 Universal Technology Adoption and Use (UTAUT)

UTAUT came about because of a comprehensive review of various theories to predict computer use by Venkatesh, Morris, Davis, and Davis (2003). These theories include the theory of reasoned action (TRA), technology acceptance model (TAM), motivational model (MM), theory of planned behaviour (TPB), combined TAM and TPB (C–TAM–TPB), model of PC utilisation (MPCU), innovation and diffusion theory (IDT) and social cognitive theory (SCT) (Venkatesh et al., 2003). According to Venkatesh et al. (2003), these theories are fragmented and lack a cohesive model that accounts for the numerous factors that influence technology use.

UTAUT consists of four key determinants of use and four moderators of individual use behaviour. The four key determinants of individual use are performance expectancy, effort expectancy, social influence, and facilitating conditions. The moderating factors are gender, age, experience, and voluntariness of use. UTAUT has not been much used as a theoretical framework in examining teachers' adoption of technology.

All the technology adoption models discussed above are used mostly in information systems environments rather than in education environments where teachers are adopting technologies in their practices. Thus, these models hardly consider the social setting that schools, learners, and teachers are confronted with. These social settings sometimes lead teachers to take difficult decisions when trying to adopt technologies in their classrooms. Also, the above-mentioned models are not discipline specific. In this study the focus is on mathematics teaching and learning. Thus, a model that is discipline-appropriate is relevant for this study.

3.3 Competence as a Concept

Competence is often associated with concepts such as performance, capabilities and abilities, traits and motives, self–confidence, effective behaviour and knowledge, skills, and attitudes (Le Deist & Winterton, 2005; Stoof, Martens, Van Merriënboer & Bastiaens, 2002; Westera, 2001). In this study, competence is operationalised from some of the concepts mentioned above. Thus, it was essential to explore the concept 'competence'. It can be deduced from the above explanation that there is a variety of interpretations of competence. This is seen in the many definitions of competence found in literature (Le Deist & Winterton, 2005; Stoof et al., 2002; Westera, 2001). These numerous definitions exist because of the different contexts in which the concept 'competence' operates (Stoof et al., 2002). In their quest to develop a viable definition of competence, Stoof et al. (2002) first gave a brief account of the two contexts in which the definition of competence was developed. These two contexts are business and industry, and education. The authors found that, in business and industry, competence started as a quest to recruit the most suitable candidate through the recruitment process. However, it was no easier to define the concept 'competence' than it was to decide who was competent. In the context of education, the authors further indicated that the origin and development of competence were not clear. They assumed that the notion of competence in education might have emerged as a response to and a derivation from the business environment. As learners may be regarded as future workers, it seemed important for educational sector to align its programmes with the expectations of the business. Schools should produce learners that are economically relevant to business organisations because business organisations are clients of the education sector.

As indicated above, Stoof et al. (2002) conceded that there can be no absolute definition of competence and that the definition should be adaptable. The adaptability of this definition is dependent on the following variables:

- *People*. People's background and expertise influence the way competence is defined.
- *Goal*. The purpose for which the definition is used will influence the way the concept is defined.
- *Context*. The organisational type and processes have a significant influence on the definition of competence.

According to Stoof et al. (2002), competence is defined from the perspective of a boundary scenario that determines what competence is and what it is not. The "area" of the definition (what it covers) is, in the model of Stoof et al. (2002), determined by forces from within, called "dimensions", and forces from the outside formed by "terms related to the competence concept" (Stoof et al., 2002, p. 354). The conscious choice of, or emphasis on, certain dimensions and terms expands or restricts the competence concept and leads to the most appropriate definition. These different "dimensions" and "terms" provided by Stoof et al. (2002) supply a comprehensive list of various aspects of the competence concept. Some of these aspects are important for understanding the conceptual framework in Chapter 4 of this study, in which most of the aspects were applied. A summary and a discussion of these dimensions and terms are provided below, starting with the dimensions that determine the scope of competence and followed by terms that are often used interchangeably in the discussion of competence.

1. *Personal versus task characteristics*

Stoof et al. (2002) indicated that approaches to competence that stress personal characteristics focus on those personal characteristics that lead to superior performance. Thus, the behaviour that an individual demonstrates can result in effective and/or superior individual performance, depending on the context. On the other hand, they indicated that approaches to competence that stress task characteristics focus on essential elements of the task that is to be fulfilled. In short, the personal characteristics approach to competence focuses on how an individual performs a specific task while the task characteristics approach to competences focus on how a specific task is performed. Looking at the TPACK framework, both personal and task characteristics are essential in the classroom environment. Teachers need to know when, how and why to use technology in the classroom. Also, teachers' use of the technology should make learning meaningful and interesting to learners.

2. *Individual versus distributed competence*

Individual competences are viewed as something belonging to a single individual (Stoof et al., 2002). Here, the focus may be on the training and development of the competences of an employee. On the other hand, distributed competences refer to two or more individuals working on the same project (Stoof et al., 2002). The theory of distributed cognition helps in understanding the distributed approach (Salomon, 1993, as cited in Stoof et al., 2002). According to Stoof et al. (2002) this theory states that cognition occurs not only in individual minds, but through the cooperation of many individuals. Systems are viewed as a whole, hence the existence of systems thinking. In this instance, the role of social capital in terms of informal learning is important in developing teachers' and learners' competences. Social capital is discussed in chapter 4. In this study cooperation and collaboration among members of the school community was viewed as one of the contributing factors to both teachers' and learners' competences in the use of educational technologies.

3. *Specific versus general competence*

The scope of competence definitions can be narrow, referring to only a specific task as part of a job, or it can be broader, covering a whole profession (Stoof et al.,2002). In this study, competence was both specific and general, as it was determined in terms of a variety of technological competences as well as the competence to use these technological tools in the classroom environment.

4. *Levels of competence versus competence as a level*

Levels of competence refer to grading of competence (Stoof et al., 2002). While competence does not equate to excellence, it does imply a level of proficiency that has been judged to be adequate for the purpose of the activity in question. In this view, an individual has a certain amount of competence ranging from a novice to an expert (Mirable, 1997 as cited in Stoof et al., 2002). That is, an expert will be more competent, in other words, will have a higher level of competence, than a novice. On the other hand, competence can also be regarded as one specific level. Here, competence is a delineated stage, in between other stages. For example, competence may be approached as a stage in the development of a practitioner from novice to competent and from competent to expert. TPACK can be differentiated into different levels through which teachers can progress; however, progression is dependent on the tool, the pedagogy, and the content being presented.

5. *Teachable versus non-teachable competence*

Some of the terms associated with the competence definition as mentioned above refer to teachable skills, while others do not. Skills and knowledge are easy to teach, while other aspects of competence are difficult to develop (Spencer & Spencer, 1993, as cited in Stoof et al., 2002). It is important to understand how teachers and learners have acquired their competences. Training is one of the most effective ways of equipping teachers with competence in the use of educational technology (Belland, 2009).

The above-mentioned dimensions indicate the flexibility involved in constructing the definition of competence. One’s choices should be based on these dimensions. Below are terms that are often confused with competence:

1. *Competence versus performance*

Competence is performance that is, at the least effective (Stoof et al., 2002). Stoof et al. (2002) further show that the distinction they draw between competence and performance is like an aspect of Chomsky’s linguistic theory (Chomsky, 1957, 1965, cited in Stoof et al., 2002). Chomsky differentiated between linguistic competence and linguistic performance. Chomsky explained language competence as the innate ability to acquire and creatively use the mother tongue, while language performance is seen as the actual language behaviour that a speaker generates. Though the study is not about language, the distinction between competence and performance was from this explanation. Knowledge acquired in the use of educational technology constituted competence, while the actual behaviours demonstrated in the classroom when educational technologies were used constituted performance.

2. *Competence versus qualification*

Competence does not necessarily imply qualifications (Stoof et al., 2002). They pointed out that qualification is associated with standards and certificates. In some contexts, qualification is not appropriate, for example being a competent guardian does not require any qualification. On the other hand, in most professional environments, qualification is incorporated into the competence definition, for example a qualified and competent teacher. However, there are instances where one is qualified but not competent, for example, a qualified teacher whose learners consistently fail her subject or grade.

3. *Competence versus capability and ability*

Competence, capability, and ability refer to intrinsic features necessary to get something done satisfactorily (Stoof et al., 2002). Stoof et al. (2002) further indicated that ability is sometimes used in the definition of competence to describe the causes of a performance. However, this does not provide a meaningful explanation of competence. Capability comes into competence sometimes when one wants to understand the causes of competent performance, the attributes needed and the way the attributes are used. Capability could refer to personal features that are not necessarily used or that the owner is not even aware of (Stoof et al., 2002). Competence, on the other hand, seems to be related to personal features that are required to perform an activity (Stoof et al., 2002). The performer may already possess these features or may acquire them through training. In this study both teachers and learners could use educational technologies for purposes other than teaching and learning. The realisations of these capabilities translate into competent performance.

4. *Competence versus knowledge, skills, and attitudes*

Competence incorporates knowledge, skills, and attitudes. Thus, a cluster of knowledge, skills, and attitudes is often used to define competence (Gonzi et al., 1993; Parry, 1996, as cited in Stoof et al., 2002). Skills are related to competence more than knowledge is because of their relation to action and performance. Skills refer to doing something, whereas knowledge is a more inherent feature. Teachers who have acquired knowledge on how to use educational technologies in their classrooms will demonstrate this knowledge when using the tools in their classroom environment. They appreciate, value, and persist in the use these tools in their classroom environments.

5. *Competence versus expertise*

Herling (2000, as cited in Stoof et al., 2002), stated that competence refers to minimal efficiency, whereas expertise refers to optimal efficiency. From the discussions on levels of competence above, expertise is seen as the highest level of competence. Thus, there is a close relationship between expertise and competence (Stoof et al., 2002). The South African government has developed a framework for teachers' ICT competences. The highest level that teachers can attain is clearly defined. This assists the country in planning for teacher development. The use of educational technology in the classroom is one of the required teachers' competences.

Westera (2001) indicated how competence was defined in literature by showing the most significant characteristics of competence. He firstly showed that most studies used the approach that defined competence from a performance or behavioural perspective. In this definition competence was related to effective performance or behaviour (Le Deist & Winterton, 2005). This definition was more output-driven as it focused on the observable actions and it also compared individual performance against performance standards in a job. Secondly, Westera demonstrated the approach that defined competence from the perspectives of abilities. In this approach competence was related to the functions of the task that were to be performed by an individual and was also output driven. Thirdly, he showed the definition of competence from an operational skill perspective. In this approach competence was viewed from an individualistic approach, could be improved through training, or teaching and was input driven. These above-mentioned definitions underpinned the competence definition that is applicable in the education context as indicated below. As shown above, Westera's definition is related to Stoof et al.'s (2002) competence concepts.

Subsequently, Westera (2001) identified two distinct representations of competence in education. They are the theoretical perspective and the operational perspective.

The theoretical perspective represents competence as a cognitive structure that facilitates specific behaviour. In this study teachers and learners needed to be able to choose appropriate tools that would assist in enhancing teaching and learning. The operational perspective shows that competence comprises a broad range of higher order skills and behaviour that represent the ability to cope with complex, unpredictable situations. This operational perspective includes knowledge, skills, attitudes, metacognition, and strategic thinking, while it presupposes conscious and intentional decision making.

Westera (2001) stressed that in complex non-standard situations, competences combine knowledge (or cognition), skills and specific attitudes. Competences have a mental component involving thought and a behavioural component involving competent performance**.** Competent individuals should be able to make the right choice from several different possible behaviours by anticipating the effects of their intervention.

Owing to its complexity, competence may be divided into sub-competences (Westera, 2001). The sub-competences can be broken down into more specific competences. This process results in a hierarchical structure of sub-competences that become more specific. Eventually, there comes a stage in which the sub-competences are identical to the supporting skills. While maintaining the idea of skills as being different from competences, we should acknowledge that skills themselves can also be divided into a hierarchical system of sub-skills.

However, Westera (2001) identified two problems with the above description of competence. First, it tries to set cognitive standards for behaviours that cannot be standardised. Secondly, from a research perspective, competences make up a subcategory of cognitive skills.

In this study the focus was on competence as a highly valued quality that accounts for the effective use of knowledge and skills in a specific context (Westera, 2001). Mastering of relevant skills and knowledge alone would not serve as a guarantee that an individual was competent. Both teachers and learners should be able to select from the available knowledge and skills in such a way that efficient and effective behaviour occurs which requires special abilities that consider the characteristics of a special context (Westera, 2001). TPACK, which was the theoretical framework of the study, was used to define competency in the use of educational technology in this study. The TPACK framework is discussed in detail in Chapter 4. If both teachers and learners are to be effective in the use of technology in the learning environment, they need to be competent in the use of these tools.

3.4 Use of Technology by Teachers and Learners

The use of ICT in teaching and learning requires new competences from teachers and learners to be able to use these tools in a meaningful and effective way in their classrooms. Both teachers and learners should be able to select the appropriate ICT tool(s) out of a variety of these tools and use them to improve teaching and learning (Westera, 2001). In the context of this study, both learners and teachers might display efficiency and effectiveness in their work using ICT in their classrooms. These tools enable both teachers and learners to improve teaching and learning. So, for this to happen, both teachers and learners need to have a certain level of competence in using technology. The skills needed to use various technological tools will facilitate a focus on conceptual mathematics development rather than on the skills required to operate a specific technological tool.

3.4.1 Use of Technology by the Teachers

3.4.1.1 Technological competence

Teachers' competence in the use of educational technology influences the decisions they make during their planning for classroom interactions. This is because teachers need to adopt new roles when they use educational technologies meaningfully in their classrooms (Sandholtz, Ringstaff & Dwyer, 1992). UNESCO (2011) developed an ICT competence framework for teachers (ICT–CFT). The aim of developing the framework was to help countries to develop their national teacher ICT competence policies and standards. The purpose of this ICT–CFT was to equip teachers with teaching methods that are appropriate for an evolving knowledge society. UNESCO further indicated that learners should be equipped both with ability to acquire in-depth knowledge of their school subjects and the ability to generate new knowledge using ICT tools. The framework is made up of three approaches that connect education policy with economic development and represent different stages in the use of ICT. The approaches are mapped onto the six components of teachers' work. Figure 3.1 below shows UNESCO's ICT–CFT.

Figure 3.1.

UNESCO ICT–CTF

ASPECTS OF TEACHERS' WORK	TECHNOLOGY LITERACY	KNOWLEDGE DEEPENING	KNOWLEDGE CREATION
Understanding ICT in Education	Policy awareness	Policy understanding	Policy innovation
Curriculum and assessment	Basic knowledge	Knowledge application	Knowledge society skills
Pedagogy	Integrating technology	Complex problem solving	Self-management
ICT	Basic tools	Complex tools	Pervasive tools
Organisation and Administration	Standard classroom	Collaborative groups	Learning organisations
Teacher professional learning	Digital literacy	Management and guidance	Teacher as a model learner

Source: UNESCO, 2011, p. 3

This ICT–CTF is a guideline for countries to develop their teacher training programmes on the use of ICT in teaching and learning. Countries differ in terms of their economic status and educational development; thus, different countries may adopt an approach or approaches that best suit them.

Based on the UNESCO ICT–CTF, South Africa has developed its own ICT in education competence framework (DoE, 2007). The South African competence framework is called "Guidelines for Teacher Training and Professional Development in ICT" and is abbreviated as GTTPD–ICT in this study. GTTPD–ICT adopted the three UNESCO approaches; however, the approaches emanate from the Apple

Classroom of Tomorrow (ACOT) stages of the evolution of technology use in the classroom (Sandholtz, Ringstaff & Dwyer,1992). According to Sandholtz et al. (1992), ACOT teachers' approach to technology use evolves through orderly stages. The stages are entry, adoption, adaptation, appropriation, and invention. Below follows a brief explanation of each of the stages.

- Entry: In this stage teachers are not comfortable with the technologies, and they avoid using them. They cannot make any connection between technology and the curriculum. Teaching is focused on the teacher and traditional ways of teaching. No learner uses any technology.

- Adoption: The teacher uses technology to support traditional instruction. The technology is used mainly to benefit the teacher, like using a Word document in lesson planning. Learners do sometimes use the technologies, but for a limited time.

- Adaptation: Technology is used to support traditional classroom practice. Both teachers and learners use technology.

- Appropriation: Teachers consider teaching objectives in relation to the best approaches to attain them when using the most appropriate technological tools. New instructional patterns are emerging. The technology is used for higher order thinking skills, collaboration and cooperation, enhanced comprehension and problem solving.

- Invention: New ways of using technology are discovered. Technology is part and parcel of the curriculum. Learners work on different tasks, collaborate on different aspects of projects, and create knowledge in a meaningful context.

These stages are grouped according to teachers' competence levels which are:

- Basic ITC knowledge and skills: This competence involves the knowledge and skills to use ICT at a basic level and corresponds with entry and adoption levels of the ACOT stages. It is the lowest competence level.

- Integrative knowledge and skills: This competence involves the ability to integrate ICT into the design and practice of teaching and learning and corresponds with the adaptation and appropriation ACOT stages. This is the middle level competence.

- Specialised ICT knowledge and skills: This competence involves the ability to use ICT to transform the role of the teacher and the classroom environment and correspond with the invention ACOT stage. It is the highest competence level.

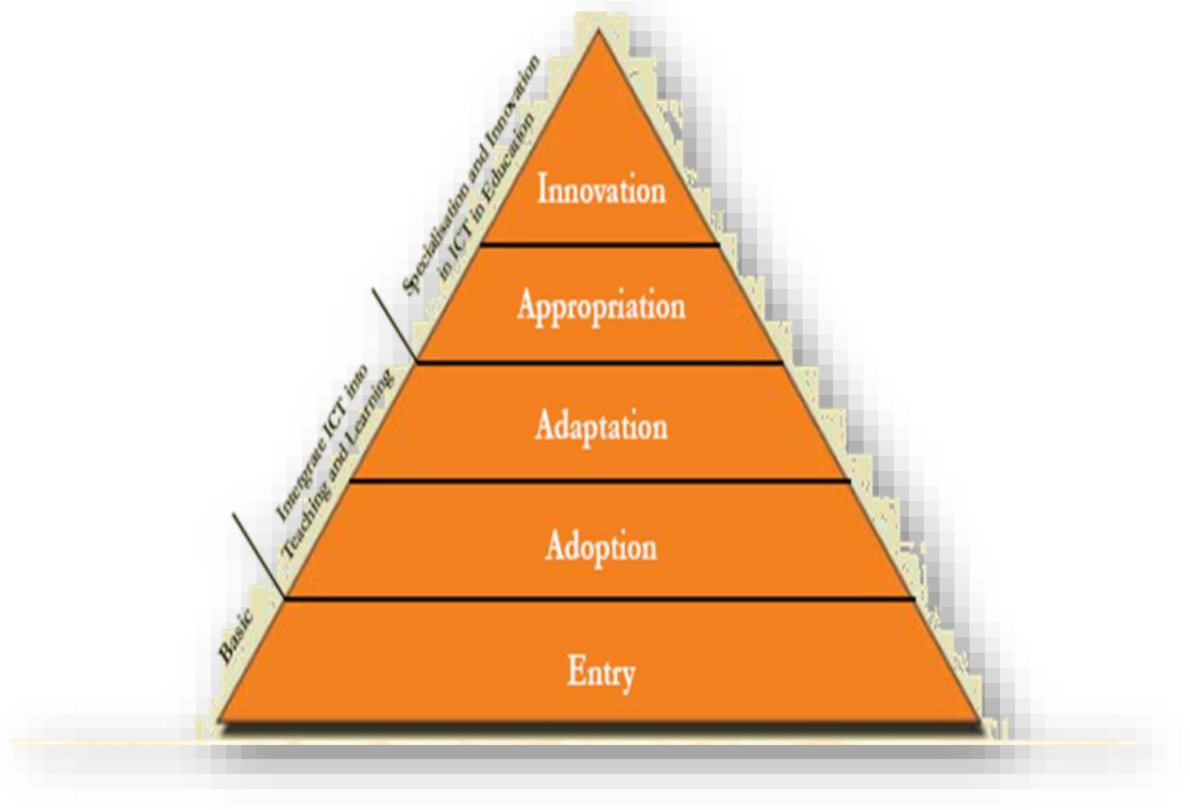
Approaches are mapped to the following concepts:

- ICT Professional Aptitude: This involves the teachers' attitudes, knowledge, values, and skills in respect of ICT. It is important for teachers to have confidence in the use of ICT. Teachers who have confidence in the use of ICT are not anxious to experiment with ICT in their classroom (Msila, 2015).
- Integration of ICT into the curriculum: The focus is on teachers' ability to use different ICT learning environment to develop learners' critical thinking, informed decision making, higher order thinking skills and collaborative and experiential learning. In these learning environments learners are given opportunities to take charge of their learning while the teacher is guiding their learning. Teachers' planning of the learning environment is of critical importance.
- Management: Teachers demonstrate the ability to manage ICT in education.
- Innovation: Teachers can contribute to educational innovation with their in-depth knowledge of the learning process and the role played by ICT in this process.

Figure 3.2 below shows GTTPD-ICT.

Figure 3.2.

South African GTTPD–ICT



Source: DoE, 2007, p. 7.

The GTTPD–ICT, includes both technical ICT competence and pedagogical ICT competence. These two aspects are important in the pedagogical use of ICT in teaching and learning. Based on GTTPD–ICT targets, in-service teachers who have access to ICT should have been trained to the adaptation level by 2010 (DoE, 2007). Also, pre–service teachers who graduated after 2010 should have left their institutions equipped with GTTPD–ICT adaptation level (DoE, 2007). Thus, it may be inferred those teachers who have access to ICTs in their schools are at a level higher than adaptation in their use of technologies in their classrooms. However, policies sometimes have unexpected consequences and hamper change (Christie, 2008). The GTTPD–ICT falls short of a rollout plan and may therefore give rise to different interpretations by policy implementers, particularly in the South African context, where different provinces have different priorities. For example, in one province the priority might be infrastructure while in another it might be teachers' professional development. Despite these provincial disparities, South Africa needs teachers who are competent in the use of technologies in teaching and learning.

3.4.1.2 Mathematics competence

Since the advent of the constitutional democracy, the South African government has been undergoing transformational processes to address the imbalance under the previous regime. A curriculum that is learner–centred, relevant, and accessible in terms of a hierarchy of demonstrable and measurable competencies was developed (Pudi, 2006). The curriculum was based on critical outcomes and corresponding learning areas outcomes. However, owing to the packaging of the curriculum there were implementation problems (Chisholm, 2005). This warranted reviews which occurred in 2000 and 2005 (Pudi, 2006). The 2000 review resulted in the Revised National Curriculum Statement (RNCS) Grades R–9 and the National Curriculum Statement (NCS) Grades 10-12 policies (Pudi, 2006). The 2009 review amended the two above-mentioned documents to form the Curriculum and Assessment Policy Statement (CAPS) for each subject. In the CAPS document, specific aims and specific skills are identified (DBE, 2011c). Specific aims are the overall subject outcomes, while specific skills are expectations of learners in that phase. Specific skills are both behavioural and performance based. Skills are paraphrased as follows (DBE, 2011c):

- Use mathematics language correctly;
- Collect, analyse, and organise quantitative data to evaluate and critique conclusions;
- Use mathematical processes skills to identify, investigate and solve problems creatively and critically;
- Use spatial skills and properties of shapes and objects to identify, pose and solve problems creatively and critically;
- Participate as responsible citizens in the life of local, national, and global communities and
- Communicate appropriately by using descriptions in words, graphs, symbols, tables, and diagrams.

There are no clearly indicated mathematics competences for teachers. However, one of the competences for beginner teachers is a sound knowledge of the subject matter (Department of Higher Education and Training (DHET), 2011). The assumption could be that teachers who were teaching these grades prior to 2011 have the conceptual mathematics knowledge.

Mathematics content knowledge is one of the components of mathematics teachers' competences (Döhrmann, Kaiser & Blömeke, 2012). Döhrmann et al. (2012) further indicated that teachers' mathematical content knowledge should cover a higher level than the mathematics content of the grade the teacher would teach. However, Döhrmann et al. (2012) focused mainly on mathematics cognitive skills. By contrast, Niss and Jensen (2002) view mathematics competence as a well-informed readiness to act appropriately in situations involving a certain type of mathematical challenge. Thus, it follows from Niss and Jensen (2002) that mathematics competence encompasses skills, knowledge, abilities, opinions, and decisions about mathematical challenges. Niss and Jensen (2002) identified eight mathematical competencies that make up mathematics competence. These competences are discussed in 3.4.2 below.

3.4.1.3 Pedagogical competence

Teachers' epistemological stances play a significant role in how technology is used in their classrooms. Teachers use these tools to support their epistemological stances (Tondeur, Van Braak, Ertmer, & Ottenbreit-Leftwich, 2017). This implies that educational technologies are also designed to support different epistemological stances. Tondeur et al. (2017) indicated that teachers choose technologies that they are experienced in using.

On the other hand, educational technologies provide opportunities to access an abundance of information using multiple information resources and to view information from multiple perspectives, thus fostering the authenticity of the learning environment (Drijvers et al., 2016; Drijvers, Kodde-Buitenhuis & Doorman, 2019). Through simulation programmes, abstract concepts can be made more practical and accessible to all learners with different learning styles. However, all these opportunities do not occur automatically. Appropriate and relevant pedagogies are vital to ensuring that these opportunities are realised. Teachers have the daunting task of trying to adopt appropriate technological tools in the learning environment. This implies that teachers' pedagogical practices will be affected, together with teachers' and learners' roles and their classroom practices. Loughran (2013) defined pedagogy as a relationship between learning and teaching, the influence that these two concepts have on each other and their coexistence. The teacher purposefully develops activities that will ensure that the learners' learning is enhanced (Loveless, 2011). However, there are several views on how these concepts coexist in the learning environment.

One view of teaching and learning emphasises the role of the teacher, whereas learners are passive participants in the learning environment (Al-Zu'be, 2013). The teacher fills the learners with information or knowledge. Learners' assessment is based mainly on tests and order is always maintained in the classroom. The aims of teaching and learning, in this view, are preparing learners for upper secondary education and beyond, improving learners' performance in examinations and satisfying parental and community expectations (Law & Chow, 2008). Learners work individually and, in most instances, are engaged in doing exercises or completing worksheets. Learners' test results are important indicators of attainment of the learning objectives. This approach does not produce creative or self-motivated learners.

Teachers who subscribe to this view of teaching and learning perceive technology as an add-on in their classrooms, and thus use technology as a tutor more than anything else. This implies that the technology is used to deliver learning. According to Niederhauser and Stoddart (2001), these teachers tend to prefer skills-based software programs. Teaching in this environment is teacher centred. Demetriadis et al. (2003) found that these teachers were strongly oriented towards fulfilling the established school instructional target. As a result, teachers ignored innovative learning activities because they were disturbing (Demetriadis et al., 2003). However, if the concepts to be dealt with in the classroom are still new to the learners, this approach is appropriate, because learners need to form an understanding of these new concepts. As mentioned above, the new curriculum, which focuses on improving teachers' pedagogical approaches, was introduced in 1998. Thus, most teachers in South African schools were trained in traditional teacher-centred pedagogical practices. It was interesting to find out how these practices affected teachers' use of technology and how the technology affected these teachers' practices.

On the other hand, there is another view which describes teaching and learning as the process by which learners are actively engaged in the learning environment (Al-Zu'be, 2013). In this view, learners are provided with activities that incorporate their lived experiences to acquire new knowledge. Learners are also given opportunities to learn among themselves, from one another, from experts and from their teachers. The teacher is seen as a facilitator, a guide, or a mediator of learning. Learners are active participants engaged in presentations, discussions among themselves and with their teachers, collaborations with their peers within and outside the school environment, as well as reflecting on their own learning.

Teachers who subscribe to this view of learning create an intellectual environment in which knowledge is acquired. Problem solving, higher order thinking skills and deep understanding are emphasised (Keengwe & Onchwari, 2011). The use of instructional strategies that encourage learners' active learning and address learners' needs is imperative. In such learning environments learners are given opportunities to construct knowledge by using technologies. Also, different forms of technologies are used to facilitate collaborations among learners themselves, among teachers and learners, and among teachers, learners, experts, and parents. Teaching in this environment is learner centred. This is seen as the most appropriate pedagogical practice that best suits the use of technologies in the educational environment (Keengwe & Onchwari, 2011; Sang, Valcke, Van Braak, Tondeur & Zhu, 2010).

In South Africa the White Paper on e–education (DoE, 2004) encouraged the following classroom practices:

- Learner-centred learning;
- exploratory, inquiry-based learning;
- collaborative work among learners and teachers; and
- informed decision making.

These practices have implications for the roles of teachers and learners in the classroom. Teachers need to explore new ways of teaching, and these are being opened by ICT tools. The relationship between teachers' pedagogical practices and

ICT tools is important, as it dictates teachers' implementation strategies (Wong, Li, Choi & Lee, 2008). In their study, Wong et al. (2008) found that teachers moved from a teacher-centred to a learner-centred teaching approach, owing to the implementation strategy followed by the school. In a school where implementation was a balance between pedagogically driven strategies and technologically driven strategies, teaching and learning transformation was experienced (Wong et al., 2008). Teaching and learning transformation were also experienced in a school where implementation focused on pedagogically driven strategies (Wong et al., 2008). In both instances the principal of the school played a pivotal role as the guide towards teaching and learning transformation (Wong et al., 2008).

Furthermore, teachers' frequent use of ICT in teaching and learning also influences their pedagogical practices. A study conducted by Pelgrum and Voogt (2009), based on SITES 2006 data, found that teachers in countries with a high frequency of ICT use apply more learner-centred pedagogical practices than those in countries with a low frequency of ICT use. In South Africa, ICTs are not yet widely used in mathematics and science as recommended in the White Paper on e-education (Howie & Blignaut, 2009). According to Howie and Blignaut (2009), this is because essential conditions are not yet in place in the large majority of schools. In most schools, the focus is on the provision of basic infrastructural resources like toilets, classrooms, and furniture, among others. In the few schools with technological resources, teachers are not adequately trained in the use of ICT in teaching and learning. These schools are still learning about ICT as opposed to learning through ICT (DoE, 2004).

According to Olive (2013), the appropriate use of technological tools can enhance mathematics teaching and learning, support conceptual development of mathematics, enable mathematical investigations by learners and educators, and influence how mathematics is taught and learnt. Webb and Cox (2004) found that effective mathematics pedagogies with ICTs promoted learners' interaction with learning activities and with each other. However, they indicated that published literature shows cases of effective mathematics pedagogy with ICTs. Webb and Cox indicated further that many mathematics teachers are still oriented towards a transmissive view of teaching and learning. This is consistent with studies by Eickelmann, Gerick and Koop (2017) and Tay, Lim, Lim and Koh (2012), which are more recent. Tay et al.’s (2012) study on primary school mathematics teachers’ pedagogical approach to ICT integration found that mathematics teachers adopted a behaviouristic type of approach in their teaching. Similarly, Law (2009) found that the activities most frequently adopted by mathematics teachers were exercises to practise skills or procedures, teacher lectures and the discovering of mathematics principles. Law and Chow (2008) found that South African teachers’ self-reported data on pedagogical competence in ICT use were at the lowest levels of competence. This implied that teachers were not able to develop learners’ critical thinking and problem-solving skills (Drijvers et al., 2010; Pierce, Stacey & Barkatsas, 2007; Tay et al., 2012). Thus, there is a need to come up with some implementation strategies that will help teachers to develop both technical and pedagogical competences in the use of educational technologies in teaching and learning. It is also important to understand the reasons that could be hampering teachers’ progress in acquiring competences in the use of educational technologies in their classrooms.

The above discussions show the significant influence of teachers’ pedagogy on the way in which technologies are used in the classroom. This influence also has an impact on learners’ attitudes towards the use of these tools in their learning. Thus, teachers need to adopt many different types of roles according to the types of technology involved, the types of learners and the curriculum goals. They need to come up with a vision that will guide their pedagogical approach. Teachers who do not have a vision that guides their pedagogical approach are still trapped in traditional pedagogies when using technology in teaching and learning (Kozma, 2003). They see technology as an add-on to their pedagogical practices. On the other hand, teachers who do have a vision for using educational technologies in their classrooms try their best to transform their pedagogical practices and align them to ICT using pedagogies or digital pedagogies (Kozma, 2003; Law, 2009; Wong et al., 2008). In this study, two types of pedagogical approaches were used to understand teachers’ pedagogical practices in the use of educational technology. As mentioned above, the two pedagogical approaches were the learner-centred and the teacher-centred approach.

3.4.2 Use of Technology by the Learners

Learners are currently exposed to a variety of technological tools. Public and private sectors are making every effort to equip schools with technological resources. It is widely assumed that the learners at these schools will have developed technological skills because of this exposure (Beckman, Bennett & Lockyer, 2014; Corrin, Lockyer & Bennett, 2010). However, some authors challenge this assumption, asserting that exposure to technology does not necessarily result in the acquisition of skills (Selwyn, 2008). In the learning of mathematics learners need to use technological tools that have been provided to support their mathematics conceptual development. In South Africa, the Curriculum and Assessment Policy Statement (CAPS) identifies the mathematics concepts that learners need to acquire (DBE, 2011c). These concepts are identified as specific skills that learners are expected to have in a particular phase. Basic education in South African context is divided into four phases. These are, Foundation phase: grades R to 3; Intermediate phase: grades 4 to 6; Senior phase: grades 7 to 9; and Further Education and Training phase: grades 10 to 12 (DBE, 2011c). Skills are outlined as follows:

- Use mathematics language correctly;
- Collect, analyse, and organise quantitative data to evaluate and critique conclusions;
- Use mathematical processes skills to identify, investigate and solve problems creatively and critically;
- Use spatial skills and properties of shapes and objects to identify, pose and solve problems creatively and critically;
- Participate as responsible citizens in the life of local, national, and global communities and
- Communicate appropriately by using descriptions in words, graphs, symbols, tables, and diagrams.

Niss and Jensen (2002), on the other hand, indicated that mathematical competence is a well-informed readiness to act appropriately in situations involving a certain type of mathematical challenge. The mathematical challenge dictates the type(s) of mathematical competencies that are evoked. Niss and Jensen (2002) identified eight mathematical competences which together make up the overall mathematical competence. These competences are mutually related, overlap and cannot be isolated from each other. Each of the competences is discussed below and compared to the learners' specific skills as paraphrased from the CAPS document.

3.4.2.1 Mathematical thinking competency, mastering mathematical mode of thought

This competence consists of an awareness of the nature of the mathematics of different objects. This is the ability to realise that there is a logical flow of reasoning in mathematics (Niss & Jensen, 2002). It is important to know what constitutes mathematics properties of any object and to be able to pose and answer questions based on these properties.

Furthermore, this competence comprises being able to understand and handle the extent and limits of given mathematical concepts (Niss & Jensen, 2002). Niss and Jensen (2002) indicated that this competence also includes being able to distinguish, both passively and actively, between different types of mathematical statements. These include definitions, theorems, conjectures, examples, corollaries, etc. It is important to understand the role played by explicit or implicit quantifiers in mathematical statements, not least when these are combined.

According to Niss and Jensen (2002), the procedure of attaining an answer is a core element in the mathematical problem tackling competence (dealt with below), while the correctness of the answer is the core of the mathematical reasoning competence (dealt with below).

This competence embraces the following two CAPS mathematics-specific skills:

- Collect, analyse, and organise quantitative data to evaluate and critique conclusion and
- Use mathematical processes skills to identify, investigate and solve problems creatively and critically.

The use of the Dynamic Geometry System (DGS) was found to support and encourage learners to develop and understand geometric conceptual systems (Olkun, Sinoplu & Deryakulu, 2005). Olkun et al. (2005) further indicated that learners were able to achieve higher levels of geometric thinking when they used DSG to analyse geometric shapes. Instead of memorising lists of geometric properties, learners were able to observe and investigate behaviours of different shapes. Thus, learners used the technology for explorations and simulations of mathematics concepts (Lassak,2015a). This was also found to lead to new understandings about geometrical constructions (Lassak, 2015a). This also helped learners to develop a deeper mathematics conceptual knowledge that supports higher order mathematical thinking (Gonzalez & Herbst, 2009).

3.4.2.2 Problem tackling competence – formulating and solving mathematical problems

This competence partly involves being able to put forward different kinds of mathematical problems and being able to solve such mathematical problems in their already formulated form (Niss & Jensen, 2002).

Niss & Jensen (2002) defined a mathematical problem as a mathematical question, where mathematical investigation is necessary to solve it. Sometimes an argument is given to justify the solution. In a way, questions that can be answered by means of a (few) specific routine operations also fall under this definition of “problem” (Niss & Jensen, 2002, p55).

This competence encompasses the following two CAPS mathematics specific skills:

- Use mathematical processes skills to identify, investigate and solve problems creatively and critically and
- Use spatial skills and properties of shapes and objects to identify, pose and solve problems creatively and critically.

Most of the studies conducted in these categories focused on the calculator as a computational tool (Doerr & Zangor,2000; Goos et al., 2003; Lassak, 2015a; Parrot & Leong, 2018; Polly, 2008). In these studies learners used calculators to manipulate numerical values. Ruthven and Hennessy (2002), Smeets and Mooij (2001) and Webb and Cox (2004) identified various attributes of educational technology tools that support learners when they are faced with problem solving. These attributes include:

- Enabling quick and accurate feedback for the learners.
- Enabling learners’ testing and discovering of mathematics idea.

- Allowing learners to focus on strategies and interpretation of answers instead of wasting valuable time on unnecessary computation.

Thus, by using educational technologies learners can verify their processes of problem solving by considering different methods to arrive at the solution (Lassak, 2015a).

3.4.2.3 Modelling competence – being able to analyse and build mathematical models concerning other areas.

This competence involves learners being able to develop mathematical meanings from real-life contexts (Niss & Jensen, 2002). Concrete entities, objects and pictures are used to represent mathematics concepts (Niss & Jensen, 2002). This enables learners to generalise and infer from given real–life contexts.

Arseven (2015) identified the following as key processes in modelling competence. Firstly, there is the ability to structure and simplify the real area or situation that is to be modelled. Then comes the ability to translate the objects, relations, and problem formulation, among others, into mathematical terms, resulting in a mathematical model. One must then be able to work with the resulting model, including solving the mathematical problems that may arise as well as verifying the completed model by assessing it both in relation to the model's mathematical properties and in relation to the area or situation being modelled. Furthermore, there is the ability to analyse the model critically both in relation to its own usability and relevance, and in relation to possible alternative models, as well as the ability to communicate with others about the model and its results. Finally, active modelling also includes being able to monitor and control the entire modelling process.

This competence encompasses three CAPS mathematics skills which are:

- Use spatial skills and properties of shapes and objects to identify, pose and solve problems creatively and critically;
- Communicate appropriately by using descriptions in words, graphs, symbols, tables, and diagrams and
- Use mathematics language correctly.

Studies in this category focused on different educational technology tools. Kay's (2014) study focused on web-based learning environments. Ang's (2010) study focused on computers. Ang (2010) used an Excel spreadsheet to develop simulation activities for learners. The study found that the spreadsheet activities resulted in meaningful mathematical modelling by the learners. The teachers' skills in the spreadsheet as well as the pedagogy involved in using the technology contributed to learners' benefiting from the technology (Ang, 2010). Also, Agyei (2013) found that the spreadsheet enhanced conceptual understanding of mathematics. Bowers and Stephens (2011) study focused on web – based learning environment that included a Camtasia video.

Programmes like the computer algebra system (CAS), dynamic geometry system (DGS) and spreadsheet program (SP) help learners to build and analyse mathematical models (Oldknow, 2009). Oldknow (2009) further showed that using these tools makes mathematics practical to the learners. This supports the acquisition of a deep mathematical conceptual knowledge.

3.4.2.4 Reasoning competence – being able to reason mathematically

This competence is the awareness of inductive, deductive, and logical reasoning in mathematics. Learners build arguments to support their solutions to problems and then defend these arguments (Albaladejo, Del Garcia & Sanchez, 2015). That is, objects, symbols, statements, diagrams, and representations are analysed based on given information or assumptions, and then conclusions are drawn based on the given or assumed information. The competence also comprises being able to uncover the basic ideas in a mathematical proof, including distinguishing between main lines of argument and details, as well as between ideas and technicalities (Niss & Jensen, 2002).

Learners who are competent in mathematical reasoning can apply these competences in an unfamiliar environment and this serves as the basis for future learning. Through justification, learners can tackle mathematics problems successfully. They are also able to model mathematics problems. Thus, justification plays a significant part in reasoning, modelling and problem-tackling competences.

This competence encompasses all the CAPS mathematics skills which are:

- Use mathematics language correctly;

- Collect, analyse, and organise quantitative data to evaluate and critique conclusions;
- Use mathematical processes skills to identify, investigate and solve problems creatively and critically;
- Use spatial skills and properties of shapes and objects to identify, pose and solve problems creatively and critically;
- Participate as responsible citizens in the life of local, national, and global communities and
- Communicate appropriately by using descriptions in words, graphs, symbols, tables, and diagrams.

Learners are enabled to reason mathematically. Through educational technology tools like Cabri and Geometer's Sketchpad, learners can create and explore geometric relations (Granberg & Olsson, 2015). These tools also support the development of formal proofs of geometric concepts by learners (Albaladejo, et al., 2015).

3.4.2.5 Representing competence - being able to handle different representations of mathematical identities

A representation in mathematics is a configuration of signs, characters, and objects (Goldin & Shteingold, 2001). A representation can stand for something other than itself. Thus, this competence comprises the ability to interpret, distinguish between, depict, symbolise, decode, or encode different kinds of mathematical objects, phenomena, problems, or situations. It also consists of being able to choose and switch between different representational forms for any given entity or phenomenon, depending on the situation and purpose (Niss & Jensen, 2002).

Symbolic representations are of special importance in mathematics. This is seen in how learners draw diagrams or write formulae to describe what they are thinking. In doing this, learners are also showing their mathematical thinking competence and mathematics communication competence. Thus, there is a clear relationship between representational competence, mathematical thinking competence and mathematical communicating competence. Communicating competency will be dealt with later in this section.

This competence, like the above competence, encompasses all the CAPS mathematics skills as indicated in the above competence. Technologies like CAS provide different representations of the same object. This is done by connecting graphic representations and formal definitions.

3.4.2.6 Symbol and formalism competence – being able to handle symbols and formal mathematical language

This competence involves decoding symbols and formal language; being able to translate back and forth between the mathematic symbol language and natural language; and being able to treat and utilise symbolic statements and expressions, including formulas (Niss &Jensen, 2002). They further indicated that this competence includes having an insight into the nature of the rules of formal mathematical systems.

Niss and Jensen (2002) showed that there is a difference between symbol and formalism competence and representation competence. According to them, symbol and formalism competence focuses on the character, status and meaning of the symbols as well as the way these are used, including the rules for such usage.

Unlike the above-mentioned competences, which encompass more than one of the CAPS mathematics skills, this competence forms part of one CAPS mathematics skill, which is the following:

- Communicate appropriately by using descriptions in words, graphs, symbols, tables, and diagrams.

It is important for learners to know both the symbol represented on a computer program and its conventional representation in textbooks. There is sometimes a slight difference of representation between these media (Polly, 2011).

3.4.2.7 Communicating competence – being able to communicate with, about and in mathematics or develop the correct use of language of mathematics

Language plays a significant role in the teaching and learning of mathematics. Mathematics is a language on its own and it is therefore important for its users to acquire it. Communication of mathematics concepts using appropriate mathematics language is an indication of deep mathematics conceptual development.

Mathematics communications enables learners to present their analysis in a clear and coherent argument, reflecting the mathematical sophistication appropriate to their level (Niss &Jensen, 2002). Communication can be visual, oral, or written. Thus, several diverse forms and media representations are used in this competence. Using different forms of communication in mathematics help learners to acquire clarity in understanding its ideas and concepts, which will in turn develop their interest in the subject (Lomibao, Luna & Namoco, 2016). As indicated above, this competence is closely linked to the representation competence. This can be seen in instances where communication makes use of mathematic symbols and terms, which serves to highlight the link to the symbol and formalism competency.

The communicating competence, however, goes further than the other competences described above. The communication happens between the sender and receiver. It is therefore important that the mathematical context be considered in communications.

This competence encompasses two of the CAPS mathematical skills which are:

- Use mathematical language correctly and
- Communicate appropriately by using descriptions in words, graphs, symbols, tables, and diagrams.

Different tools allow both learners and teachers to communicate about mathematics and promote proficiency in mathematics language. These tools include blogs, Google hang outs and social networks. Freeman, Higgins and Horney (2016) found that learners were better able to communicate their mathematics ideas in an informal social maths blog environment than in their maths tests or homework books. This assisted learners in acquiring deep mathematical understanding. The study was conducted in a developed context that does not present challenges of infrastructure encountered in developing context (Hennessy et al., 2010).

3.4.2.8 Aids and tools competence – being able to make use of and relate to the aids and tools of mathematics (including ICT)

This competence involves awareness and knowledge of appropriate tools that can be used in the learning of mathematics. Because of the abstract nature of mathematics, various kinds of tools have been used to enhance the teaching and learning of the subject. It is always important to consider the context in which tools are used, as well as the tools' limitations.

Tools are not limited to digital technological tools; non-digital technological tools are also included. Aids and tools help learners to develop their mathematical thinking and encourage them to work on their own and use the tools more often in their learning (Ahmed, Clark-Jeavons & Oldknow, 2004). This competence involves being able to deal with and relate to such aids.

Using different aids involves one or more types of mathematical representation. This competence is hence closely linked to the representing competence. Furthermore, since using certain aids often involves observing somewhat definite rules and rests on certain mathematical assumptions, the aids and tools competency is also linked to the symbol and formalism competency.

This competence does not include any of the CAPS mathematical skills. Thus, learners are not expected to have skills in the use of educational technology in their learning. This seems to be a contradiction as one of the minimum requirements for beginner teachers, as indicated above, is to be skilled in the use of educational technologies (DHET, 2011). What is more the South African government has policies in place for the use of technology in teaching and learning (DoE, 2004; DoE, 2007). For effective use of educational technologies in the classroom, both teachers and learners should have the skills and knowledge to use these tools in the teaching and learning environment.

3.5 Benefits of Using Technology in the Teaching and Learning of Mathematics

The growth of technology in today's societies has been received with widespread optimism and use, in the educational sphere as much as anywhere else. Countries are reaping the benefits of using these tools, in the teaching and learning of mathematics as in other areas. The main benefits of using technology in teaching and learning are the following: it increases collaboration among learners and encourages communication and knowledge sharing; it enables quick and accurate feedback for learners, leading to positive motivation; it allows learners to focus on strategies and interpretations for answers, instead of wasting valuable time on unnecessary computations; and it supports constructive pedagogy, that is, learners use technology to discover mathematical ideas and gain a deep understanding of mathematics (Smeets & Mooij, 2001; Ruthven & Hennessy, 2002; Webb & Cox, 2004). However, schools can only realise these benefits if educational technology tools are used effectively in their classrooms.

Additionally, the use of technology in teaching may enhance learner achievements in mathematics tests results. (Mistretta, 2005; Pierce et al., 2007) and increases the teaching and learning resources that are available to both teachers and learners. Technology ought to be integrated into teaching to ensure that learners also improve their electronic literacy skills (Dellicarpini, 2012). In this study, grade 12 learner participants were exiting the schooling system, while grades 11 and 10 were almost exiting the schooling system. All these learner participants needed digital literacy skills to be able to conduct their studies in higher education institutions. Thus, the use of ICT in teaching may be regarded as a responsive and innovative tool in the classroom for both the learner and the teacher.

However, the above-mentioned benefits to learners can be realised only if learners have access to the technology both on and off the school's premises. The types of technology used in mathematics, as well as the activities that learners are involved in, play a significant role in enabling leaners to realise the potential benefits of technology (Hillmayr, Ziernwald, Reinhold, Hofe & Reiss, 2020; Livingstones, 2012). Collaboration among learners is enabled by mobile technologies like smartphones, tablets, and iPads. However, the teacher should develop mathematics activities that will encourage communication among learners using different technology from that which they usually have access to (Fabian, Topping & Barron, 2018). In these kinds of learning environments learners share ideas and knowledge. They build new knowledge in a highly engaging, stimulating and rewarding atmosphere because of the collaborative activities created by the teacher (Borba, Clarkson & Gadanis, 2013). These activities help learners to improve their mathematical thinking, problem tackling, reasoning, representing and communication competences (Niss & Jensen, 2002).

Software programs like DSGs also provide settings in which learners can construct and experiment with geometrical objects and relationships (Sinclair & Robutti, 2013). Furthermore, Hillmayr et al. (2020) found that simulations and tutoring systems had greater effect sizes than drill and practice programs. This was because they offer immediate feedback to the learners as well as paced and guided activities. Thus, learners' explorations are encouraged. This help learners to discover mathematical ideas and gain a deep understanding of mathematics (Sinclair & Robutti, 2013). Ruthven, Hennessy and Deanery (2008) further indicated that DSGs have the potential to change learners' view of mathematics from a static-deductive activity that emphasises existing proofs to an exploratory-inductive activity that emphasises the heuristics involved in discovering results. These software programs enhance learners' modelling, representing, reasoning and aids and tools competences in mathematics (Niss & Jensen, 2002). However, most schools in low socio-economic circumstances cannot afford these tools (Hennessy et al., 2010)

Kerrigan (2002, cited in Mistretta, 2005) describes the following benefits of using mathematics software packages:

- Promoting learners' higher order thinking skills: mathematical games and simulations help learners to apply mathematical ideas to problem situations.
- Developing and maintaining learners' computation and communication skills: calculators increase learners' speed when solving mathematical problems, which leads to more accurate results and improved learners' confidence in mathematics.
- Introducing learners to collection and analysis of data: databases and spreadsheets give learners the confidence to analyse a large amount of data accurately.
- Facilitating learners' algebraic and geometric thinking: geometric and algebraic software offers learners a bridge from the abstract world of mathematics to the concrete world, allowing them to create and observe numerical, symbolic, and geometric representations.
- Showing learners, the role of mathematics in an interdisciplinary setting: integrated mathematics software packages allow learners opportunities to explore problem-based learning.

Muthomi, Mbugua and Githua (2012) study on teachers' disposition towards the use of scientific calculators in mathematics in Kenya found that calculators were ubiquitous in schools, assisted learners in problem solving by reducing computation time, made mathematics enjoyable and motivated learners to learn mathematics.

However, teachers did not believe that the use of a calculator would change their role in mathematics instruction. As the study was quantitative, teachers' beliefs could not be probed further. Pierce and Stacy (2010) indicated that using the calculator in this way focuses on the functional aspect of calculator use and does not consider the pedagogical aspect. The pedagogical use of a calculator focused on improving learning. However, the functional use of the calculator forms the basis of its pedagogical use in teaching and learning.

As far as the benefit to teachers are concerned, teachers can now search different internet websites and find various video clips and lesson plans to foster excitement and interest in the learning environment. By using technology in teaching, teachers create an interesting and stimulating learning environment that seeks to accommodate the different learning styles and different learning abilities of today's learners. According to Lynch (2006), the benefits of technology in schools can be seen in two ways: the pedagogical benefits and the administrative benefits. The pedagogical benefits imply that the technology enhances teaching and learning practices.

Technology enables teachers to use more efficient ways to develop aspects of learners' thinking, such as reasoning, understanding and creativity, that they would not achieve when employing traditional teaching practices (Tedla, 2012). Furthermore, certain capabilities such as comprehension and problem solving can be better learnt using interactive media. Through interactive media learners can visualise different representations of mathematics concepts and conceptualise relationships (Drijvers et al., 2010). Teachers should create these learning opportunities for their learners to maximise the effective use of educational technology.

South African schools are culturally and socio-economically diverse. Teachers need to consider different backgrounds and learning styles and levels of ability in their classrooms. According to Anthony and Walshaw (2009), effective teachers draw on a range of resources to support the development of mathematics concepts within the classroom. Instant precise computations, construction of graphs and symbolic processing using technology have shown to be beneficial in the teaching and learning of mathematics topics and concepts (Forster, 2006). Generally, teachers recognise technology in their teaching as an important tool for effective mathematics instruction (Franz & Hopper, 2007; Mistretta, 2005). In mathematics classrooms, technology influences the mathematics being taught and supports the mathematics learning of learners when integrated appropriately within the classroom (Li & Edmonds, 2005; Lin, 2008).

The use of technology has had a far-reaching effect on areas of school mathematics (Anthony & Walshaw, 2009). For example, by using technology to monitor learners' strengths and weaknesses while solving different types of problems, teachers may encourage success in the classroom (Anthony & Walshaw, 2009). The use of technology in teaching creates new ways of teaching and understanding abstract concepts in addition to addressing multiple learning needs. Technology in mathematics teaching creates a stimulating and collaborative learning process which engages learners in the material being taught (Anthony & Walshaw, 2009; Loch & Donovan, 2006). Using calculators, computers and dynamic software, learners can study complex abstract mathematics concepts (Franz & Hopper 2007). Additionally, the use of technology within mathematics classrooms, when integrated suitably with teaching methods, policy documents and assessments, has proved to support learning and has demonstrated an improvement in learners' mathematics achievement (Lin, 2008).

Despite the above-mentioned benefits to teacher of the use of technology in mathematics, its use does not guarantee the achievement of these benefits. Combining technology with effective pedagogy can be a complex task (Law, 2009). If technology is not well adopted in the school, educators may view its use for curriculum delivery as an add-on and not as an integrated part of teaching and learning. It is therefore necessary to understand the factors that affect the process by which teachers use the technology in teaching, to the point where technology becomes spontaneously incorporated into their teaching and learning process. This calls for different teacher knowledge and this knowledge, which is found in the TPACK framework. Teachers' progress in acquiring TPACK can help them to use technology in such a way that the above-mentioned benefits of technology in mathematics are realised.

3.6 Factors that Influence Learners' Use of Technology in Learning Mathematics

Learners' use of technology may be affected by several factors, which may be either contextual or personal. Contextual factors are those that relate to learners' specific situations, the schools' socio-economic status and teachers' influence on learners' use of technology. Personal factors are those that relate to the learners' characteristics, such as their competence in the use of technology.

3.6.1 Contextual Factors

Teachers play a significant role as learners' role models (Lai, 2015). The relationship that develops between teachers and learners has an impact on learners' learning (Davis, 2003 as cited in Lai, 2015). Lai (2015) found that when teachers encouraged and, commended learners, and guided them in their use of technology, learners continued to use technology outside the classroom environment. However, Lai (2015) study was conducted at a university, with sufficient technological tools for the learners, whereas the current study was conducted at secondary schools with insufficient technological tools for the learners. Wang, Hsu, Campbell, Coster and Longhurst (2014) further showed that learners' technology experiences were shaped and influenced by their use of technology in their classroom learning. Thus, learners need to be guided and supported in how to use technology for effective learning.

Teachers' use of technology in the classroom give the learners opportunities to use the technology in the classroom. If learners are allowed to use the technology regularly together with the teacher, learners can see the usefulness of technology in the classroom. Thus, they become motivated to use the technology due to their classroom experience (Agyemang, Hagan & Agyabeng, 2019). Agyemang et al. (2019) further mentioned that the school location contributes to learners use of technology in learning. Agyeman et al. (2019) found that learners from urban schools in Ghana used technology more often than learners from rural schools. Their assumption was that the urban environment was better resourced than rural the environment.

3.6.2 Personal Factors

Learners' ability to use technology for learning is one of the factors that make them persist in its use (Kim & Park, 2018). These learners are confident, not anxious when they use the technology (Agyemang et al., 2019). Learners' competence in the use of technology may be attained through its prolonged use, with the resultant gaining of experience. Learners' experience in the use of technology has been identified as one of the factors contributing to their competence in its use (Ainley, 2018). Other factors related to learners themselves are age, gender and number of years in school. Agyemang et al. (2019) found that older learners who were above 20 years of age use technology more often than learners below 20 years of age. However, they did not mention the reasons that contributed to these patterns of technology use.

3.7 Attitudes of teachers and learners towards the use of technology in the teaching and learning of mathematics

3.7.1 Attitudes of Teachers

Moila (2007) research findings pointed to numerous challenges that teachers faced in their efforts to use computers in their classrooms. One of these challenges was lack of training in the classroom use of computers (Moila, 2007). Furthermore, those who were trained indicated that the training was not enough, and that it was done after work and the teachers were consequently tired (Moila, 2007). Despite these challenges, most of the teachers were using these tools for their personal benefit (Moila, 2007). This calls for an understanding of teachers' confidence in the use of these tools in their classrooms. The way teachers perceive their competence in the use of educational technology plays a role in their use of these tools, and these perceptions can be influenced by their attitudes towards technology.

Attitudes towards technology play a prominent role in how technology will be used in teaching and learning (Agyei & Voogt, 2011; Govender & Maharaj, 2005; Sang, Valcke, Van Braak & Tondeur, 2009). Abedalaziz, Jamaluddin & Leng (2013) defined a person's attitude towards technology usage as their general evaluation or feeling about technology. The feeling or the evaluation will be either a positive or a negative feeling or evaluation. Positive outcomes result in one being motivated to use the technology, whereas, if the outcome is negative, one is likely to avoid the technology. Teachers' attitudes towards the use of technology in mathematics teaching and learning is a key element in their technology usage in that field. Sang et al. (2009) indicated that attitudes towards technology usage directly influence intentions with the use of technology and ultimately the extent to which technology will be used.

Studies on computer attitudes confirmed that individuals' attitudes towards technology usage are a result of many interacting factors (Reed, Drijvers & Kirshner, 2010; Sang et al., 2009; Yusuf et al., 2012). These factors include, among others, technology competency and confidence, length of training in technology usage, and access to technology tools. The various technological environments which teachers and learners find themselves also contribute to attitudes towards the use of technology (Cox, 2003). Cox further argued that understanding the scope and meaning of different technological environments is important for promoting positive attitudes towards technology.

Studies on technology confidence and attitudes have found a significant correlation between computer confidence and positive attitudes toward technology (Al-Zaidiyeen, Mei & Fook, 2010; Christensen & Knezek, 2008). Christensen and Knezek (2008) further indicated that confidence with computers is recognised as a necessary condition for effective use of technology in the classroom. However, confidence is gained through experience of practising an action – in this case the use of technology in mathematics teaching and learning. It is through in-service training programmes that practising teachers will gain the necessary experience. As teachers undergo training, they become more and more competent in the use of technology.

Familiarity with technology also contributes to gaining confidence and competence in using technology (Christensen & Knezek, 2008). Technology competence is differentiated into pedagogical technological competence and basic technological competence (Mishra & Koehler, 2006). Pedagogical technological competence refers to skills and abilities that one possesses to use technology in the teaching and learning environment, while technological competence refers to skills and abilities that one possesses to operate or manipulate any technological tool (Mishra & Koehler, 2006). In teaching and learning, pedagogical technological competency takes precedence, however teachers still need basic technological competence (Niess et al, 2009). Technological competence supports pedagogical technological competence and thus enables teachers to use technologies effectively in teaching and learning.

Other factors like gender, socio-economic status and age also contribute to attitudes towards technology (Agyei & Voogt, 2011). Socio-economic status is important, particularly in a developing context like South Africa where challenges of access to technological resources are still common. Schools in low socio-economic communities acquire technological resources by means of donations which are always insufficient (Isaacs, 2007). These schools have high teacher-learner ratios, and teachers are compelled to improvise because they must manage with a shortage of resources (Hennessy et al, 2010). In instances where teachers cannot improvise, there will be serious repercussions for the potential of ICT in teaching and learning (Hennessy et al., 2010). In short, socio-economic status in South Africa affects access to technology, which in turn affects competence in using technologies (Hennessy et al., 2010; Isaacs, 2007). Schools with cutting edge-technologies in European countries were reported to have good practice in technology usage in teaching and learning (Agyei & Voogt, 2011) because teachers had positive attitudes towards technology.

Most technology attitude studies are quantitative studies involving self-reported data (Christensen & Knezek, 2008). In South Africa, a quantitative study conducted by Govender and Maharaj (2005) in the province of Kwazulu-Natal found that teachers' attitudes towards the adoption of technology in teaching and learning were positive despite the limitations that characterise the status of educational technologies in South African schools. Most South African schools have inadequate computer resources (DBE,2019). However, in the same province, Kwazulu-Natal, in schools that had technological tools, large numbers of teachers were not using technology in teaching and learning (Govender & Govender, 2009). Govender and Govender (2009) further indicated that this was due to lack of teachers' competence in the use of educational technology in teaching and learning. Based on these studies, one can posit that the availability of technological resources and teachers' attitudes towards the use of technology are not enough to guarantee use of technology in teaching and learning. Over and above these factors, other aspects like technology courses for pre-service teachers, professional development for in-service teachers on technology use, and school culture need to be in place for technology to be used effectively in teaching and learning. These aspects may result in teachers developing confidence in the use of technology in teaching and learning. Govender and Maharaj (2005) concluded that policy makers could draw on teachers' positive attitudes toward technology to better prepare them to incorporate technology into their teaching and learning. However, their article did not go further to indicate how to foster these positive attitudes in teachers.

Sang et al. (2009) indicated that teacher training is of paramount importance in fostering positive attitudes towards using technology in the teaching and learning processes. It is through training that teachers can develop confidence, competence, and a sense of the perceived value and usefulness of the technology. Training should include modelling the use of ICT in teaching and learning (Govender & Govender, 2009). Ertmer and Ottenbreit-Leftwich (2010) suggested the form pre-service programmes could take in addressing attitudes towards the innovativeness of teachers in technology usage. Strategies include, among others, presenting models of teaching with technology to support new ways of learning, providing opportunities to implement new practices, and receiving feedback and providing opportunities to reflect on those practices.

3.7.2 Attitudes of Learners

There is a dearth of studies on learners' attitudes towards the use of technology in mathematics. In a study conducted in two South African township schools, Bovee, Voogt and Meelissen (2007) found a significant relationship between learners' attitudes towards computers, poor computer access and experience. A more recent study in a similar context, conducted by Sincuba and John (2017) found that most of the learners in their study had positive attitudes towards Mobile Learning Technology Based Instruction (MLTBI). The study was conducted in a grade 10 mathematics class of a historically disadvantaged school in the Eastern Cape province of South Africa. Sincuba and John (2017) concluded that MLTBI helped to build a positive attitude towards the use of educational technology in mathematics. However, the technology use was in the learning of functions. Thus, it cannot be inferred to other mathematics concepts.

What is more, not all learners respond in the same way to working with technology in mathematics. Reed, Drijvers & Kirschner (2010) found in their study that learners' attitudes and behaviours are influenced by school and classroom factors. School factors are aspects like school leadership and school culture, while classroom factors include aspects like teachers' attitudes and pedagogical practices. Teachers' attitudes and pedagogical practices have the potential to influence learners' attitudes towards technology and mathematics.

3.8 Chapter Summary

This chapter reviewed literature concerned with my investigation. Technology adoption set the tone for the chapter. Competence as a concept was discussed and teachers' and learners' use of technology was discussed based on their competence. The chapter further discussed the benefits of using technology in the teaching and learning of mathematics, factors that influence learners' use of technology and attitudes of teachers and learners towards the use of technology in teaching.

Chapter 4

Conceptual Framework

4.1 Introduction

The previous chapter highlighted pedagogical practices, competence in mathematics, the use of educational technology in mathematics and technology adoption models. In this chapter I describe the conceptual framework used in this study. The conceptual framework helped me to link all the elements of my study. Through the conceptual framework I was able to define the research problem; establish theoretical coherence; arrange the research design and implement and frame conceptual conclusions.

This study was informed by the Technological Pedagogical Content Knowledge (TPACK) framework which was used to investigate teachers' and learners' competence and confidence levels in using technology in teaching and learning. Firstly, I will discuss TPACK, which is used as the main theoretical framework of the study. I will then discuss the theoretical perspectives that are relevant to this study and will conclude the chapter thereafter.

4.2 Technological Pedagogical Content Knowledge (TPACK)

As indicated in the previous chapter, the way mathematics is taught in our schools is influenced by teachers' epistemological views. This view is sometimes influenced by how learners perform in their final examinations. Thus, some teachers take the trouble to review previous examination question papers with their learners in the classroom. Mishra and Koehler (2006) indicated that technology in teaching and learning introduces another variable that requires teachers to reconsider their teaching practices. It is on this basis that they developed a TPACK framework. TPACK is derived from Pedagogical Content Knowledge (PCK) which is Shulman's (1986, as cited in Koehler et al., 2014) new way of thinking about the knowledge teachers need for teaching. PCK is explained as the understanding of the subject matter together with the development of appropriate instructional strategies and skills for teaching and learning. Mishra and Koehler (2006) extended PCK to

Technological Pedagogic and Content Knowledge (TPACK). This extension considers the role that technology knowledge can play in effective teaching and learning. Thus, TPACK supports effective technology usage in the classroom.

TPACK consists of three main components which are Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). The interaction between these three components results in Technological Pedagogical Knowledge (TPK), Pedagogical Content Knowledge (PCK) and Technological Content Knowledge (TCK), while the intersection between the three results in Technological Pedagogical Content Knowledge (TPACK). In this study, the TPACK framework provided a means to investigate the influence of teachers' pedagogical practices and competence in mathematics on their use of educational technology in mathematics teaching and learning. Figure 4.1 below shows the TPACK framework, and it is followed by a brief overview of each of the TPACK components.

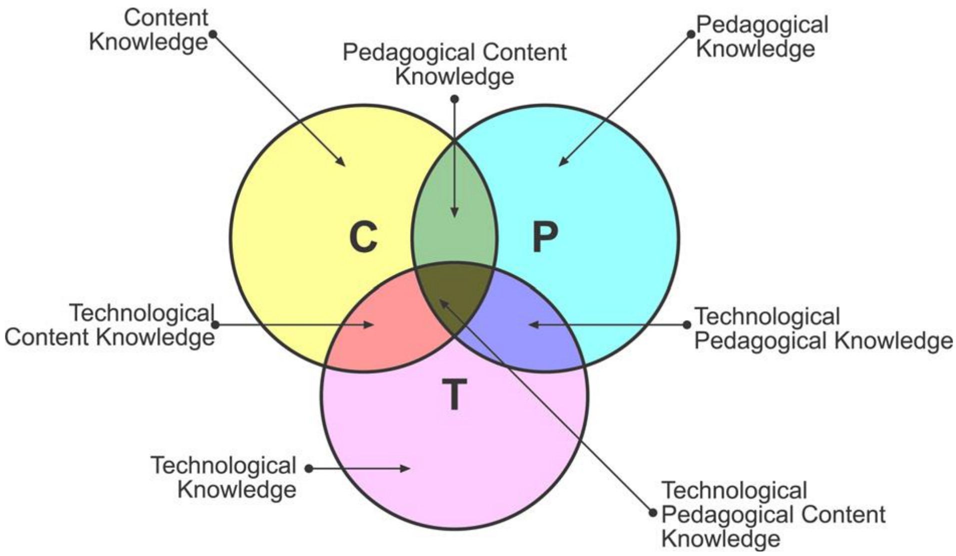


Figure 4.1 TPACK framework. Source: Koehler, Mishra & Cain, 2013, p. 15

The following sections provide full details of each of the domains of the TPACK framework to establish their individual elements and characteristics.

4.2.1 Content Knowledge

Content knowledge (CK) is about the subject matter knowledge the teacher possesses (Koehler, Mishra & Cain, 2013). Koehler et al. (2013) point out that teachers must know and understand the subject they teach, which encompasses concepts, theories, ideas, organisational frameworks, evidence, and proof as well as established approaches and practices towards developing such knowledge. Teachers would have acquired this knowledge during their schooling as grade 10 to 12 learners and during pre-service teacher training. However, if teachers do not have a comprehensive CK, there is a likelihood that learners will be taught incorrect information, which will result in misconceptions about the content area (Pfundt & Duit, 2000, as cited in Koehler et al., 2013). Furthermore, it is also unlikely that a teacher who is not well grounded in the subject matter will be able to use technology effectively enough to facilitate learning.

From 3.2, the discussion on competence, I deduce that teachers' CK stresses their personal characteristics of the competence domain. Teachers as individuals should possess knowledge of the subject matter; in this study teachers should possess the CK of mathematics. This is also a specific competence domain. Teachers also need to have attended formal schooling to acquire mathematics knowledge. This implies that mathematics CK is teachable. Thus, CK knowledge stresses both personal characteristics and specific domains of competence and is teachable. CK assisted me in exploring the influence of teachers' mathematics competence on the use of technology in teaching.

4.2.2 Pedagogical Knowledge

Pedagogical knowledge (PK) is deep knowledge about the process and practice or methods of teaching and learning (Koehler et al., 2013). Koehler et al. (2013) further indicate that PK embraces educational purposes, values, and aims. A teacher with a deep PK knowledge understands how learners construct knowledge and acquire skills, develop habits of mind and a positive disposition towards learning (Koehler et al., 2013). Teachers acquire deep PK through their experience as in-service teachers.

PK can also be developed through teachers' professional development (Yenmez, Erbas, Alacaci, Cakiroglu & Centikaya, 2017). In their study, Yenmez et al. (2017) found that a lesson study professional development contributed positively towards teachers' development of PK in mathematics. PK assisted me in exploring teachers' pedagogies when using technology in mathematics teaching.

4.2.3 Technological Knowledge

Technological knowledge (TK) is the knowledge, skills and values that enable a person to accomplish a variety of different tasks and develop different ways of accomplishing a given task using technological tools (Koehler et al., 2013). Teachers with a deep understanding of TK can effectively apply technology in their work. Such teachers are also assumed to make learning more interesting and comprehensible to learners. They can be innovative in terms of how to select appropriate technology to facilitate learning. From the explanation provided above, it is evident that knowing how to operate a specific educational technological tool would not place one on a high technological knowledge level. Rather, it is the skills and the appropriate use of the technological tool in teaching and learning that constitutes a high technological knowledge level.

Teachers may acquire competence in the use of a specific educational technological tool. This implies that a teacher has acquired the skills and knowledge to manipulate specific technological tools. For example, a teacher might have the skills and knowledge of using GeoGebra program in mathematics but lack the skill and knowledge of using Microsoft Excel. They can also acquire competence in a variety of technological tools. Thus, TK competence is specific to the individual teacher who demonstrates the competence. Also, TK competence can be acquired through learning, it is thus teachable. TK assisted in exploring the influence of teachers' mathematics competence on the use of technology in teaching.

4.2.4 Technological Content Knowledge

Technological Content Knowledge (TCK) is an understanding of the way in which technology and subject content constrain and influence each other (Koehler et al., 2013). Teachers need to know technologies that would be appropriate in helping them to represent learning content in an interesting and meaningful way to learners. Also, the technology exposes teachers to a variety of new ways of representing content to learners. Thus, it is important for teachers to understand that appropriate technologies should be used to address their subject content areas. For example, some graphing technologies often attempt to connect disjoint function pieces resulting in diagrams that appear as though the function is connected and continuous (Lassak, 2015b). This results in the tool representing mathematics in different forms. Mathematics conceptual representations by different technological tools should not differ from the conventional mathematics representations.

In acquiring TCK competence to represent mathematics content, teachers would have acquired the specific domain competence. TCK competence is acquired through learning and thus it is teachable. Through TCK I was able to explore the influence of teachers' competence in mathematics and technology on the use of technology teaching.

4.2.5 Technological Pedagogical Knowledge

Technological Pedagogical Knowledge (TPK) is an understanding of how teaching and learning can change when different technologies are used in specific ways (Koehler et al., 2013). Koehler et al. (2013) indicated further that development of teachers' TPK includes knowing the pedagogical affordances and constraints of a range of technological tools as they relate to disciplinarily and developmentally appropriate pedagogical design strategies. That is, the teachers demonstrate the capability and ability of managing the classroom, providing appropriate activities for the learners, ensuring that learners are working on tasks and guiding learners towards the attainment of the learning outcomes while using technology in teaching. This would, in turn, require the development of a deeper understanding of the affordances of technologies and the disciplinary contexts within which they function. TPK assisted in exploring the influence of teachers' mathematic knowledge on the use of technology teaching.

4.2.6 Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) is an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interest and abilities of learners and presented for instruction (Shulman, 1986, as cited in Koehler et al., 2013). Teachers with deep PCK can transform the subject matter and making it accessible to all learners in their classrooms. This is seen in how teachers pursue their questioning and structure the learning concepts. Teachers' questions evoke mathematical thinking, promote learners' understanding of mathematics and identify learners' errors and misconceptions.

PCK is a teachable competence domain. Teachers acquire this competence through their teacher training programmes as pre–service teachers. They can also acquire the competence through practice. However, it is developmental, which means that teachers can move from a lower to a higher level of knowledge. PCK assisted in exploring the influence of teachers' mathematic knowledge on the use of technology in teaching.

4.2.7 Technological Pedagogical Content Knowledge

As mentioned above, Technological Pedagogical Content Knowledge (TPACK) is the intersection of the three knowledge components and is the heart of good teaching with technology. According to Koehler et al. (2013), teachers with deep TPACK should demonstrate the following competences:

- Representation of concepts using technologies,
- Pedagogical approaches that use technologies in constructive ways to teach content,
- Knowledge of learners' prior knowledge and theories of epistemology and
- Knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones.

Teachers' instructional practices were investigated through the TPACK component to explore what they do with technology with learners in their classrooms. The quantitative study by Andyani, Setyori, Wiyona & Djatmika (2020) found that TPACK competence had a direct influence on teachers' pedagogy in the use of technology in the teaching and learning environments. As the study was purely quantitative it was not indicated how TPACK influenced teachers' pedagogy in the use of technology. It was important to have a better understanding of how teachers could best use ICT tools in their classrooms to address mathematics challenges experienced in there. A high level of technological knowledge confidence and competence was important because teachers needed these skills when they use the tools in their classrooms. Most teachers in South African schools were not trained in technology integration during their pre-service training, hence they lack confidence and competence in manipulating technological tools (DoE, 2007). Their training was based on content and pedagogy. This lack of training in the use of technology has had a negative effect on their use of technology in mathematics teaching and learning (Bingimlas, 2009). Lack of competency and confidence in manipulating different ICT resources limit teachers' abilities to choose appropriate and relevant ICT resources in mathematics (Bingimlas, 2009). Appropriate and relevant ICT resources help teachers to enrich the learning environment and achieve the learning outcomes in their classes (Koehler et al., 2013). This is because different ICT resources afford different content representation (Polly, 2010).

One significant criticism of the TPACK framework has been its lack of clear, universally accepted definitions of the core constructs, and the blurry boundaries between them (Angeli & Valanides, 2009; Archambault & Crippen, 2009; Jimoyiannis, 2010). In addressing these identified weaknesses Cox and Graham (2009) conducted a conceptual analysis of the TPACK framework, which resulted in a more precise TPACK definition that highlighted the unique features of each construct. Despite the criticisms, Mishra and Koehler (2006, p. 1044) explain as follows why the TPACK framework will work:

> One of the most frequent criticisms of educational technology is that is driven more by the imperatives of technology than by sound pedagogical reasons. The TPCK framework we argue has given us language to talk about the connections that are present (or absent) in conceptualization of educational technology. In addition, our framework places this component, the relationship between content and technology, within a broader context of using technology for pedagogy.

TPACK has been used in mathematics teachers' professional development programmes (Kafyulilo, Fisser, Pieters, & Voogt, 2015). Kafyulilo et al. (2015) found that teachers' TPACK development impacted positively on their classroom practices and learners' learning. The TPACK framework has also been used in secondary data analysis to measure mathematics teachers' TPACK level (Leendertz et al., 2013). Leendertz et al. (2013) found a significant association between teachers' TPACK level, impact of ICT use in mathematics, teachers' practices, teachers' confidence, and barriers to ICT use in mathematics teaching and learning. Guerrero (2010) found that TPK played a prominent role in the TPACK components in mathematics. A study by Stoilescu (2015) found that teachers' TPACK contributed to how they used the technology in their classrooms. Teachers were able to redesign their pedagogical practices and used the technology as learning support for the learners (Stoilescu, 2015). In this study, the TPACK framework was used to help understand the teaching and learning opportunities created by the technological tools and how the opportunities enhanced teaching and learning in mathematics classrooms. The context of the study was poorly resourced schools. It was imperative to investigate how teachers and learners responded to these opportunities created by educational technology tools.

4.3 Theoretical Perspective

Schools are social organisations. Social processes within the school affect how technologies are used in the classrooms (Frank, Zhao & Borman, 2004). A school's social networks consist of teachers, learners, and parents. Social networks provide people with resources. The relationships between teachers, learners, and parents constituted the school as an organisation. The school's social resources include the collaborative relationship in which teachers, learners and parents use technologies to contribute towards improving the teaching and learning of mathematics. Every member of the social network possesses personal resources. These members bring their resources with them to the social network. However, there are some individuals who are more resourceful than other members of the school organisation. These individuals have the capability and the ability to influence others' opinions, attitudes, and action.

Social networks influence the power and durability of attitudes (Granovette, cited in Plagens, 2011; Visser & Mirabile, 2004). Visser and Mirabile (2004) found that people with similar attitudinal views react in more similar ways than people with contrasting attitudinal views. Further on Granovette (cited in Plagens, 2011) described the connections individuals make within homogeneous groups as strong ties and those made across heterogenous groups as weak ties. Schools with more teachers who are experts in the use of technology might not resist using technology in their classrooms. On the other hand, schools with few or no experts in the use of technology might resist using technology in their classrooms. Teachers' changing or resisting attitudes will influence their behaviour towards the use of educational technologies in their classrooms. In this study teachers' resources include their confidence and competence in the use of technology, trust in their colleagues, and learners, and their pedagogical practices. Learners' resources are their confidence and competence in the use of technologies and their trust in their teachers, peers, and parents.

The above-mentioned collaborative activities, personal resources and social influence are associated with social capital. This study also drew on the theory of social capital. Social capital evolved through the works of Bourdieu, Coleman and Putman (Plagens, 2011). Plagens (2011) pointed out that these authors view social capital as a resource contained in social relations. I assume that teachers' networks contribute toward their competence and pedagogical practices in ICT use in mathematics teaching and learning. As schools share common goals, teachers working in the same school are likely to source help from one another and from learners in the use of ICT in mathematics teaching and learning. Teachers are likely to follow their colleagues in how they use ICT in teaching and learning. Drawing on their colleagues' and learners' expertise will influence their competence and pedagogical practices in the use of ICT in teaching and learning (Frank et al., 2004). Furthermore, the schools in the study obtained their technological tools by means of donations, which means that they do not have the financial muscle to enable the training of teachers in the use of technology in teaching and learning. Thus, social capital has a direct effect of teachers' use of technology in their professional practice (Barton, 2013; Frank et al., 2004; Li & Choi, 2014).

A study conducted by Barton (2013) found that leadership, trust, social networking, and social and cultural awareness were enablers of social capital. Barton (2013) further indicated that these aspects resulted in teachers being motivated, empowered, mentoring each other, and taking initiatives in the use of technology in teaching and learning. These factors mediated the adoption of technology and new ways of teaching (Barton, 2031).

On the other hand, teachers feel more comfortable teaching the way they were taught in their school days and how they have always taught as in-service teachers (Belland, 2009). Transforming their pedagogical practices threatens their comfort zones and negative attitudes develop as a result (Bingimlas, 2009; Ertmer, 2005; Govender & Maharaj, 2005). Instead of transforming, teachers would rather fit the technology into their pedagogical practice (Belland, 2009). In trying to explore the influence of teachers’ pedagogical practices and competence in mathematics on their use of technology and factors the affecting learners’ use of technologies in mathematics, I used a social constructivist lens to understand the knowledge development of both teachers and learners.

Constructivism is one of the influential philosophies regarding learning and teaching. Constructivism involves the way learners make sense of the learning material and how the material can be taught effectively (Amineh & Asl, 2015). In a constructivist learning environment, the teacher takes cognisance of what the learners know and allows learners to put their knowledge into practice (Amineh & Asl, 2015). A few theories have emerged from constructivism. Social constructivism is one of the two major strands of constructivism (Hyslop-Margison & Strobel, 2008), the other strand being cognitive constructivism. Social constructivism was adopted as a theoretical framework for this study. Social constructivism argues that knowledge is constructed through social interactions, interpretations and understanding (Vygotsky, 1962, cited in Adams, 2006). Adams (2006) further indicates that learning in a social constructivist environment is viewed as an active process where learners construct knowledge within and from social forms and processes.

Social influence or support plays a significant role in shaping the influence of teachers’ pedagogical practices and competence on their uses of educational technology in mathematics classrooms (Perienen, 2020). Social interactions among individuals in a specific context shape pedagogical practices of ICT usage in mathematics teaching and learning as well as their patterns of usage (Perienen, 2020). In this study, the schools’ socio-economic status is the context under which the investigation was conducted. Schools with high socio-economic status have cutting-edge ICT tools, whereas schools with low socio-economic status have limited ICT tools that might not be up to date. The type of ICT resources a school has at its disposal shapes its social interactions; and the social interactions are shaped by these tools (Yang, Lee & Kurnia, 2009). It is through this social constructivist lens that teachers apply learner-centred pedagogical approaches where learners are co-constructors of meaning and knowledge.

As mentioned above, TPACK is essential in understanding the effective use of ICT in teaching and learning. Most practising teachers gain technology skills through professional development. However, technological tools are always in a state of flux. This can affect the level of competence associated with the technology knowledge component of the TPACK. Lack of competence in any of the three main TPACK knowledge components will affect the framework. On the other hand, teaching is a social activity and teachers' knowledge will therefore develop from their social influence. It is important to understand the influence of social capital on teachers' knowledge development in the use of technologies in mathematics and the factors that contribute to learners' use of technologies in mathematics. Teachers' TPACK development will be shaped by their social interactions. The availability of expert teachers in a school will help teachers to develop a high TPACK level. Thus, their technology usage decisions are consistent with their TPACK level.

The majority of TPACK studies focus on measuring or developing different TPACK components while ignoring the TPACK context. However, few studies focused on the TPACK context, and these were in teacher education institutions (Archambault & Barnett, 2010; Boris, Campbell, Cavanagh, Petocz. & Kell, 2013; Kazu & Ertmer, 2014; Moroney & Haigh, 2011; Mouza, Nandakumar, Ozden & Karchmer-Klein, 2017; Owusu, Corner & Astall, 2015; Sahin, 2011; Schmit et al., 2009). These studies looked at the preparation of pre-service teachers to use technology in teaching in developed countries. The context in which the technology is used is important. In the above-mentioned context, access to technology and training of teachers on the use of technology are better as compared to developing countries. In the developing countries context, some schools might lack teachers who are competent in the use of technology. This implies that the sourcing of expertise should not be confined to the school environment. Professional exchange with institutions outside the school can provide teachers with access to expertise that the school does not have. This will help to develop teachers' TPACK level, which implies that teachers will have the knowledge, skills, and competences to use technological tools in their mathematics classrooms. As mentioned above, teachers' choice of technological tools will be guided by their pedagogical approaches, the content to be presented, and the representational effect the tool has on learners.

In this study I propose that teachers' TPACK level is likely to be related to the classroom practices employed in the school. The school's social structures also contribute to teachers' TPACK level, the classroom practices that are adopted, and the relation between the teachers' TPACK level and their classroom practices. The relationship between teachers' TPACK level and their classroom practices may also be one of the contributing factors influencing learners' use of educational technology in mathematics. The way learners use educational technology in learning determines whether they benefit from using these tools. It is therefore important to investigate the skills, values, and attitudes that learners possess. These attributes of competence are essential for ensuring that learners use technologies to benefit their learning. Figure 4.2 is the conceptual framework of the study.

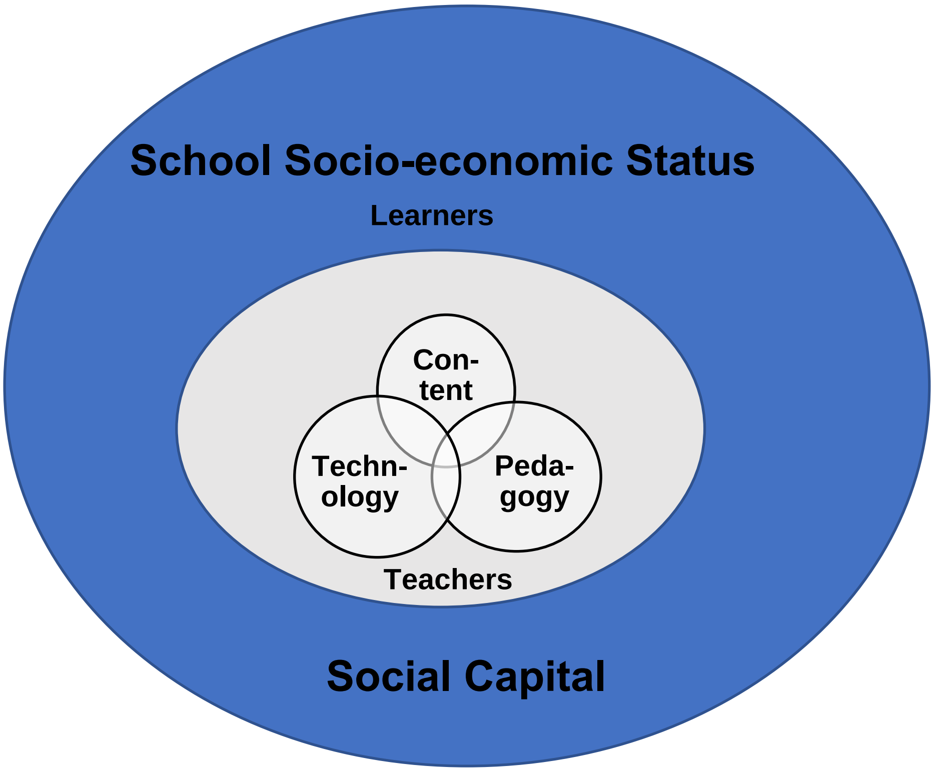


Figure 4.2 Conceptual framework

Figure 4.2, which is the conceptual framework I developed for this study, consolidates the above–mentioned discussions. Social capital and the socio-economic status of the schools underpin the framework. Teachers' pedagogical practices and their competence in mathematics and technology influence how they use educational technologies in mathematics. Teachers' use of educational technologies contributes to the factors that influence how learners use these tools in mathematics learning. The TPACK framework is at the heart of this study’s conceptual framework.

4.4 Chapter Summary

In this chapter I presented the conceptual framework that was developed for the study. TPACK as a measure of teachers’ competence in the use of technology in the classroom was discussed. The role that social capital plays in shaping teachers’ and learners’ competence in the use of technology was also explained.

Chapter 5

Research Design and Methods

5.1 Introduction

According to Hesse-Biber (2010), knowledge claims in research are supported by evidence that is supplemented by a clear articulation of the epistemology, methodology and methods that shape the research design. This implies the need for careful planning that will ensure coherence in the research. In this chapter I outline the methodology and plan for this study and, in so doing I demonstrate its coherence. The chapter gives an account of the research design employed in the study to obtain valid and reliable responses for the two research questions:

- How do teachers' pedagogical practices and competence in mathematics influence their use of educational technology in mathematics teaching and learning?
- What factors influence learners' use of educational technology in mathematics learning?

The study used a mixed method approach to investigate teachers' and learners' uses of educational technology in mathematics in two South African schools in Limpopo based on the school's socio–economic status and informal social processes. The chapter is divided into nine sections. Section 5.1 above is the introduction. Section 5.2 explains the philosophy of my ontological and epistemological stance and how this stance guided me towards the research paradigm. Section 5.3 describes the research methodology of the study. Section 5.4 gives an account of the research population and sampling. Section 5.5 justifies the selection of data collection methods. Section 5.6 explains the data collection procedures followed in the study. Section 5.7 discusses the measures taken to ensure the quality of the research. Section 5.8 explains the data analysis strategies adopted. Section 5.9 gives an account of the ethical considerations and Section 5.10 serves as a summary of the chapter. In this discussion, a link between the research problem and research methods is established.

5.2 Research Paradigm

According to Kuhn (1962, as cited in Sweeney, 2012), paradigms identify what is to be studied, the questions to be asked, and the nature of the questions along with the results. Thus, considering specific philosophies and selecting a suitable approach for research is essential when conducting research (Creswell, 2014). This implies that the way we view our world(s), what we take understanding to be, and what we see as the purposes of understanding inform our understanding of the world and influence how we conduct research. This is reflected in the methods and methodology that are employed to address the research questions (Creswell, 2014). A few research paradigms have been applied in mixed methods studies. They include realism, pragmatism, and transformative research paradigms (Hall, 2013). Teachers and learners' experiences in their social environment played a significant role in this study. Consequently, the study adopted a pragmatic view. The discussions below show how teachers' and learners' experiences in their social environment in a specific context contributed to the ontological and epistemological aspect of this study.

5.2.1 Pragmatism Research Paradigm

Pragmatism views knowledge and its development to be dependent on personal experiences, the environment in which experience is encountered, and social and collaborative processes to address the problems at hand (Biesta, 2014). Even though knowledge is a personal experience, through negotiated conversation individuals can have shared meanings (Biesta, 2014). Thus, two different people might experience an incident differently, but through negotiated conversation they may come to a shared understanding. This results in practical solutions based on experiences (Biesta, 2014). In this study, both teachers' and learners' experiences of technology use might have been similar or different even though they were from the same school. Also, the interpretation of their experiences might have been similar or different. Thus, the study explored teacher participants' reality in terms their competences and pedagogical practices and learner participants' reality in terms of their technological practices as a way of knowledge construction. These varied or similar experiences pose challenges in research and thus appropriate strategies of enquiry had to be used to understand them.

Hesse-Biber (2010) and Creswell (2014) argued further that the context in which meaning is sought plays a significant role as it provides the tools through which meaning will be created and hence a subjective understanding of the world which is varied and multiple. Most schools in South Africa are poor as they lack basic resources like furniture, toilets, and classrooms. Also, most in-service teachers were not trained in the use of technology teaching and learning during their pre-service training programmes. However, they are still expected to use these tools in their classrooms. Thus, it is important to understand how their pedagogical practices and competence in mathematics influence their use of educational technologies in their classrooms based on their schools' socio–economic status. On the other hand, learners are attending school in an era where technology is ubiquitous. What are the factors that influence learners' use of technology in learning mathematics?

From a research point of view, the challenge was that there are multiple perspectives on social reality, and therefore appropriate methods of enquiry must be used to understand such reality. My argument was that teachers' and learners' practices are informed by their social processes while interacting with educational technology tools that have the potential to change or transform their classroom practices. In this study both teachers and learners shared their experiences of the use of educational technology in teaching and learning. These experiences may influence their views on the value of using such technology in teaching and learning. As a researcher I looked for the complexities of these varied and multiple views of the participants' understanding of the use of educational technology in teaching and learning of mathematics (Creswell, 2014; Hesse-Biber, 2010).

The goal of research is to add value and knowledge to the area of study (Greener, 2008 as cited in Maarouf, 2019). For me to succeed in obtaining the participants' varied and multiple views, I ensured that enough data was collected. In getting enough data I used a combination of a quantitative and a qualitative approach. Although quantitative and qualitative methods are separate research approaches, pragmatism argues that they can be used to complement each other's weaknesses. Pragmatism assisted me in designing and conducting my study in the way that best serves to answer the research questions (Creswell, 2014). Thus, I used both qualitative and quantitative research approaches as research methods that "work" (Maarouf, 2019, p.5) in conducting my study.

It was also important to make a link between the epistemological stance and strategies employed in research (Creswell, 2014). The research design below outlines how the paradigm influenced this study.

5.3 Research Methodology: Mixed Methods Study

This study, as mentioned in 5.2 above, describes and analyses participants' experiences in their practices of the use of educational technology in mathematics teaching and learning environment. To generate a deeper and broader insight into the problem the study used a mixed methods approach. A mixed methods approach is described as a research approach where the researcher mixes both quantitative and qualitative approaches in a study (Creswell, 2014). The mixed methods approach facilitated a better understanding of how teachers' pedagogical practices and their competence in mathematics influence their use of technology in mathematics and of factors influencing learners' use of technology in mathematics. The data was collected from both teachers and learners using qualitative and quantitative approaches. This assisted in improving the interpretation of results as the data was triangulated. Thus, I got a thorough understanding of how learners and teachers make meaning out of their experiences.

There are several prior studies that used a mixed methods approach to investigate the use of educational technology in mathematics teaching and learning (Ashiono, Murungi & Mwoma, 2018; McKim, 2017; Mendoza & Mendoza; 2018; Ndlovu, Ramdhany, Spangenberg & Govender, 2020).

5.3.1 Quantitative Approach

This research approach involves a numerical or statistical approach to research design. Data is used objectively to measure reality (Creswell, 2014). I used objective questionnaires to create meaning, soliciting information about learners' competences and attitudes towards the use of technology in mathematics learning. Statistical information simplified into percentages made communication easier and brought reality to the reader. The statistical information was used at the data analysis stage of this study. Thus, a descriptive data analysis process was followed (Creswell, 2014).

5.3.2 Qualitative Approach

This is described as an unfolding model that occurs in a natural setting and enables the researcher to develop a level of detail from close involvement in the actual experience. One identifier of a qualitative research is the social phenomenon being investigated from the participants' viewpoint. In this study, four teachers and 14 learners out of 79 learners were interviewed. An observation was conducted of two teachers, one in each school. Gaining a rich and deep understanding of teachers and learners' experiences, meaning, and perspectives and capturing their voices and conversations, was of utmost importance in this approach.

I perceived the use of technology in mathematics as a social construction based on certain social values and necessarily affected by a multiplicity of factors within a given context. It was essential to determine how learners and teachers constructed their meaning in relation to the use of technology in mathematics teaching and learning in the studied schools. Communicating with and observing both teachers and learners provided a clear understanding of the influence of teachers' competence and pedagogical practices on their use of technology. Also, factors affecting learners' use of technology in mathematics learning were revealed.

5.3.3 Types of Mixed Methods Designs

There are a variety of mixed methods designs. Creswell (2014) classified the mixed methods designs as follows: Convergent parallel mixed methods, explanatory sequential mixed methods, exploratory sequential mixed methods, transformative mixed methods, and multiphase mixed methods. In this study a convergent parallel mixed method approach was adopted.

A convergent parallel mixed method design involves collecting both quantitative and qualitative data separately, analysing the data separately and then comparing the results to see if the findings confirm or disconfirm each other (Creswell, 2014). This stage of comparing the findings is termed convergence or divergence (Creswell, 2014). Convergence is when the findings confirm each other while divergence is when the findings disconfirm each other (Creswell, 2014). As indicated in 1.2 of Chapter 1 above, that the aim of the study was to investigate the influence of teachers' pedagogical practices and mathematics competence on their use technology in a mathematics teaching and learning environment and the factors affecting learners' use of technology in mathematics in two secondary schools in Mopani District in Limpopo Province in South Africa. Thus, both teachers and learners' competences in the use of technology in mathematics were investigated. Quantitative data in the form of a questionnaire was used to triangulate qualitative data in the form of interviews and observations. This assisted in maximising the interpretation and understanding of the research problem.

Though the convergent parallel design was chosen for the study, it had its own shortcomings. The mixing of the data during the writing process is a potential pitfall, as it can result in the two datasets diverging (Hesse-Biber, 2010; Creswell, 2014). In this study, divergence of data was identified as one of its limitation. The research design for this study is shown in figure 5.1. Figure 5.1 shows the relationships between the research questions that underlie the interview, observation and questionnaire approach, the findings from the research and the discussion of the results considering the research questions, the study implications and recommendations.

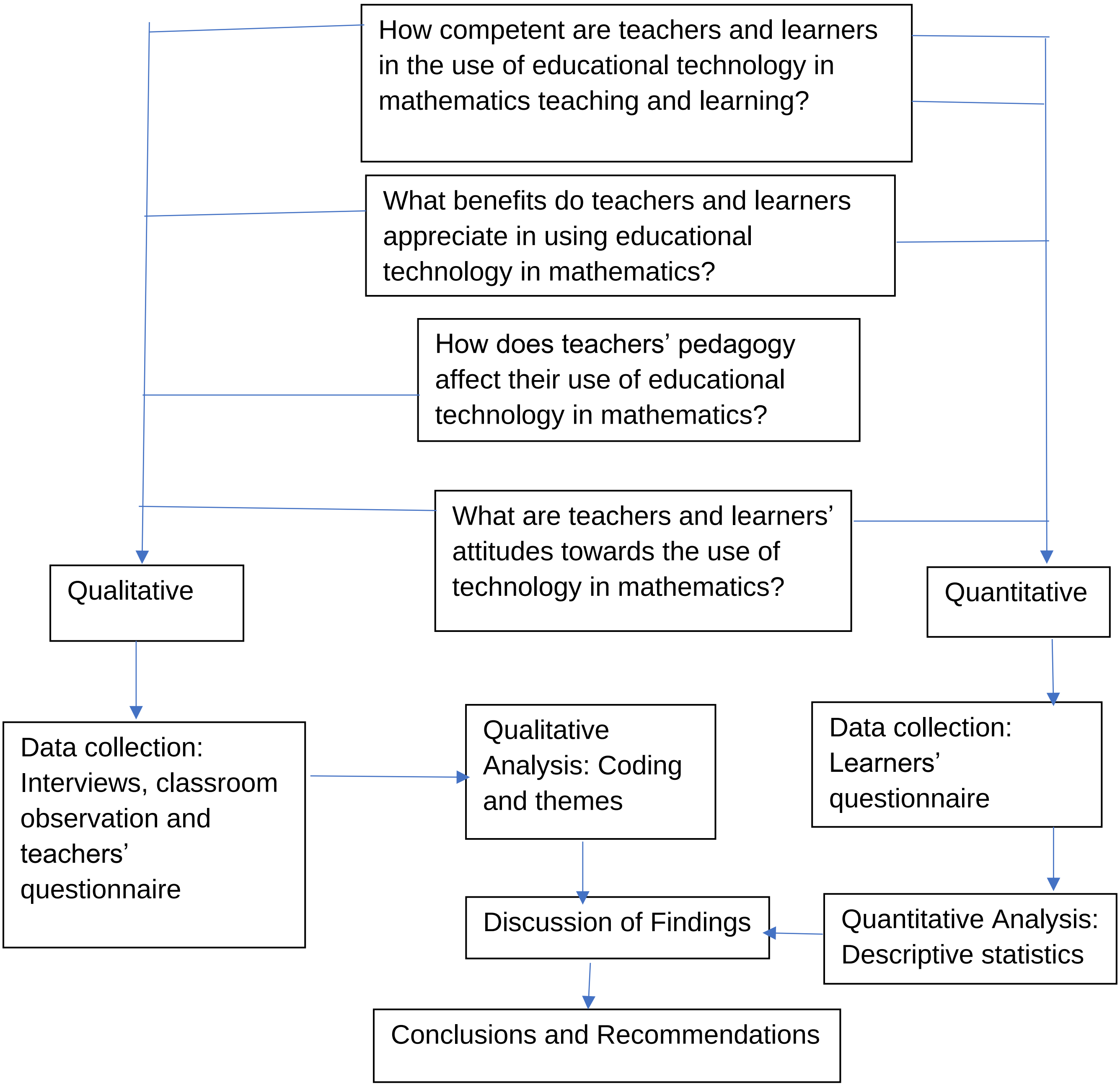


Figure 5.1 Research design

5.4 Research Population and Sampling

Two schools were identified in Mopani District of Limpopo province. The schools were purposefully identified to participate in the study. I had asked the ICT district coordinator about schools that were implementing educational technologies in their teaching and learning and were in low a socio-economic community. Thus, the schools were handpicked based on the information I received from the ICT district coordinator. I was therefore limited to two schools. The schools (referred to as school A and school B) were also in the same district in which I was working and were situated in the same circuit. Thus, it was convenient for me to access the schools, making it easier for me to collect the data.

My intention was to have all the mathematics teachers and 60 sampled learners in grades 10-12 for each school participating in the study. The following formula was used to choose 20 learner participants per class per school.

Number of learners/n = 20, and every nth learner was recruited to participate in the study.

Grade 10-12 learners were chosen because the South African government pays more attention to these grades as the learners are exiting the Department of Basic education (DBE) to the Department of Higher Education and Training (DHET). There is pressure on South African government to increase the number of learners exiting basic education with a good grade 12 mathematics pass. Thus, all the strategies that may help mathematics learners to exit with a good pass are important.

It was envisaged that 20 learners per grade would be chosen to participate in the quantitative part of the study. A further sampling was done for learners to participate in the qualitative part of the study. In school A, two mathematics teachers agreed to take part in the study. All the teacher participants were males. However, one educator withdrew from the study. A total of 43 learners returned their signed parent consent forms indicating their agreement to allow their children to participate in the study. Of the 43 learner participants, 18 were females while 25 were males. In school B, three mathematics teachers agreed to take part in the study. Two males and one female. A total of 38 learners returned their signed parent consent forms indicating their agreement to allow their children to participate in the study. Of the 38 learner participants, 26 were females while 12 were males. However, two female learners did not return their questionnaires and were subsequently withdrawn from the study.

5.5 Data Collection Methods

Selecting appropriate data collecting methods for answering research questions is important in ensuring that the research is valid. In this study validity was ensured by using both quantitative and qualitative research approaches. As indicated in table 5.1 multiple data collection methods were used for this research. Table 5.2 below gives a summary of the comparative strengths and weaknesses of the data collection methods for this study. Interview' strengths and weaknesses are based on Lune and Berg (2017) and Queiros, Faria and Almeida (2017). Observation' strengths and weaknesses are based on Queiros, Faria and Almeida (2017). Questionnaire strengths and weaknesses are based on Creswell (2014)

Table 5.1

Sources of Evidence: Strengths and Weaknesses

Sources of Evidence	Strengths	Weaknesses
Interviews	• Allow participants to give detailed and insightful information • Allow the researcher to follow the interest and thought of the participant • Generate rich data	• Time consuming • Response bias • Inaccuracies due to poor recall • Participants might give what the researcher wants to hear
Direct Observation	• Data is collected immediately in real time • Contextual–can cover the participants' context	• Time-consuming • Selectivity–broad coverage difficult without a team of observers • Participants may act differently because they are being observed • Dependent on the observer's impartiality
Questionnaires	• Low level development • Cost effective • Easy data collection and analysis using statistical methods • Can reach a wide audience • High representation • Not affected by the subjectivity of the researcher	• Reliability of data is dependent on the quality of answers and the survey structure • The questionnaire has a rigid structure • Do not capture emotions, behaviour or changes of emotions of respondents

Below follows a discussion on each of the data collection methods displayed in Table 5.1 above. I start by discussing the qualitative data sources, then followed by a discussion of the quantitative data source.

5.5.1 Semi-structured Interviews

Interviews are viewed as some of the most important sources of data generation in the qualitative research approach (Lune & Berg, 2017). In semi-structured interviews, respondents are asked the facts of a matter as well as their opinions about events or their insights, explanations and meanings related to certain occurrences (Lune & Berg, 2017). Lune & Berg (2017) indicate further that, respondents can be asked to offer their own insights into certain occurrences, which may be used by interviewer as the basis for further inquiry. The semi-structured interview questions for this study were developed from literature reviewed in Chapter 3, and from Chapter 4 which is the conceptual framework of the study. Guiding questions together with prompts were developed to elicit responses from participants (see appendices D & E). The questions also became more specific to elicit the required information (see appendices G & H)

5.5.1.1 Teachers' interviews

The purpose of using interviews in this study was to initiate a conversation with teacher participants about their experiences, competences, and pedagogical practices in the use of educational technology generally, and in mathematics teaching specifically. The information collected from the teachers' interviews gave an insight into how teachers' pedagogical practices and competence in mathematics influence their use of educational technology, and factors influencing learners' use of educational technology. The questions were grouped in five sections (see Appendix G). The first section consisted of questions related to the implementation of educational technology usage based on their school context and how their context has influenced implementation. The second section sought to elicit teachers' experiences of the use of educational technology and the barriers encountered. The third section focused on teachers' opinions on the value of the use of educational technologies. In the fourth section the questions were about teachers' pedagogical orientation. The last section focused on teachers' confidence level in mathematics and the use of educational technologies.

5.5.1.2 Learners' focus group interview

I also initiated a conversation with learners about their experiences and practices in the use of technology generally as well as in mathematics learning. The learners' interview questions were divided into four sections (see Appendix H). The first section sought to get information on learners' access to technological tools and the support they get from the school. The second section focused on learners' skills in the use of educational technology. In the third section questions were related to learners' persistence in and attitudes towards the use of educational technology in mathematics. The last section sought to obtain information about learners' perceptions of the value of the use of educational technology in learning.

5.5.2 Observations

Observation, as a data collecting strategy, enabled me to see the behaviour and actions of participants first-hand in real–life situations. In the observation I spent at least one hour and ten minutes observing a lesson in which educational technology tools were used. In school A I observed one teacher participant because the other teacher withdrew from the study. Though I interviewed three teachers in school B, I also observed only one teacher.

The purpose of my observation was to investigate the interaction among learners, the teacher, and the technological tools in the classroom environment. Through observations I was able to gather information about the physical setting in use, the classroom layout, and the place where the positioning of educational technologies. The observation strategy further afforded me the opportunity to explore how educational technologies were used by either the teacher or the learners for various purposes. These purposes were both instructional and motivational and were understood within this interaction between learners and teachers. Lastly, the observation enabled me to understand and explore the pedagogical orientation of the teachers when they used educational technologies in their pedagogical practices.

Since the observations formed part of the qualitative approach, they were unstructured. These teachers had never attended any training in the use of educational technology in mathematics; their use of the technologies was therefore based on their beliefs about mathematics teaching and learning. I also introduced myself in the beginning of the observation and explained the purpose of my presence at the classroom to make learners feel at ease and free. All observed lessons were videotaped with the permission of the teacher and the learners, and later replayed for transcription purposes. This also provided me with the opportunity of replaying the lessons if I needed to get a clear picture of the observation lesson.

5.5.3 Questionnaire

The questionnaires in this study involved the use of questions to elicit responses in a self-completion format to generate data. In this study two formats of questionnaires were used – one for teachers (Appendix I) and another one for learners (Appendix J). The questionnaires were used to triangulate the interview and observation data.

5.5.3.1 Teachers' questionnaire

Two teachers from school A and three from school B responded to the questionnaire. As indicated above, the data from one teacher in school A was disposed of as he withdrew from the study. The purpose of the teachers' questionnaire was to get an understanding of how teachers perceived their competence in the use of educational technology in teaching. The questionnaire was convenient as teachers could complete it in their own time in the absence of the researcher. Teachers' competences on the use of educational technology may be influenced by their personal characteristics as well as environmental factors (Ertmer, 2005). Thus, the questionnaire focused on both teachers' personal characteristics and environmental factors. Information about teachers' personal characteristics included demographic information, their perceptions about their use of educational technology using the TPACK survey measure, and their attitudes towards educational technology tools in the mathematics classroom. Information about teachers' environmental factors included technologies that teachers own and use. Thus, the questionnaire consisted of four sections.

The demographic information requested participants' school, name, age, experience in teaching mathematics, highest qualification in mathematics and gender. In the section on uses of technology, respondents were requested to mention the technologies they owned and used in mathematics teaching. The first part requested respondents to put a cross in a box next to the name of the technological tool they owned. Respondents were asked to select from the options provided, which included the following: a smartphone, a tablet, an iPad (or other tablet), a laptop, a computer, and a programmable calculator.

The second part requested respondents to mention technologies they used in mathematics and to explain how they used each of the mentioned technologies. The TPACK measure requested participants to indicate their capability in the different knowledge components of the TPACK model. Although the questions were grounded in TPACK, the focus was not to assess teachers' TPACK knowledge directly. Rather, it was designed to assess teachers' perceptions of their competence in the use of educational technology in mathematics classrooms. The TPACK measure was designed based on Sahin's (2011) TPACK survey. Sahin's measure has seven subscales which are CK, PK, TK, TPK, PCK, TCK and TPACK. The questionnaire focused only on teachers' ability as a measure of their competencies (subscales TK, PK, PCK, TCK, and TPACK). The assumption was that teachers might be able to perform certain competences in relation to the use of technology in mathematics teaching even though they did not use technologies in their classrooms. The CK subscale focused on teachers' conceptual knowledge of mathematics and the way they used this knowledge in the classroom. The assumption was that in–service mathematics teachers should have enough content knowledge to impart the knowledge in the classroom. The CK subscale was based on Boris et al.'s (2013) survey. They developed a survey for investigating in-service mathematics teachers' perceptions of their use of educational technology using the TPACK framework. The TPACK section has 74 items. A five-point Likert scale was used on which participants indicated the extent of their agreement with a given statement, ranging from strong disagreement to strong agreement (1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*). Below is Table 5.2 that describes the subscales developed for the section on TPACK. The first column displays the name of the subscale. The second column indicates the number of items developed for each subscale. The third column shows a representative item of each of the seven TPACK subscales. See Appendix I for teachers' questionnaire. The questionnaire was also pretested.

Table 5.2

TPACK questionnaire subscale description

Subscale name	Items number	Sample item
Technological knowledge (TK)	3	I can learn new software on my own.
Pedagogical knowledge (PK)	15	I adapt my teaching based on what students currently understand or do not understand in mathematics
Content knowledge (CK)	5	I am good in geometry
Technological Pedagogical knowledge (TPK)	34	I use technology to support learner–centred strategies that address the diverse needs of all learners in learning mathematics
Technological Content knowledge (TCK)	28	I facilitate equitable access to technology resources for all learners in learning mathematics
Pedagogical Content knowledge (PCK)	21	I use appropriate and effective teaching strategies for my content area in mathematics
Technological Pedagogical Content knowledge (TPACK)	45	I facilitate technology–enhanced mathematical experiences that encourage all learners to develop higher order thinking skills

The attitude measure had 12 items which focused on respondents' confidence in using educational technologies in mathematics and were positively worded statements. Respondents rated each statement using a similar Likert scale to the one in TPACK. The attitude measure was developed from literature on attitudes towards the use of educational technology in mathematics (Agyei & Voogt, 2011; Pierce & Ball, 2009; Sang et al., 2009; Siragusa & Dixon, 2008). Confidence items focused on respondents' perceived likelihood of success when using technologies and whether they perceived success in the use of technology as being under their control. High scores for each item indicated respondents' confidence in respect of the use of technology in mathematics.

5.5.3.2 Learners' questionnaire

In this study a learner questionnaire was used to investigate learners' perceptions of their competences and confidence in the use of educational technology and the factors that influenced the use of educational technologies in mathematics learning. The questionnaire consisted of three sections which were demographic information, participants' technology use, and their attitudes towards mathematics and the use of technologies in mathematics. In the demographic information, participants were requested to indicate their age, grade, school, and gender.

The section on technology use had three parts. In the first part, participants were given a list of different technologies and asked to use a tick to indicate the technologies that they owned. In the second part, they were required to list the technologies they used for mathematics learning and how they used them. The last part was subdivided into three parts. In the first subdivision participants were given statements and had to indicate how frequently they used technologies to perform specified activities at home and at school. The scale for use of technologies ranged between *Never, Yearly, Monthly, Weekly* and *Daily,* which indicated a low frequency of use to a high frequency of use. This section focused on learners' competence in the use of technology generally and in mathematics learning specifically.

The second subdivision focused on learners' attitudes towards the use of technologies in mathematics learning. This section consisted of statements that were ranked on a Likert scale. The statements were taken from literature on learners' attitudes towards mathematics and the use of ICT in mathematics (Barkatsas, Kasimatis & Gialamas, 2009; Farooq & Shah, 2008; Reed, Drijvers & Kirschner, 2010; Visser & Mirabile, 2004). The scale was a Likert like the one in TPACK. The last subdivision focused on learners' confidence in the use of technology in mathematics learning. As in the second subdivision, the statements were ranked on a Likert scale. Appendix J is the learners' questionnaire

5.6 Data Collection Procedure

I made an appointment to meet with the circuit manager of the two schools and explained the purpose of my study during the meeting. I produced the file that contained the necessary information about my research: consent forms, questionnaires, interview and observation schedules, and the data collection plan.

Based on this detailed explanation of my research, the circuit manager granted me access to the schools to conduct the study. He did not write a permission letter but appended his signature on the permission letter (Appendix C) from the provincial department.

A series of meetings were arranged with each of the schools. The first two meetings were with the principals of each of the schools, at which I presented the permission letter from the Limpopo Provincial Department of Education and the appended signature on the letter from the circuit office. Permission was obtained from each school, and I was directed to the head of the mathematics department. The third and fourth meetings were with the head of the mathematics department and the mathematics teachers of each of the schools. At these meetings I explained my research to the potential teacher participants, including the aim of the study and what the study intended to achieve.

In school A two mathematics teachers agreed to participate in the study. However, one later withdrew as indicated in 5.3 above. All mathematics teachers in school B agreed to take part in the study. All participants were issued with consent forms. Lastly, I met with the grade 10-12 learners at both schools. At these meetings I explained my research to all the learners. I also indicated that a maximum number of 20 learner participants per class was required and the criteria for choosing participants were explained as indicated in 5.3 above.

As mentioned in 5.3 above, a parallel mixed method research design was used. Thus, the two data sets were collected independently of each other. I now outline the procedure I followed in collecting these two data sets.

5.6.1 Qualitative Data

In this study, five mathematics educators were interviewed: –two from school A and three from school B, and two focus group interviews were conducted with the learners: –one from school A and the other one from school B. However, as indicated above, one teacher from school A withdrew from the study. The data collected from this teacher was never used in the study. As indicated, there was purposeful sampling for learner participants. No sampling was done for teacher participants as I viewed all mathematics teachers as participants. The interviews were conducted outside normal working hours as I could not interfere with the normal teaching and learning time in the two schools. In school A, one teacher was interviewed in the office of the mathematics head of department, while the other educator was interviewed in his own office. The venues were convenient for my participants; there was no disturbing noise or in-out movement of either colleagues or learners. The focus group interview with learners was conducted in the computer laboratory. In school B the three teachers were individually interviewed in the office of the mathematics head of department. As in School A, the venue was convenient for all the teacher participants. The focus group interview with the learners was conducted in the science laboratory. Each focus group session had a moderator and a note-taker. An audiotape was used to record the interview responses with the permission of the participants.

As indicated in 5.3 above, two types of samples were drawn for learner participants. The first was a random sample selecting learners to participated in the study. The second level of sampling was created from the learners sampled in level 1. The level 2 sampled learners participated in the focus group. Learners who indicated that they were using more than three different technological tools on a weekly basis were regarded as active users of technologies. They were chosen as a probable source of rich data about learners' uses of technologies. The information gathered from the focus group interview gave insight into learners' competence in the use of educational technology and the factors influencing learners' use of technology. In each schools the focus group consisted of seven learners.

An appointment for a lesson observation was scheduled with each of the teachers observed. However, in school A I was compelled to reschedule because on the day of the appointment the school laptops were not accessible. The head of department (HOD) for commercial subjects, who was charged with the responsibility for taking care of the laptops, was absent. I spent at least one hour and ten minutes observing a lesson in which educational technology tools were used. In school A I observed one teacher participant because the other teacher had withdrawn from the study. Though I interviewed three teachers in school B, I also observed only one teacher. The other two teachers did not allow me to observe them.

During the observation there was no interaction between me the learners, or the teacher. After each observation I held a follow-up interview with each teacher to understand why they chose the tool they had used for that lesson, how the tool assisted them in realising the lesson objectives, and how appropriate the tool had been for the lesson.

Field notes were also recorded. The field notes allowed me to maintain and comment upon impressions, environmental contexts, behaviours, and nonverbal cues that I could not adequately capture through the audio recording. Field notes also helped me to start the analysis during the data collection process (Spradley, 1980). This gave me the opportunity to question teachers' practices immediately after the observation lessons. The field notes were useful in the interpretation and evaluation of the observations and interviews of both learners and teachers.

5.6.2 Quantitative Data

Both the teachers' and the learners' questionnaires were pretested before they were administered to the participants. The pre-test study was done to identify unclear and ambiguous terms and questions. Teachers and learners who participated in the pre-test were not part of the main study. On my second visit to the school, I distributed teachers' questionnaires and requested a meeting with the sampled learners who returned their declaration forms. A meeting was scheduled for that same week in school A while in school B it was scheduled for the following week. The purpose of the meetings was to take the learners through the questionnaire while they were completing it. This assisted me in getting a 98% response on learners' questionnaires. It also assisted in providing clarity to learners on questions they did not understand.

5.7 Reliability, Validity and Credibility

To ensure the quality of my research, I used several strategies throughout my research process. Although only four teachers completed the questionnaire, a pre-test study assisted in determining the stability of the questionnaire (Bryman, 2008). It was pretested with 22 participants who were not part of the study. The Chronbach's Alpha score for the Likert-type scale questions were all greater than 0.7. Thus, the questionnaire was reliable. Also, the teachers' questionnaire was based on Boris et al.'s, (2013) survey which was found to be valid and reliable.

Reliability for the learners' questionnaire was based on Chronbach's Alpha score. When calculating the Cronbach's Alpha score for the Likert-type scale questions it was found that all the scores were greater than 0.7. Thus, the learners' questionnaire was also reliable.

In ensuring the credibility of my study, the following procedures were followed:

Firstly, I talked little and listened a lot. The interviews required participants to elaborate on their responses. In instances where a one-word response was provided, a probing question followed. I used voice and video recorders, and this gave me the opportunity to relive the field work even though participants were not present. This helped deepen my understanding of the cases in my study. Also, after transcribing all the data, I sent the transcriptions to participants to check accuracy and confirmation of the shared information.

Secondly, the debriefing meetings that I held with participants and the pilot tests that I conducted helped me in identifying any biases that existed with my participants. I also presented my study at three national conferences and my presuppositions were highlighted in those presentations.

Thirdly, I triangulated my data. Triangulation is the use of two or more methods of data collection in the study of some aspect of human behaviour to demonstrate credibility and validity in qualitative research (Cohen, Manion & Morrison, 2000). Cohen et al. (2000) indicated that researchers should strive to reduce the deficiencies and biases that stem from using a single method. By using multiple methods, researchers are creating the potential for counterbalancing the flaws or weaknesses of one method with the strengths of another (Cohen et al., 2000). Triangulation also helps researchers to validate the meanings and experiences of participants accurately in the presentations of findings (Yin, 2011). Various data collection methods and techniques used in this study allowed me to cross-check the accuracy of the data gathered. The triangulation process is represented in three forms: -methodological, space, and data triangulations (Cohen et al., 2000).

5.7.1 Methodological Triangulation

Methodological triangulation is the use of the same method on different occasions or different methods on the same object of study (Cohen et al., 2000). In this study I used multiple methods like interviews, observations, questionnaires, audio and video recordings and field notes. These data collection strategies gave me different perspectives on how educational technology is used in the mathematics classrooms of the two schools.

5.7.2 Space Triangulation

Space triangulation is used as an attempt to overcome the limitations of studies conducted within one culture or subcultures (Cohen et al., 2000). The two schools were in different communities and were managed by two different management teams that created different school cultures.

5.7.3 Data Triangulation

Data triangulation is the use of the same method on different participants. There were four teacher participants and 79 learner participants from whom I collected data. This helped to establish patterns and themes in the analysis process.

5.8 Data Analysis Procedure

In this section I show how I made meaning of the data that I gathered through the data generation strategies outlined above. Data collected from the interviews and classroom observations was analysed using qualitative analysis while data gathered from learners' questionnaire was analysed using quantitative techniques.

5.8.1 Quantitative Data Analysis

I first organised the data by scoring it, determining the type of scores to use, and creating a codebook (Mills & Gay, 2019). A numerical score was assigned to each response for each question on the questionnaire. The organised data was captured for analysis with the SPSS programme. A descriptive statistical technique was used to analyse the data because the research design leant more towards the qualitative aspect. The interpretation of the learners' questionnaires was represented by the different tests that were run on the SPSS program. These tests included summary statistics and the chi-square test of dependence. The chi-square test of independence was used to determine whether statistically significant relationships existed between learner participants' technology ownership and technology use. The critical value (p) for the test of independence is set at 0.5. Values less than p are significant and vice versa. If the value is less than the critical value, the null hypothesis is rejected meaning that the relationship between technology ownership and technology use was not due to chance.

5.8.2 Qualitative Data Analysis

According to Yin (2014), data analysis in qualitative research undergoes five phases, which are:

- Compiling a database: According to Yin (2014), this phase involves putting collected data into some order. In this study I created a database for each school. Each record represented data generated for each data collection strategy per school. For example, there was an interview transcript record for school A, separate from an interview transcript record for school B. The teachers' audio interviews were transcribed verbatim. Some learner participants used their home language, which is Khelobedu. The transcripts were translated into English. The observations were transcribed based on table 5.3.

Table 5.3

A guideline to transcribing observations

Type of technology used	Technology user	Activities in which the technology is used	How does the technology support the instructional strategies?	How does the technology support learning?

- Disassembling data: This phase involves breaking data into smaller pieces and assigning new labels to these smaller pieces of data (Yin, 2014). In this study I started assigning codes to interview and observation transcripts and teachers' questionnaires. I coded the teachers' interview transcripts first then followed with the learners' focus group transcripts. Lastly, I coded the observation transcripts. When coding I considered verbal and non-verbal cues expressed by each of the participants as indicated in the transcripts.

- Codes were compared to see the emerging patterns. The comparison was based on the research questions. Codes from the teachers' interview transcripts were compared separately from codes from the learners' focus group interviews.

- Reassembling data: This involves reorganising disassembled data into different groupings and sequences (Yin, 2014). In this study all the coded data was grouped under different themes.

- Interpreting data: In this phase the researcher gives his/her own meaning to the reassembled data (Yin, 2014). The interpretation of interview and observation transcripts was presented in words, tables and figures that give a clear picture of what transpired in the field.

- Conclusion: This involves coming up with overarching statements that elevate the findings of a study to a higher conceptual level or broader set of ideas (Yin, 2014). In this study the conclusion was drawn from the analytical framework which was developed from the conceptual framework. Figure 5.2 is the analytical framework that was used for the study.

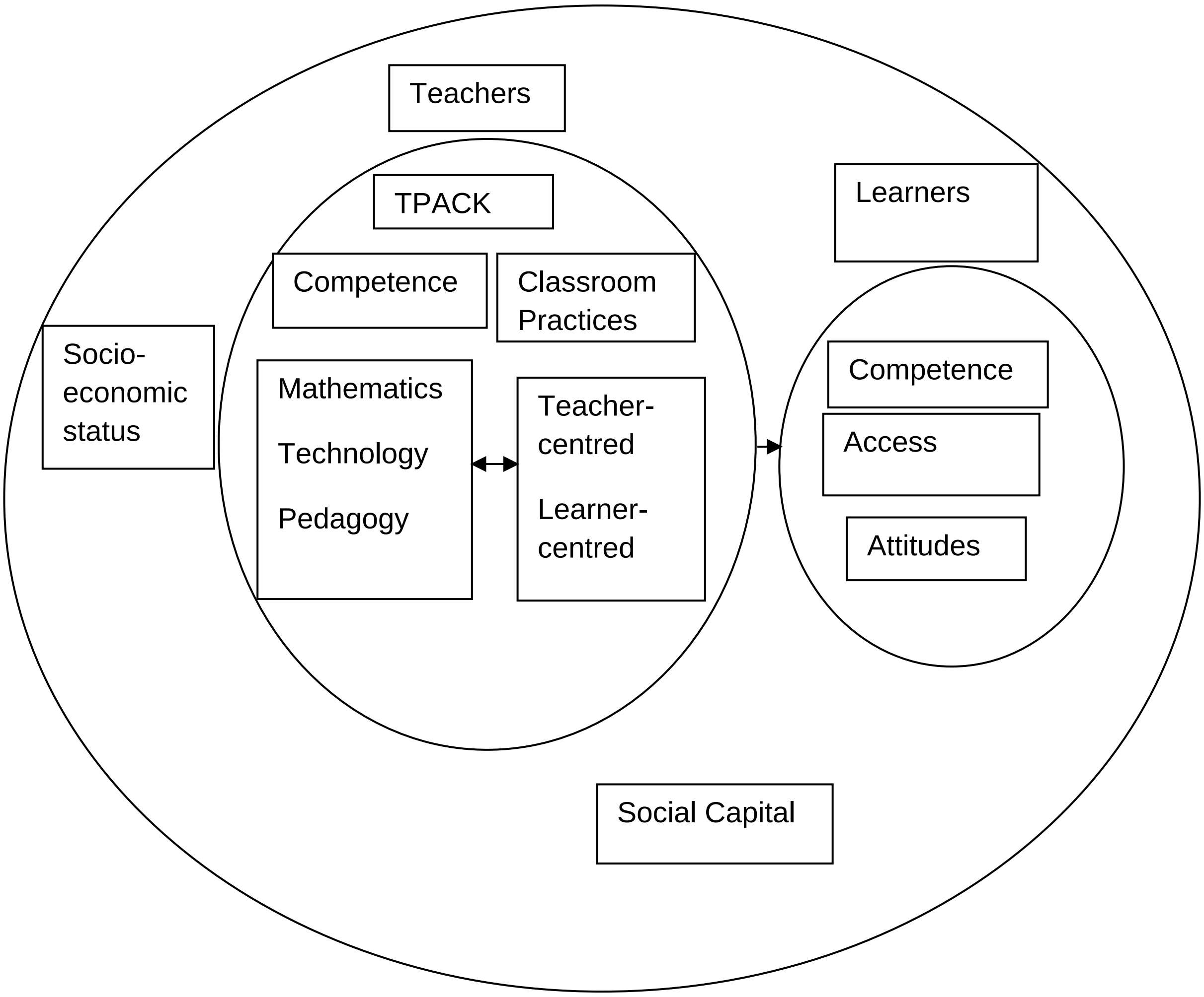


Figure 5. 2 Analytical framework

The analytical framework was built from the conceptual framework. The framework was based on the context in which teachers and learners use educational technologies in both schools. The socio-economic status of the community is influential in schools in relation to use of educational technology. Poor schools are found in low socio-economic status communities, whereas affluent schools are found in high socio-economic status communities. Schools in low socio-economic communities cannot afford to train their teachers in the use of educational technology in their classrooms. Thus, teachers and learners depend on their social contacts for acquisition of skills in the use of educational technologies. Teachers' competence in mathematics influences how they use educational technologies in their classrooms. Teachers' competence in mathematics and their use of educational technologies contribute to factors influencing learners' use of educational technology.

5.9 Ethical Considerations

Before going into the field for data collection, ethical issues involving human participants were considered. It is the responsibility of the researcher to ensure that ethical standards are adhered to. In adhering to ethical standards, the following procedures were followed:

An ethical clearance certificate was obtained from the University of the Witwatersrand to allow me to conduct the study in Limpopo Department of Education. The clearance certificate is attached as Appendix B. A permission letter was received from the Limpopo Provincial Department of Education. The permission letter is attached as Appendix C

5.10 Chapter Summary

In this chapter I explained in detail the methodology and design of my study. The chapter outlined the processes that I used in my study to achieve its purpose and answer the research questions.

Chapter 6

Data Presentation, Analysis and Discussion

6.1 Introduction

This chapter provides the findings from the two schools that were used for the study. I present, analyse, and discuss the data. The chapter focuses on how teachers' mathematics competence influences their use of educational technology. It also shows how this influences learners' use of educational technology in mathematics. Section 1 is the introduction to this chapter, and section 2 provides the biodata of the participants. Section 3 gives a detailed account of what teachers and learners do with technology in mathematics. Section 4 deals with the benefits of using technology in the teaching and learning of mathematics, and Section 5 provides a detailed discussion on teacher pedagogy and use of technology. Section 6 deals with the factors affecting learners' use of technology in the mathematics. The last section is the conclusion of the chapter.

6.2 Biodata of Participants

In this section I first describe the contexts of the two schools and then the participants' demographic information.

6.2.1 Schools' Contexts

School A context

This school is found in a peri–urban area. A peri–urban area is an area that was initially referred to as a township. Townships were established for black people near a town or white community and economic hub, so that the residents could provide cheap labour to the white community during the apartheid era (Sadiki & Ramutsindela, 2002). As blacks were not allowed to stay in the white community, this arrangement was a convenient way for the white community to obtain easy access to labour. Schools in this kind of community environment were the most disadvantaged during the apartheid regime. However, the current democratic government is trying to address the socio-economic imbalances of the past. The school is in quintile 3, and the learners are exempted from paying school fees. The quintile system is the ranking of schools by the DoE for funding purposes with the aim of addressing equity in schools (DoE, 2006). The school had an enrolment of about 800 learners from grade 8 to grade 12 at the time of the study, with 27 teachers. Of the 27 educators, five were responsible for teaching mathematics to the whole school. The school had 30 classrooms and six classrooms were not occupied by learners. Three of these six classrooms were used by educators as their staffrooms.

The school had an administration block housing the principal's and deputy principal's offices, mathematics and science department, social science department, administrative staff, and African languages department. The school also had two laboratories; one was a computer laboratory, while the other one was a science laboratory. The computer laboratory had about 20 computers that were no longer functional and had been donated some 14 years before by the South African government in collaboration with Telkom to encourage schools to use technologies in teaching and learning. The school had received the donation as it had been classified as a "Dinaledi" school. The Dinaledi project was a short-term measure by the DoE to raise the participation and performance of historically disadvantaged learners in senior certificate mathematics and physical science (Taylor, 2007).

The computer laboratory had a storeroom that contained 20 laptops interconnected via a server from Vodacom Yebo Millionaire project. The Head of Department (HOD) for commercial subjects had entered a competition on behalf of the school and had won the laptops. Out of the 20 laptops, 14 were in working condition, three were not functional and three could not be accounted for. The claim for the unaccounted laptops was that some teachers had borrowed them, but they had not been recorded as per the school's normal procedure. However, Mr Phetole, the teacher participant, believed that the teachers involved would return the laptops. The laptops had CAPs-aligned programs for all subjects in the school for all the grades. The laptops were also connected to a secured Wi-Fi, which teachers had access to. Learners' access to laptops and Wi-Fi depended on the availability of teachers to supervise them. In most instances, teachers were occupied during school hours, which made it difficult for learners to access the technological resources. In addition to the Vodacom-donated laptops, the school had purchased five laptops which were kept in the principal's office.

To ensure the safety of the laptops, the school had subscribed to a security company that had an alarm system for securing the school. The computer centre was also fitted with a security door and the windows were fitted with burglar bars. The storeroom which housed the laptops was also fitted with a security door. The laptops were stored in a locked safe in the storeroom. The HOD for commercial subjects was assigned the task of taking care of the laptops during working hours. She was the only person with the key to the safe that held the laptops. When laptops were issued or returned, she recorded the names of relevant teachers in a register that she kept in her possession. Although teachers had access to the laptops, the access depended on the availability of the HOD for commercial subjects. She did not delegate the responsibility for taking care of the laptops during working hours. Thus, if she was absent from work no one had access to the laptops. This arrangement made teachers' access to the laptops somewhat difficult. When the caretaker teacher was not around, there was no substitute assigned. I witnessed this during my data collection period. I had arranged for a lesson observation with a teacher participant, but the laptops could not be accessed on the appointed day because the caretaker teacher was absent. I was thus compelled to reschedule another date for the lesson observation.

The various departmental offices housed teachers in those departments together with their respective HOD. However, in the maths and science department office, the HOD was the only occupant of the office. The fact that the maths teachers were scattered all over the school premises did not facilitate ease of communication among them. For example, if the HOD was looking for a teacher, he would first check on the timetable to see whether the teacher in question was teaching. If not, the HOD would move from his office to the room occupied by the teacher. Moving from one place to the other was a waste of time. The sharing of space in this instance was important because some of the school buildings were far from the administration block. Thus, the HOD would prioritise urgent matters when looking for teachers, which could result in minimising teachers' interaction. However, instead of the HOD walking physically to look for subordinate teachers in other buildings, he could have used the school Wi-Fi to communicate with teachers wherever they were. This scenario could have created an opportunity for teachers to establish a collaborative environment as they had access to the school Wi-Fi, but the opportunity just slipped through their hands. The mathematics HOD did not encourage departmental office sharing the way the HODs of other departments did. Some of the teachers in this department used a laboratory as a staffroom. The laboratory was used by the biology, agricultural science, geography teachers, and one mathematics teacher.

In terms of mathematics teaching and learning, teachers seemed committed, as they also encouraged learners to participate in extracurricular activities involving mathematics. The school paid for learners to participate in the Mathematics Olympiad. The Mathematics Olympiad is a competition for learners organised by the Association for Maths Educators in South Africa (AMESA). In this competition learners are assessed on their mathematics knowledge involving problem solving strategies. Learners also participated in the science expo. The science expo is a competition in which learners develop mathematics, physical science, biology, or technology projects and exhibit them during the competition. The competitions are organised by the Department of Science and Technology. Despite this commitment from the mathematics teachers, there was little evidence of any encouragement for teaching and learning using technological tools. This impression was confirmed by the school's lack of a planned schedule or policy on accessing and/or using laptops. The technology could have assisted in preparing for the science expo exhibitions as well the Mathematics Olympiad competitions.

School B context

This school is situated in a rural area. A rural area in this context is explained in terms of communal land tenure, villages, or scattered groups of dwelling, typically located in the former homelands and the presence of one or two small towns in the area (Palmer & Sender, 2006, as cited in Atkinson, 2014). In this kind of settlement there are very few economic activities. Schools found in these settlements were the most disadvantaged during the apartheid regime; thus, the democratic government is trying to address the past socio-economic imbalances. The school is also a quintile 3 (see School A context above).

School B was the only secondary school in this traditional area and had an enrolment of about 1 000 learners and 30 educators. Of the 30 educators, three were responsible for mathematics. The school had an administration block, a computer centre, a library and two science laboratories. The administration block consisted of the principal's office, the deputy principal's office, the administrative staff office, the social science department office, and the languages department office. The departmental offices housed the head of department (HOD) and teachers in their respective departments. Of the two laboratories, one was used to house the HOD for mathematics and all mathematics teachers. The other was used as a natural science departmental office and all the biology, agricultural science, physical science, geography, and natural science teachers were accommodated in this laboratory. There was no HOD for physical science as the deputy principal was a physical science teacher. Unlike in school A, teachers in school B who belonged to the same department occupied a shared space as their staffroom. This arrangement helped to facilitate smooth communication among colleagues in the same department. The library had books but no computers. A card cataloguing system was used in this library. The school did not have a librarian; instead, one of the English teachers was charged with taking care of the library. She opened the library after her lessons and during break.

During my observation visit to the school, I noticed that the computer centre had about eight desktop computers that were operational and connected to the internet. There was also a data projector, and a smart board that was no longer functional. The smart board was used as a projection screen. There were also five laptops and another data projector stored in the principal's office – these were usually used by different HODs for administration purposes. Microsoft Office software programs had been installed on the desktop computers and laptops. The desktop computers used to have mathematics and science software programs that had been licensed two years previously. The school had not able to afford the licensing fees and had stopped renewing the licence, which meant that those software programs were inactive.

School B could afford the technological resources because there was a mining company nearby. During my conversation with teacher participants, I was informed that the mining company used to support the school as its commitment to community social upliftment. The desktop computers in the computer room, one data projector and the smart board were some of the tools the school had received from the mining company. They further indicated that owing to economic instability in the mining sector, it was no longer easy for the school to get donations from the mining company. This had huge financial implications for school B. The school could not come up with ways to supplement their financial allocation from the government that would enable them to maintain some or all the technological tools.

Although the mining company had heeded the call for social responsibility, the donated computers they donated were still not enough for the learners. The computer-learner ratio worked out to be 1:125. Based on this ratio, not all the learners could have access to the desktop computers. The most difficult task that the school was facing was to schedule all learners' use of the computer room. Instead, the school prioritised and gave access to the grade 12 learners. Even so, grade 12 learners had to take turns to use the computers because they could not use them simultaneously. Grade 12 learners were given access to the computers to apply to higher education institutions where they hoped to study the following year. They were supposed to be helped by their teachers while completing their applications.

In terms of mathematics teaching and learning, the teachers went the extra mile for their learners. They also encouraged them to participate in extracurricular mathematics activities like the Mathematics Olympiad competition and science expo exhibitions. These were opportunities that allowed learners to develop a deeper understanding of mathematics concepts and relate mathematics to real life problems. However, the teachers did not use technology to assist learners when they were preparing for the competitions. The teachers also offered extra mathematics lessons at no cost to learners who were not coping in the classroom environment. On days when a teacher had other commitments and was unable to make it to the extra classes, the learners helped one another.

There was also teamwork displayed by the mathematics teachers. During my visit to the school, I observed maths teachers discussing a marking tool for a grade 11 class. A culture of cooperation and trust had been inculcated among the school community. Members of the community felt responsible and obliged to help each other, and a sense of belonging was displayed. Although no documents had been developed to control and regulate the acquisition and use of educational technology, there was support from the school to encourage teachers to use educational technologies in their classrooms. Teachers were given access to these tools and opportunities to learn how to use them. Teachers also helped and learnt from each other. Mr Lehlokwa, one of the teacher participants acquired the skill of working on the Excel spreadsheet from his colleagues.

6.2.2 Teacher Participants

As mentioned above, there were four teacher participants whose data were used in this study. School A had one teacher participant while school B had three. Detailed biographical information on each of the participants follows below:

Mr Phetole (a pseudonym)

Mr Phetole (which was his pseudonym) from school A was a 26-year-old male teacher. Mr Phetole remained the only teacher participant after his colleague withdrew from the study. He had three years teaching experience and a Bachelor of Education degree qualification in mathematics and physical science. He taught grade 11 and 12 mathematics and grade 10 physical science classes. During his pre-service teacher training programme, he had been trained in the use educational technology in teaching and learning.

He had been using educational technology tools for eight years. However, when he enrolled for his teachers' degree, he did not have any knowledge or skills in how to operate a computer. He indicated that he would have appreciated having a little knowledge about how to operate a computer before enrolling at university. The teaching programme included a course on the use of educational technology in teaching and learning in which students were taught how to use computers generally and for preparing lessons as student teachers. As his teaching qualification was in mathematics and physical science, he was taught how to use computers in a mathematics and physical science teaching and learning environment. Through a questionnaire, an interview, and an observation of his lesson I was able to gain a good understanding of Mr Phetole's use of educational technology in mathematics. He showed some basic knowledge of the use of technology in mathematics. Mr Phetole owned a personal desktop computer and a smartphone.

Mr Lehlokwa (a pseudonym)

Mr Lehlokwa was a 52-year-old male teacher from school B. He had a Senior Primary Teachers Diploma (SPTD) qualification and had been teaching for 30 years. He also had an Advanced Certificate in Education (ACE) certificate which did not focus on mathematics education. He taught grade 8 and 9 mathematics. Mr Lehlokwa did not have any qualification in the use of educational technology or technological skills. Nor had he never attended any training or workshop on the use of educational technology. His was self-taught in the use of educational technology in teaching and learning and had also acquired knowledge from colleagues. He also indicated that he had been using a computer for about five years. However, the computer was not used in the classroom environment.

Ms Makgona (a pseudonym)

Ms Makgona from school B was a 56-year-old female teacher with 34 years' teaching experience. She had an ACE in mathematics as her highest mathematics qualification. She taught mathematics in grade 10 and 11. Ms Makgona did not own any digital tool or use one in the classroom environment. Her use of digital tools was confined to administrative purposes. Like Mr Lehlokwa, Ms Makgona's technology skills were self-taught or learnt from colleagues. However, she had decided to upskill herself. She had enrolled for a qualification in computer literacy and had acquired the qualification. However, the qualification was not recognised by the Department of Basic Education (DBE), and she had thus not received any incentive towards its acquisition; nevertheless, she indicated that she had found the course fulfilling. She claimed that the qualification had given her the confidence to use a computer. However, she did not use the computer in her lessons.

Mr Tsebo (a pseudonym)

Mr Tsebo was a 41-year-old male teacher from school B; he had 19 years' teaching experience and he is from school B. His highest qualification was an ACE certificate in mathematics. Mr Tsebo owned a smartphone and a desktop computer. However, he used the school's laptop in his classroom. He taught mathematics in grade 11 and 12. He was also the HOD for the mathematics department. Mr Tsebo had acquired the skills of using technology in teaching and learning when he was studying for his ACE qualification. One of the modules involved the use of educational technology in teaching and learning. In this module they were supposed to do lesson preparation, presentations and sketch drawings using educational technology. Although he had passed the module, it was only a theoretical study of the use of educational technology, as they were not taken to a classroom environment to apply what they were learning. However, it seems as though the module contributed positively towards his use of educational technology in teaching and learning, as he persevered in using the tools in the classroom environment. He showed some basic knowledge of the use of technology in mathematics.

6.2.3 Learner Participants

There were 43 learner participants from school A. Participants consisted of 11 grade 10, 17 grade 11, and 15 grade 12 learners. There were 25 male and 18 female participants. Most of the learner participants owned smartphones and programmable calculators. A total of 40 learner participants owned a smartphone, 24 owned a calculator, 20 owned a desktop computer, 16 owned a laptop, 14 owned a tablet and two owned an Ipad (another form of tablet). Learner participants' technology ownership was not consistent with the school's socio-economic status.

There were 36 learner participants from school B. Participants consisted of 12 grade 10, 11 grade 11 and 13 grade 12 learners. There were 24 female participants and 12 male participants. Many of the participants owned smartphones and programmable calculators. A total of 24 of the learner participants owned a smartphone, 21 owned a calculator, two owned a tablet, one owned an Ipad (another form of tablet), three owned a laptop and four owned a desktop computer.

The type of technology owned by the learner participants painted a picture of their socio-economic status. I could deduce that almost all the learners came from a low socio-economic situation.

6.3 What Teachers and Learners Do with Technology in Mathematics.

In this section I first report on what teachers do with technology in mathematics, then discuss what learners do with technology in mathematics.

6.3.1 What Teachers Do with Technology in Mathematics

The focus was on teachers' experiences and classroom practices in the use of education technology. The teachers' questionnaire, the interview schedule and the observation were used to obtain this information. The discussions in this section involve teachers' access to and use of educational technology and their classroom practices.

6.3.1.1 Teachers' access to and use of educational technology

The discussion is based on the TPACK framework, and it is divided into three parts: teachers' technological competence, their mathematics content competence, and their pedagogical competence. Technological competence focused on teachers' access to educational technology, educational technology skills, teaching and learning opportunities created by educational technologies in mathematics, and the support among the school community members. This focus is informed by the two components of the TPACK (Technological Pedagogical Content Knowledge) framework which are: TK (Technological Knowledge) and TCK (Technological Content Knowledge). Mathematics competence focused on teachers' conceptual knowledge of mathematics. This focus is informed by CK (Content Knowledge) component of the TPACK. Pedagogical knowledge focused on teaching and learning strategies used in the classroom, goal-directed teaching and learning, and the essential use of technology in the classroom. This focus was informed by three components of the TPACK framework: PCK (Pedagogical Content Knowledge), TPK (Technological Pedagogical Knowledge), and PK (Pedagogical Knowledge). The data on each of the mentioned part is presented below.

Mr Phetole (School A)

Technological Competence

As indicated in 5.5.3, the questionnaire consisted of four parts. The second part involved technology ownership and technology used in mathematics. In his response to the second and part of the questionnaire, Mr Phetole indicated that he owned a smart phone and a computer, and that he used the calculator and a laptop in his teaching. He indicated that he used the calculator to show learners number computation and finding special angles. As far as the laptop is concerned, he indicated that he used it to present lessons, process learners' marks, and print mark sheets.

Mr Phetole's response to the questionnaire on the focused TPACK framework components indicated that he perceived himself to be competent in TK. He strongly agreed with all the statements in the TK, which implied that he had the skills of operating technological tools. However, he perceived himself not to be competent in TCK. TCK consisted of five statements. He neither agreed nor disagreed with three of the statements which were: I use technologies to enhance learners' understanding of mathematics, I facilitate equitable access to technology resources for all learners in mathematics, and I develop projects involving the use of educational technology. He disagreed with one statement which was: I develop class activities involving the use of educational technologies. Lastly, he agreed with the statement: I use technology in my class to easily achieve the learning outcomes of my lesson. However, by agreeing to this statement he was inconsistent with his response to the first statement, with which he neither agreed nor disagreed. He can only achieve the learning outcomes of his lessons when learners' understanding of mathematics is enhanced.

Mr Phetole demonstrated knowledge of how to use technologies in his classroom. This was seen in how he explained his use of GeoGebra when dealing with trigonometry in his classroom. He explained the use of technological tools in trigonometry in this way:

> *We have programs like GeoGebra that you can use in trigonometrical graphs. You can play around with the program to show them (learners) how the graph changes. You can change the domain and the range right on the computer and learners will see how the graph changes.*

However, from his comment I deduced an inconsistency between this statement and his response on the questionnaire about using technology to enable learners to understand mathematics better. As already indicated in his response to the questionnaire, he neither agreed nor disagreed with the statement. Also, he seemed not to allow learners to explore the changing of the graphs themselves. Although he explained how the GeoGebra program was used in trigonometry, I could not confirm his claim as this was self-reported data. Mr Phetole's school did not have this kind of program. He relied on the subject-specific software on the school's laptops, which did not include GeoGebra. If his knowledge was not put into practice; it was not going to benefit the learners.

In his instructions to learners while using laptops he used correct technology terms appropriate to the type of technology used. He also helped learners to do some troubleshooting tasks like increasing the screen brightness in some of the laptops that were not appropriately set. This was further seen in how he gave step-by-step instructions to learners on how to open the application program that they were going to work with. The steps were straightforward, clear, and easy to follow. This is how the instructions were given:

> *There is a button for switching on the power, press the button on (a chuckle from learners reacting to their teacher's instruction) and wait for the computer to be on. Are all our computers on? If they are on, right down on the desktop you are going to look for an application which says … (identified some students challenges with screen settings). If your computer screen is dark, increase the brightness. Press the Fn function at the bottom of the keyboard and hold. Then press the F9 function at the top of your keyboard. Let's look for a program on the desktop. It says Encarta premium. E-N-C-A-R-T-A. (spells the word) premium.*

Though the lesson was about mathematics, Mr Phetole incorporated technological skills in his lesson. The above quote confirms this. It appeared that Mr Phetole's first experience still had an influence on his use of educational technology in the classroom. Later during the lesson when he was switching from Encarta to Vodacom mathematics programs, some laptops could not open. Although he had an assistant, he physically went to every laptop that was problematic to do some troubleshooting. A total of three laptops could not open and the learners had to join the other groups. He considered himself an expert in computer technology. This was consistent with his questionnaire response above, on using technologies whose use he had heard opinions about from his colleagues.

Mr Phetole indicated that he did not enjoy his first experience of using the computer. He felt somewhat deprived not to have had the knowledge of using technological tools and application programs prior to going to university. He had been faced with the challenge of using Microsoft Office application programs such as Word, PowerPoint, and Excel to develop mathematics lessons in the early years of his studies. He would have preferred to have had some knowledge about these application programs before starting his university studies. He explained his view in the following way:

> *So, it was not easy because I did not really attend any professional training for using a computer, especially the programs of Microsoft Office. So, we had to learn there at the university, and it was not easy especially when you want to prepare a lesson; creating those tables, maybe diagrams and using symbols since it was mathematics, it was not easy.*

Thus, by incorporating the technical skills, he was equipping the learners with some of the skills they would need. This was confirmed by Mr Phetole's view during the follow-up interview after observing his lesson:

> *The reason for my computer usage was to check if learners are able to use computers and the lesson was maths related. So, I decided that I can have those computers and let learners use computers themselves.*

This indicated that Mr Phetole was aware that both teachers' and learners' technological skills were important in the use of educational technology in the classroom. Hence, he used laptops to reinforce learners' technological skills.

Mr Phetole attributed his expertise in computer technology to his first experience of using these tools. This experience motivated him to learn more and establish his position in the classroom. He explained:

> *Since I learnt the hard way of using ICT, I am now very fluent in using the computer. I don't think there is much that I cannot do unless it is a new program… if I get someone to explain what the program is all about, I won't take long to understand it.*

Mr Phetole also served as a technology expert in his school. During my visit to the school a few of his colleagues requested his assistance in laptop troubleshooting. His colleagues trusted his technological skills and thus always obtained help from him. Though Mr Phetole demonstrated some level of technological skills, these skills did not translate into effective use of educational technology in the classroom.

Based on the above extract, I can posit that Mr Phetole was aware of the consequences of lack of skills in using educational technologies in the classroom. However, he allowed learners who could operate a laptop to use the laptops in his classroom. Learners who could not operate a laptop were given the roles of reading from the screen and, in so doing, he was denying access to them. Learners who were skilled in the use of computers had access to these tools outside the school environment. On the other hand, learners who were not skilled in the use of computers did not have access to these tools outside the school environment. The school would have done well to provide such learners with opportunities to learn computer skills. By denying them this opportunity, the school perpetuated inequality among learners in terms of technical skills These learners did not have any other place to learn how to operate a laptop.

Further on Mr Phetole demonstrated knowledge of how concepts could be presented in a simpler way using technological tools. He viewed technologies as some of the tools that could help learners to understand concepts better. He noted:

> *… and again eh … Looking at the calculator it helps learners to get the answers easily. We have this new Casio calculator they can even punch in the formula, so it makes life easier for them.*

However, he did not attempt to explore a variety of technologies that could assist him to represent different mathematics knowledge processes in a variety of forms for the benefit of the learner. He pointed out that:

> *We are not using them (technologies like Geogebra, smart boards and Computer algebra system) because of lack of resources. Educational technologies would have contributed to our classroom teaching if we were using them. But now it is just a little bit.*

Thus, from the above expression I can posit that his low rating and inconsistent response on the TCK component of the TPACK framework was because he did not use educational technologies more often in his classroom. The school's socioeconomic status acted as a barrier to frequent use of educational technologies in the classroom.

Mr Phetole's experience of using educational technology was far greater than his teaching experience. He also used these tools during his micro-teaching time, but it was for a very short period as these tools were used to prepare lessons and not in the actual micro-teaching class. It is also interesting to note that Mr Phetole acquired technological skills through a desktop computer, and it was also one of the educational technology tools that he owned and used for personal reasons.

Mr Phetole's access to a variety of ICT tools and the ICT course he had enrolled in at the university contributed to his ICT technical skills. However, the school where he was working had resource challenges. As mentioned in 6.2 above, the school had 25 laptops – four were used for administration purposes, one was used for the South African School and Administration Management System (SA–SAMS) and 20 were used for teaching and learning. Also, teachers sometimes asked to use these laptops to do their own work. Thus, the laptop-school population ratio was calculated at 1:41. This showed that there was no chance that the school could have a 1:1 laptop learner ratio. This constituted an obstacle to individuals who were still gaining mastery in the use of ICT for teaching and learning.

Most of his colleagues who had a lot more teaching experience than he did were not competent in using technology in the classroom or for personal use. This was confirmed by Mr Phetole when he said:

> *Ah it's ... it's a big problem here for my colleagues, most of them are too old, so they don't use ICT and they are not even planning to use it due to the time that they are having in teaching. Some of them will be leaving soon. So, it is only a few of them. If I could mention it is less than 10, I think here at school some are familiar with computer and others are not. … they can't even print or type. You have to help them in all of those things (typing, printing, etc). When you tell them, they are saying, they say: "We are born before technology. We do not know these things".*

He was an expert in his school and thus his colleagues relied on him. Instead of seizing the opportunity to influence his colleagues, however, he chose to be influenced by them. He could have exerted pressure on his colleagues as an attempt to influence their behaviour towards the use of technology. Thus, his expertise did not benefit the whole school, but only a few colleagues when he could “type or print” for them. This is because the school did not have any policy on the use of educational technology in teaching and learning. He was also young and felt obliged to help his colleagues as a form of respect as they were much older than him. He was also not in a position of authority and could therefore not instruct them or try to enforce the use of educational technology in their teaching. Furthermore, the school was not supportive of teachers in the use of educational technologies in the classroom. As he explained:

> *The school is not yet supportive; it depends on you the teacher. If you want to teach you will teach using ICT, if not they will not even say anything. So even if suppose you want to teach and there is lack of resources, it is not easy to acquire those resources.*

The teachers at the school had access to laptops as well as the school’s Wi-Fi. He seemed not to realise that this was a form of support provided by the school. However, access to technological resources alone does not translate into meaningful use of technology.

Since the school did not have enough resources, Mr Phetole could have emulated the HOD for commercial subjects and raise funds for more educational technology resources instead of waiting for the school to provide the teachers with resources. Instead of complaining about the school environment he had the ability to influence his colleagues but chose not to do so. The fact that the school did not have a policy also contributed to teachers not being interested in fundraising for more educational technology tools. Teachers seemed not to have a sense of ownership of the school.

The above discussion demonstrated that Mr Phetole’s TK was basic. He was able to operate the laptop but could not develop learners’ activities that involved using the technology to simplify the mathematics concepts.

Mathematics Competence

Mr Phetole perceived himself to have a good knowledge of mathematics concepts. This was seen in how he responded to the TPACK questionnaire on statements that focused on mathematics CK (Content Knowledge). He agreed with all the statements in the questionnaire on knowledge of mathematics concepts. During my observation of Mr Phetole's lesson I witnessed how he used mathematical language to explain mathematics concepts to the learners. The language was correct and appropriate to the concepts he was teaching in his classroom. He introduced the topic for the lesson – coordinate geometry. He started his lesson by asking a learner to read from the laptop on colinear points. After the learner had finished reading about the concept, he explained the concepts using his own words. He later used the concept colinear to show non-colinear points. He proceeded to link points with lines and line segments. In this instance he showed his mathematical thinking competence. He used what was known to introduce and explain a new concept to the learners.

Mr Phetole moved on to show the relationship between lines. Lastly, lines were used to construct geometric structures on a Cartesian plane. In this instance Mr Phetole demonstrated several competences. He had to use symbols and formalism competence to construct the figures. He also used the communicating competence because figures conveyed mathematics messages to him.

Mr Phetole also used the chalkboard to expand and explain some concepts which he considered difficult for the learners. In this instance he demonstrated his mathematics representation competence. Concepts that were explained on the chalkboard included parallel and perpendicular lines, distinction between line segments and lines, and construction of geometric structures.

Mr Phetole's qualifications also contributed to his knowledge acquisition in mathematics concepts. The university mathematics courses equipped him with a higher knowledge level than that of grade 12 mathematics concepts as well as a deep mathematics conceptual knowledge. Mr Phetole's strong mathematics conceptual knowledge enabled him to be flexible in his classroom by asking impromptu questions and addressing unexpected statements and conjectures that arose in the classroom.

Mr Phetole's mathematics content knowledge played a significant role in making learners understand mathematics concepts. Learners who understand mathematics concepts clearly, can progress in mathematics beyond grade 12 level. The above data presentation showed that Mr Phetole was able to make learners understand what they were taught; this was facilitated by his deep mathematics conceptual knowledge (Kahan, Cooper & Bethea, 2003). Confirmation of learners' understanding of the lesson was seen in their overwhelmingly positive responses to questions related to the topic that had been presented. Learners were able to differentiate between a line segment and a line, identify parallel and perpendicular lines and determine coordinates in a plane (Kahan et al., 2003). However, all the questions were low-level questions, as they merely required learners to reproduce information.

Teachers who have a deep mathematics conceptual knowledge can simplify concepts and make them easier for their learners. However, that alone does not guarantee that one is able to impart acquired knowledge in a meaningful way. In addition to teachers' mathematics conceptual knowledge, their approach to their learners in the classroom is also important. A teacher's approach enables their learners to have a firm grip on mathematics concepts.

The above discussion demonstrated that Mr Phetole's mathematics conceptual knowledge was not basic. He was able to use the different mathematics competences to explain coordinate geometry concepts to the learners. The next section gives data on Mr Phetole's pedagogical competence and shows the approach that Mr Phetole adopted.

Pedagogical Competence

Mr Phetole perceived himself to have a good knowledge of PK, PCK and TPK. This was seen in his response to the TPACK questionnaire on statements that focused on PK, PCK and TPK. Although Mr Phetole rated himself highly on these TPACK framework components, the observation and interview data gave a different picture. He demonstrated lack of knowledge of the essential use of educational technology in his classroom. This was evidenced in how he explained his procedures in the use of educational technology. He said he did not develop any lessons plan because the school used lesson structures that were provided by the Department of Basic Education (DBE). However, I was unable to find the lesson structure that the school was following. Based on my observation of his lesson I can posit that he was using the lessons from the laptop without adjusting them to his mathematics classroom context.

By developing his lesson plan, Mr Phetole could have established before going to class whether educational technologies were essential in his classroom. If the tools were indeed essential in his classroom, learners would benefit from their use (see 3.5, a discussion on ICT and pedagogy). The mathematics lesson would be interesting and, accessible and excite the learners. On the other hand, if educational technologies were not essential in the classroom, learners might not benefit at all from their use in the class. He further demonstrated that he did not have enough knowledge of the essential use of educational technology by motivating his use of laptops in the classroom as follows:

> *Eh! It (the laptop) helps me because it has lessons that are well structured. I just actually plan by looking in their lesson … they (lessons) are aligned with our curriculum, so it was straightforward, you just go with the lesson.*

Using a soft copy of material that can also be found in a hard copy does not constitute essential use of educational technology in the classroom. However, he conceded that planning a lesson in which educational technologies were used was time consuming. This showed that Mr Phetole felt that planning an ICT-supported lesson would add to his workload and it was convenient for him not to spend much of his time planning the use of educational technology in his mathematics classroom. He expressed his view in this way:

> *You must allocate time properly because you will be using that tool which you are not familiar with it (technological tool). So, it will take time, more time as compared to planning a normal lesson, but the template is the same.*

In this above view Mr Phetole confirmed that even though he could use educational technology tools, he was still not confident in their use in the classroom environment.

The picture below shows a learner reading from one of the laptops during my observation of Mr Phetole's lesson.

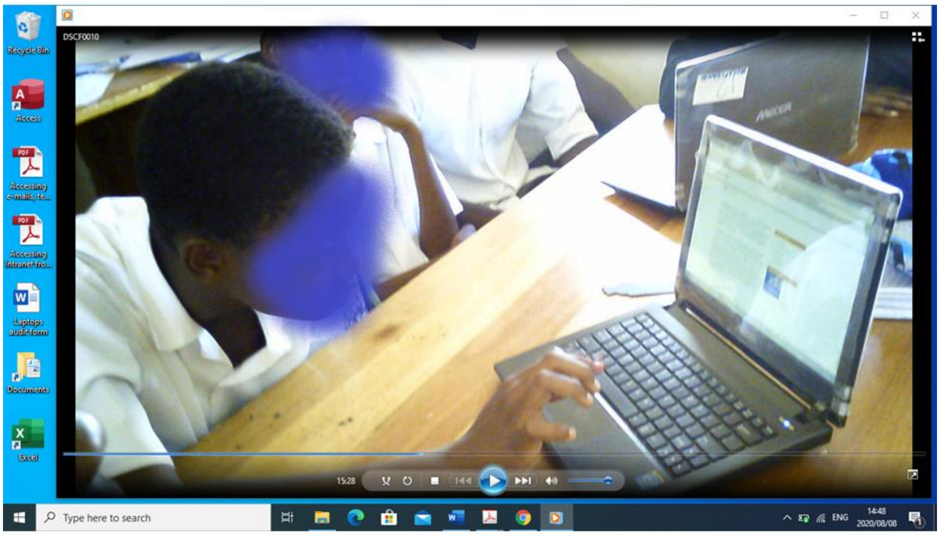


Figure 6.1. A learner reading from the laptop

The above figure shows that the laptop was not an essential tool. The tool was positioned in such a way that all the learners in the group would be able to see the screen. However, this position did not support comfortable reading. The learners' sitting positions bear testimony to this unconducive reading environment. The learner who was reading was leaning forward too much to be able to read from the laptop and was allowing other learners in her group to see what she was reading. This was a result of several learners having to share one laptop.

The above discussion demonstrated the significance of the role of the teacher in the use of educational technology. From the lesson I observed, Mr Phetole used the laptops as instructional tools or tutors. As indicated in 6.3.2 above, he gave learners clear instructions on how to access the content he was teaching them on the laptops. He also made learners read from the laptop' screens. This was further confirmed by his response in the interview on the benefits of using ICT in mathematics classroom teaching:

> *The benefits are that you teach easy since there is a machine that will be doing most of the work for you. You just explain. In some videos, they explain themselves, you just do a lesson without saying much and the learners will be understanding and learning from it.*

The response above showed that Mr Phetole viewed the technological tool as being able to replace him for some time in a lesson. This left him with a minimal facilitation role. From his response I can posit that the technology had designed the learners' task for him. He failed to establish how the technology can enhance learning in his classroom. Also, he did not provide time for learners to pose questions while watching the videos as the videos were doing the teaching. These activities equipped learners with basic computer skills and basic mathematics knowledge.

Furthermore, the above response painted a picture of Mr Phetole's scant knowledge of application of pedagogical skills in the classroom. In planning a lesson, he needed to take into cognisance how learners learn mathematics; the specific content, skills and concepts he would be teaching; learners' pre-knowledge; the structure of the mathematics curriculum; as well as ways of teaching mathematics (Superfine, 2008). By ignoring these aspects, he could not demonstrate the effectiveness of his teaching. Nor could he adjust or expand the lesson provided by the video to suit the school's context.

Mr Phetole's pre-service experience had been greater than his in-service experience as a teacher. As a pre-service teacher he had spent most of his time studying the theory of principles, practices, and method of teaching instead of teaching practice. Policy stipulates that, pre-service teachers are required to spend at most 12 weeks a year on teaching practice. The teaching practice must be limited to 32 weeks in the entire duration of the programme (DHET, 2011). DHET further indicates that of the 12 weeks, at least three should be consecutive. Thus, he was not allowed to do more teaching practice than the amount stipulated. Based on this policy stipulation, I can posit that the pre-service education allocated more time to equipping pre-service teachers with theoretical knowledge on pedagogy than on opportunities for pre-service teaching practice. The 32 weeks' teaching practice is not enough. Mr Phetole's teaching experience was very minimal, as indicated in 6.2.1.1 above. He was still learning the pedagogy of mathematics and trying to improve his teaching skills in the classroom. This showed how quickly he had adapted to his working environment, even though his pre-service teacher training programme had involved developing lessons using educational technology tools as part and parcel of teaching and learning.

Subsequently, when asked the difference between the laptop lesson that I had observed and the same lesson without a laptop, Mr Phetole responded:

> *It was different because learners were too excited that they are now using computers. They can use a computer, move around clicking whatever I am instructing them to do, visualise things that are happening and read from the computer. Unlike reading from the textbook, something new excites them, and they learn very much better.*

However, during the observation learners did not demonstrate any excitement. Mr Phetole was the main active participant in the lesson. Learners communicated with him by responding to questions he asked, and there was no interaction among the learners. Thus, the learners' excitement he mentioned did not relate to how learners would benefit in their mathematics learning. During my observation of Mr Phetole's lesson, learners did not wait for his instructions on how to switch on the laptops. By the time he gave instructions almost all the laptops had been switched on by the learners. Thus, the excitement was not related to the learning outcome of the lesson, but the operation of the laptops. The excitement was all about learners' experiences on the computer. He seemed to think that when learners were clicking the mouse and reading from the computer screen they were actively involved in their learning and were more motivated. As an inexperienced teacher he relied on his experienced colleagues to guide him in his pedagogical use of technology in the classroom (Frank et al., 2004).

Mr Phetole appeared to be satisfied with the laptop's lessons as long they were aligned with the Curriculum and Assessment Policy Statement (CAPS). He said:

> *The computers that we are having here at school which are from Vodacom Yebo Millionaire, they are having programs for learners for all grades and for all subjects, so everything was unfolding there. They are aligned with our curriculum, so it was straightforward; you just go with the lesson.*

The above response indicates that Mr Phetole should also refine his understanding of mathematics teaching and learning. From his response it could be deduced that his point of departure in thinking about what was to be done with learners in the classroom was the mathematics concepts to be presented and how to present these concepts. How learners were going to respond to his presentation was not something he considered when planning his lesson.

Mr Phetole further demonstrated his lack of experience in the pedagogical use of educational technology when he expressed his ideas about the use of technology in teaching and learning. This was captured in his explanation of what made him decide to use a technological tool in his classroom:

> *It is the content you will be dealing with. Somewhere they need to use a calculator because they will be calculating numbers that you cannot do with your mind and then if it is a presentation lesson then you will need a computer so that you can present whatever you will be presenting to them. And suppose I want to make them worksheets, then that is when I go to a printer and print copies.*

Although he was guided by content on which technologies to use, the technology used should help learners to grasp concepts in a meaningful way. From his explanation, a calculator was used to alleviate learners' routine work. The computer was used to present a lesson. He assumed that if he used technological tools in his classroom, learners would benefit from their use; this shows that he had missed the point. He should have identified the potentials and constraints of technology use in his classroom; if he had done so, he would have been using the tools for the benefit of the learners.

Mr Phetole's use of educational technology in mathematics is represented by diagram 6.2 below.

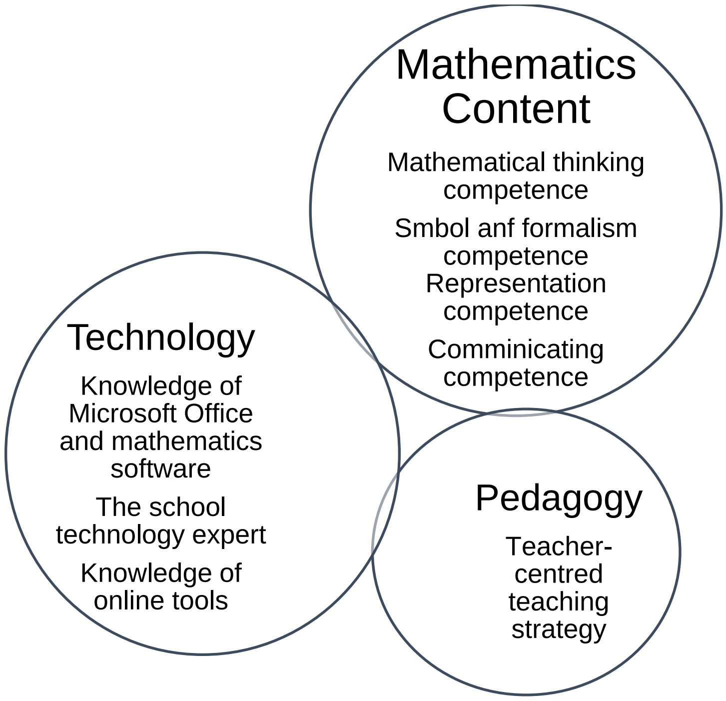


Figure 6.2. Mr Phetole's use of educational technologies in mathematics

The above diagram indicates that Mr Phetole had more confidence in mathematics conceptual knowledge than either the technology knowledge or the pedagogical knowledge. However, his confidence was the least in the pedagogical knowledge. This demonstrated that Mr Phetole lacked the pedagogical strategies of using educational technology in his class.

Overall, the findings indicate that Mr Phetole' competence in the use of laptops in mathematics teaching was basic. The laptop did the teaching work for him. Mr Phetole's limited pedagogical competence was a major issue contributing to how the laptops were used in the lesson. This is consistent with TPACK studies which found that the PK component in the TPACK framework was a contributing factor to effective use of technology in the classroom (Leendertz et al., 2013; Niess et al., 2009; Pamuk, 2011; Saudelli & Ciampa, 2016).

Mr Phetole's use of laptops was basic because he got limited support from the school. Also, the school did not have team spirit. As an expert in the use of laptops he could have allowed his colleagues to draw from his expertise. However, he only assisted a few. Thus, most of his colleagues had limited access to his expertise and did not receive the support they needed. He lacked pedagogical competence. Like his colleagues, he did not receive the social support. This demonstrated that there was limited social support within the school which resulted in low levels of social capital. This is consistent with studies which looked at the role of social capital in the adoption of technology in schools. The studies found that social capital within a school facilitated teachers' acceptance and use of educational technology in teaching and learning (Barton, 2013; Frank et al., 2004; Li & Choi, 2013).

Mr Lehlokwa (School B)

Technological Competence

Mr Lehlokwa's response to the questionnaire indicated that he did not own any technological tool. However, he indicated that he used a calculator in his classroom. He indicated that he used the calculator to show learners how to work out problems in trigonometry, geometry, data handling, exponents, and financial mathematics. Thus, Mr Lehlokwa used the calculator to reduce the routine mathematics work. The mathematics concepts mentioned involved operating very big or very small numbers.

Mr Lehlokwa's response to the TK and TCK part of TPACK indicated that he perceived himself to be competent in TK and not competent in TCK. He agreed with two of the three statements in the TK competence. The two statements that he agreed with were: "When I encounter ICT technical problems, I can resolve the problem" and "I can differentiate between hardware and software." The statement which he disagreed with was: "I can learn new software programs on my own." The TCK statements that he disagreed with were: "I develop class activities that involve the use of educational technologies," "I develop class projects that involve the use of educational technologies" and "I use technologies in teaching to achieve learning outcomes of my lesson." There were two statements with which he neither agreed nor disagreed: "I use technologies to enhance learners' better understanding of mathematics" and "I facilitate equitable access to technology resources for all learners in mathematics." However, these responses were inconsistent with responses indicated in the second part of the questionnaire. Mr Lehlokwa's response to the attitude measure questionnaire indicated that he perceived himself to have confidence in the use of educational technology. This implied that he had been using educational technology tools in his lessons.

However, when asked during the interview to name his favourite technological tool, Mr Lehlokwa mentioned two Microsoft Office software programs: Excel and Word. He spoke about using these tools to prepare mark sheets and question papers for tests and examinations. He said that he had been using these tools for more than five years and he used them at most two or three times in a week. However, he did not use these tools in his classroom, the main reason being his lack of knowledge of how to use them. Mr Lehlokwa had not undergone any formal training in how to use the two Microsoft Office application programs. He explained his acquisition of skills in the two programs as follows:

> *Ahh, I was actually helped at school by some of my colleagues. Ultimately, I ended up knowing how to use the computers where we work with Excel, adding and/or converting some marks, typing of mathematics in words and so on. I was just helped by my colleagues.*

This explanation confirms what he alluded to in the questionnaire when he rated himself low on the statement about learning new software by himself. Thus, it was important that Mr Lehlokwa was guided in how the software worked.

As a mathematics teacher, he was aware that the calculator could be used to help learners by simplifying calculations. It has the potential to represent content in a way that learners can easily understand. However, he should plan for its use in the classroom so that learners can benefit from using it, otherwise some learners might just play with it while he is teaching. In the grades he was teaching, there were some topics in which learners were to be taught the operation of a calculator. However, he did not mention these topics. This could suggest that he might not be using a calculator as he was claiming. The learners might be the ones using the calculators in his classroom. Other than these topics there is no mention in the curriculum that learners should use calculators.

Mr Lehlokwa further indicated that he downloaded past examination question papers from Limpopo and other provinces. He also had the opportunity to download teaching and learning materials that he could use in his classroom. These downloaded materials would have helped him to represent mathematics content in different ways that would be accessible to the learners; however, he chose not to use the opportunity. This was strange, because during my data collection period I observed him consulting his colleagues about mathematics concepts he was not sure of. The colleagues explained the concepts but did not show him how he could present them in the classroom. It appeared that Mr Lehlokwa had more trust and confidence in his colleagues than the technology. He reinforced this impression when he further indicated that the mathematics teachers “supported each other” and “worked as a team.”

Based on what he said, he should have been seeking more information about mathematics on the internet. Thus, I can posit that Mr Lehlokwa had limited knowledge on how he could transform mathematics concepts and make them accessible to all the learners in his class by using technology.

The provincial government did not have a rollout plan for equipping schools with computers or training teachers in how to use these computers. Thus, schools that had such tools had to make their own plan to train their teachers to use the tools. As the school was a quintile 3, it could not afford to get people to come and train its teachers. Additionally, the school got its computers from a mining company in the form of a donation. The school management team (SMT) came up with a way to force teachers to use the computer in executing their administrative tasks: the SMT would not accept a mark sheet or a schedule that was handwritten. The whole idea was to show teachers that using a computer to perform their administrative tasks would relieve them of most routine tasks and make their administrative tasks easier. Teachers who knew more were given the responsibility of helping those who knew little or nothing. This strategy influenced other teachers to use these tools in performing their administrative work. Thus, even though no formal training was organised by the school, learning took place in the form of social learning. Mr Lehlokwa was among those who knew very little about the Microsoft Office application programs. This is how he described his first experience with Microsoft Office Excel and Word:

> *It was a little bit difficult, but if you persist and keep on practising you will find it easier. It comes with some information. You just read and go on with it. It usually provides you with some commands and if you just press the key, the key will tell you do this and/or that. I think it is only following through the*

instructions on the computer. If you need something you go all out and you search, you will get what you want.

From his description I could deduce that he had been determined to acquire the skills and did not merely wait for his colleagues' help. He made a point of teaching himself the necessary skills by following commands, instructions and prompts indicated on the computer. This demonstrated his positive attitude towards Microsoft Office Excel and Word.

Although his favourite tools were the Microsoft Office programs, he did not own a technological device with the two programs; but relied on the school's computers to access them. Thus, his use of computers was confined to his work environment. He had about six hours of free time in a week, some of which he used to practise computer literacy skills if the computer laboratory was available. He could not take the school's computers home; thus, he did not have enough time to experiment and explore the contribution his favourite tools could make in the classroom. This had implications for whether he would use the technology in his classroom.

The above discussion demonstrated Mr Lehlokwa's TK was basic. He did not know how he can use the technology to simplify mathematics concepts. Below follows Mr Lehlokwa's description of his pedagogical knowledge.

Pedagogical Competence

Mr Lehlokwa perceived himself to have high competence in PK, PCK and TPK. He rated himself highly on all statements in these categories when responding to the questionnaire.

He explained that their school used to have mathematics software programs about two years ago which he had used in his classroom. From his description I gained that he saw those software programs as tools that would do the teaching on his behalf. The programs included mathematics concepts; thus, all he had to do was to present the lesson to the learners. He was not able to explain how the use of the software contributed to learners' learning. He appeared to think that if he explained what was happening during the lesson, learners would understand concepts better. When I probed further into how he explained while the program was running, he responded:

I will pause it and I will explain the concepts being presented. Eh sometimes I will ask learners some questions. Sometimes our learners do not understand the English.

His response gave me the impression that his explanation was done in the local learners' language. However, a study done by Setati (2008) found that trying to explain mathematics in learners' local language does not guarantee learners' conceptual understanding. Also, the fact that he was not trained in the use of educational technology in teaching had a major influence in his use of these tools in the classroom environment.

Mathematics is perceived to be an abstract subject. Mr Lehlokwa should ensure that his teaching process does not perpetuate this perception. Mr Lehlokwa seemed to have limited knowledge of different learning and teaching strategies that he could use to motivate and encourage his learners. This is seen in how he explained his views on the use of a calculator in his classroom:

Mmmm, we let them sit in groups where I think some learners do not actually know how to use them (calculators). What I do, I show them, eh how to make use of the calculator, how to calculate and solve some problems.

He hesitated when he started responding. It appeared he was not sure of his response. Even though learners were seated in groups he did not let them discuss the concepts among themselves or demonstrate to each other in their respective groups. He seemed not to be aware of different strategies that learners may bring to the teaching and learning environment. Mr Lehlokwa should develop activities in which learners would be able to share ideas, develop problem solving skills and critical thinking, and design their own learning. Although he claimed to be using collaborative learning to teach his learners, he seemed to think that collaborative learning implied merely putting learners into groups in the classroom. Putting learners into groups does not translate into collaborative learning. Mr Lehlokwa should come up with group goals so that when learners are in their groups, they know what is expected of them by the end of their lesson. Mr Lehlokwa should also assign roles to group members for group goals to be achieved.

Later in the interview Mr Lehlokwa revealed that he did not plan the use of educational technologies in his classroom. He confirmed this when he responded to the interview question about what guided his decision to use an educational technology in his classroom.

> *Ah, I think it is when it is needed. Then I really do say take out your calculators and check if the value of this sine or this angle are the same.*

I probed further to inquire about how he knew that a calculator was needed in his lesson, and this is how he responded:

> *I think in the calculator there are some trigonometric values that show that this is the sine, cos, and tan. Then it means we must check from the calculator where they say with the use of a calculator.*

Scientific calculators have programmed trigonometric values. There is no need to do any calculation. You just press the trigonometric ratio and the angle on the calculator's keypad, and you will get the trigonometric value. Mr Lehlokwa's response indicated that the content he was going to cover with the learners guided his decision to use a calculator. However, when pressed further, he also implied that the content should be contained in the calculator. Thus, in this instance a calculator was used as a tutor.

When the responses on the TPACK framework questionnaire were compared with the interview results, a great deal of inconsistency between them was evident. This inconsistency was especially pronounced on the PCK, PK and TPK components of the TPACK framework. Mr Lehlokwa perceived himself to be competent in relation to these TPACK components; however, the interview data painted a different picture from the questionnaire data. Thus, it could not be concluded that Mr Lehlokwa had deep pedagogical knowledge. Below is a discussion of Mr Lehlokwa's content knowledge.

Mathematics Competence

Mr Lehlokwa perceived himself to have a high CK. This was demonstrated when he agreed with all items on the questionnaire about his mathematical content knowledge. The items included strategies to develop an understanding of mathematics, keeping up to date with conferences and activities in mathematics, developing class activities that were meaningful to learners, and knowledge of geometry, trigonometry and algebra.

As mentioned in 6.2.2 above, Mr Lehlokwa had a Senior Primary Teaching Diploma (SPTD) qualification and an Advanced Certificate in Education (ACE). In his SPTD training programme, he had done ‘mathematics academic’ as one of his courses. The course involved maths concepts up to the level of grade 10. Thus, his content knowledge was supposed to be at a higher level than that of the grades he was presently teaching.

Although Mr Lehlokwa had a teaching qualification, this did not imply competence in mathematics concepts. This was confirmed by my observation during data collection in the school. I witnessed Mr Lehlokwa consulting one of his colleagues on some mathematics concepts. He was sourcing information about linear functions from a colleague whom he regarded as an expert. He could not get an answer to one of the questions that was part of the quarterly tests in grade 9. The tests were developed by the Limpopo Provincial Department of Education.

Although this was informal information sharing, it constituted some form of professional development. Because of its informal nature, Mr Lehlokwa seemed to feel more at ease. Stoof et al. (2002) conceded that one might hold a qualification like a certificate but still be incompetent. Thus, it did not come as a surprise to see Mr Lehlokwa consulting his colleague about a mathematics concept. I also, confirmed his lack of content knowledge when he was explaining how he used a calculator in his mathematics lesson. He indicated that a calculator was used, “when we factorise a number as a prime factor of itself.” The statement did not make any mathematical sense. This is an indication that Mr Lehlokwa’s mathematics thinking, communication and representation were lacking. When I probed further to understand what he meant, I realised that he meant using the calculator to get prime factors of a number.

Since 1998 the South African mathematics curriculum has changed three times in South African schools, and mathematics teachers have had to undergo professional development to stay abreast of the changes. However, there was never enough time for this as professional development programmes were conducted after normal working hours. Furthermore, teachers were usually tired because they had come straight from work to the training venues. The whole point of teachers' professional development was to improve their competence in mathematics concepts; however, the planning of the training programmes left much to be desired. This might have resulted in teachers' conceptual knowledge gaps.

As a mathematics teacher, Mr Lehlokwa should ensure that the learners he teaches understand mathematics concepts clearly and can progress in mathematics up to grade 12 level and beyond. It is important for learners in grade 8 & 9 to acquire a solid mathematics foundation. This will boost their confidence in learning mathematics and spark their interest in pursuing mathematics beyond grade 12. If Mr Lehlokwa had a deep mathematics conceptual knowledge, it would have given him a better chance to influence classroom teaching in a positive way. However, the data painted a different picture.

Teaching is a complicated task. Mathematics conceptual competence is one of the components of being a competent mathematics teacher. Teachers who have a deep mathematics conceptual knowledge stand a better chance of influencing classroom instruction in a positive way (Kahan et al., 2003). Mr Lehlokwa's mathematics conceptual knowledge was restricted to procedural knowledge. This view is supported by his explanation of the contribution of educational technology in mathematics. He indicated that the technology did the teaching for him and all he did was explain the calculations to learners and provide answers. He did not think deeply about the various procedures that were available for solving the mathematics problems and why they worked.

On the other hand, having a high mathematics conceptual knowledge alone would not have guaranteed that Mr Lehlokwa would impart that knowledge in a meaningful way (Pounara, Hodgen, Adler & Pillay, 2015). He should know how to approach his learners in the classroom. Mr Lehlokwa's long experience seemed to have contributed very little to equipping him with the skills of approaching his learners in his classroom. This was seen in how he blamed learners' errors, misconceptions and misunderstanding on the use of calculators. He commented:

> *When I see the incorrect answers from the learners when they are using the calculators, then I have just realised that lack of knowledge on how the*

calculator is used is misleading. It is misleading the learners towards the correct solutions to the problems.

He did not probe further to try to understand why those errors, misconceptions and misunderstandings were found in learners' responses. His approach was to try and remediate weaknesses in learners' responses and fill the gaps in their knowledge. He seemed not to understand why learners should make mistakes after he had taught them rules or algorithms to manipulate symbols. As a teacher with 30 years of mathematics experience, he should have developed a wide range of pedagogical skills to address the learners' mathematical needs. He should have been aware that there could be several reasons for learners' mistakes, including not being interested in their work; their alternative interpretation of mathematical ideas to create meaning, and the role of language in creating meaning as they were second language speakers (Anthony & Walshaw, 2009). Instead of focusing on learners' conceptual deficits, his focus should have been on building from learners' existing proficiency. This would have helped Mr Lehlokwa to design and develop appropriate activities for all his learners in the classroom.

Despite his evident limitations in dealing with learners' needs in his classroom, Mr Lehlokwa could have ensured that they had access to the mathematics. Coming up with innovative teaching strategies would have filled the void left by his lack of mathematics conceptual knowledge. These innovative teaching strategies would have made classroom learning interesting and meaningful to learners (Walshaw, 2012). These strategies would have encouraged and sustained learners' attention in the mathematics classroom. Learners who are encouraged and motivated to do mathematics and are also interested in the subject may proceed to study mathematics at higher levels.

Thus, Mr Lehlokwa's use of the different software programs was due to the pressure exerted by the SMTs. These tools relieved him of the routine administrative work. It was also interesting to note that Mr Lehlokwa had made sacrifices and had persevered to acquire skills in computer use. However, he seemed not prepared to share or pass these acquired skills to the learners. The school did not exert pressure on him to pass the skills on to the learners. Mr Lehlokwa probably believed that the knowledge that should be shared with the learners was what was in the textbook. On the other hand, calculators were used to relieve him and the learners from the monotony of the routine mathematics work. Mr Lehlokwa's competence in the use of educational technology in mathematics is represented by diagram 6.3 below.

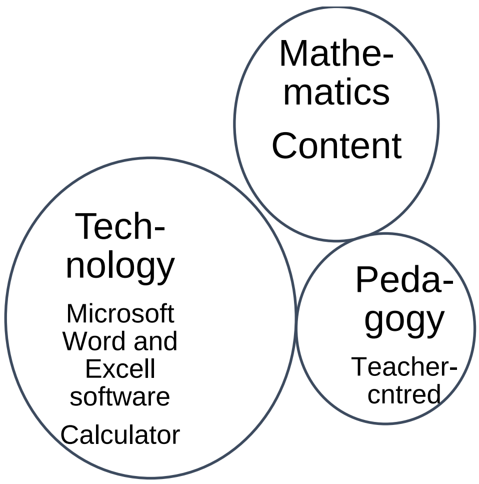


Figure 6.3. Mr Lehlokwa's use of educational technologies in mathematics

The above discussion demonstrated that Mr Lehlokwa lacked mathematics conceptual knowledge and had basic technological and pedagogical competences. He, therefore, lacked confidence in the use of technology in the classroom. This is consistent with a study by Joo, Park and Lim (2018), which showed that teachers with a high TPACK competence find it easier to use technology in their classrooms. Thus, Mr Lehlokwa's low TPACK competence influenced his use of educational technology in the classroom.

Mr Lehlokwa's school did not have guidelines on the use of technology in teaching and learning. However, the school was aware that Microsoft Office programs were essential when used for planning, recording, and processing learners' assessment information. Thus, pressure was exerted by the school management team (SMT) on teachers to use these programmes (Frank et al, 2004). Mr Lehlokwa risked using these programs because he knew there was adequate support and access to expertise from his colleagues (Barton, 2013; Li & Choi, 2013). Though there was social capital in the school, teachers were never trained in the use of technology in teaching and learning and did not see these tools being used in the classroom.

Hence their use was limited to administrative purposes. This demonstrated that Mr Lehlokwa's competence in the use of technology was consistent with his perceptions of the use of technology in teaching and learning. This was in line with the school's shared expectations.

Mr Tsebo (School B)

Technological Competence

Mr Tsebo indicated on the questionnaire that he owned a smart phone and a computer. He also indicated that he used the computer to show the learners graph representations. During the interview Mr Tsebo indicated that a computer was his favourite tool. He further indicated that by using the computer for a long time he had gained the confidence to use it in his classroom.

Mr Tsebo perceived himself to have a high TK, which was demonstrated by his response to the relevant questionnaire item. However, he regarded himself as having a low TCK. Of the five statements of this TPACK component he only agreed with one, which was: "I use technologies in my teaching to easily achieve the learning outcome." He neither agreed nor disagreed with other four statements. These were: "I use technology to enhance learners' better understanding of mathematics;" "I facilitate equitable access to technology resources for all learners in mathematics;" "I develop class activities involving the use of educational technologies;" and "I develop projects involving use of educational technologies."

Although Mr Tsebo owned a desktop computer and a smartphone, he used a laptop in his classroom which belonged to the school. The place where the computers were stored was not conducive for him to work with the learners. Thus, he used the laptop in the mathematics laboratory, which was used as his classroom. Learners went to his classroom and found the laptop and data projector ready for the lesson to begin. Also, different grades could move freely in and out of his class. Mr Tsebo acquired the skills of using a computer while he was studying for an Advanced Certificate in Education (ACE). This programme included a course in which he had to use a computer to prepare lesson plans, do presentations for some of his assignments and make sketch drawings. However, he was never taken into a classroom environment where he could continue to use the lesson plans, he had developed in a real teaching environment. Thus, it was his choice to use these tools in his classroom; nobody forced him to do so, because their school did not have a policy on the use of educational technology in the classroom. He indicated that by using the computer for a long time he had gained the confidence to use it in his classroom. He mentioned that he had been using a computer for almost ten years:

> *I think since I have been using it (computer) for a long time, I have also developed new skills on how to improve on other things. Initially it was a little bit, ah it was not easy for me using it and I was not even comfortable in using it. Since I have been using it for long, I think I have improved in the usage of it.*

According to Mr Tsebo, experience has contributed towards building his confidence and skills in the use of the computer in his classroom. However, during my observation of his lesson, I could only see a handful of his skills demonstrated. He connected the laptop to the data projector and did not struggle to get the laptop screen projected onto the larger screen. Then he opened a folder containing the mathematics concepts he was going to discuss with the learners in the classroom. The concepts were in pdf format. He presented the concepts without any adjustment. The format did not affect his presentation because he was presenting mathematics sentences, which are usually loaded with symbols and formulae. I asked him during the post-observation interview about using the pdf document for presentation and his response was, “It saves time of rewriting the work”. From his response it was evident that he was not aware that there are a lot of limitations when using a pdf document as a presentation tool. The school did not have a special program to edit pdf files. Thus, he would not have been able to edit any part of the document. Also, a pdf document is not the best presentation software when compared to PowerPoint. When the learners arrived in his classroom the lesson was already projected on the screen. All that he did with the laptop during the lesson was to scroll up and down.

Mr Tsebo further mentioned that they used to have a collaboration project funded by the mining company. Four secondary schools in their circuit had been identified to participate in this project, with his school as the hub. That was the main reason why the school had been given a smart board as a donation. They used their smart board to broadcast mathematics lessons to all schools involved in the project. Mr Tsebo had been the coordinator of the project. However, the project could not be sustained owing to a lack of financial resources. Thus, the smart board was no longer used for its purpose; it was now used as a screen for the data projector.

Mathematics Competence

Mr Tsebo perceived himself to be competent in mathematics knowledge. This was confirmed by his response to the questionnaire items about his perception of the mathematics content knowledge (CK) component of the TPACK framework. He strongly agreed with all the statements mentioned in this component on mathematics conceptual knowledge.

Mr Tsebo graduated with a Secondary Teachers' Diploma (STD) specialising in mathematics and physical science. This is an old qualification that used to be offered by colleges of education. For a student to be admitted into the programme they had to have passed mathematics and physical science in grade 12, which was called matric. The programme had a pure mathematics course called mathematics academic. The course content included a grade 10-12 mathematics syllabus and post-grade 12 concepts which were complex numbers, abstract algebra and calculus. The purpose of including post-grade 12 mathematics concepts was to equip teachers with higher conceptual knowledge than the classes they would be teaching to give them confidence and competence in terms of content. Though it was an old qualification, it was still relevant. The programme also had a mathematics didactics course. This was a course on how to teach mathematics in the classroom. The course content included developing mathematics learning programmes and lesson plans, micro-teaching and mathematics teaching theories and methods. From the above it is evident that he had received a training at a higher level than the mathematics level he was teaching.

Also, during my observation of his lesson, I noticed how he pursued learners' conceptual gaps through questioning. He started by showing learners the different formulae that were used in sequences and series. This indicated his competence in mathematics symbol and formalism and mathematics representation. He then explained what different variables represented in those formulae. In this case Mr Tsebo demonstrated competence in mathematical communication and mathematics representation. Then he moved from procedural mathematics knowledge to conceptual knowledge of mathematics. He showed learners the inappropriateness of fractions and negative numbers in determining terms' positions in a sequence. In this instance Mr Tsebo demonstrated competence in mathematics thinking, mathematics reasoning, mathematics problem tackling and representation competence. He also demonstrated knowledge of understanding the deductive nature of mathematics. This was seen in how he showed learners the connection between different mathematics concepts. While showing learners how to use a series to determine terms in a sequence, a question was raised by one learner. The learner wanted to know how he could use a series formula if one term in a sequence was unknown. Figure 6.4 below shows how the teacher explained this to the class in response to the learner's question.

Figure 6.4. Mr Tsebo's algorithm response to a learner's question

Figure 6.4 above shows how Mr Tsebo first used the formula for a series to determine term 6 in the sequence. However, the last term was unknown, thus he used both the sum and the general term formula of the sequence to determine the term. In this explanation he demonstrated mathematical thinking competence, symbolism and formalism competence, mathematical representation competence and problem-solving competence.

Later during my visit at this school, I witnessed Mr Tsebo assisting another colleague with mathematics concepts issues. This indicated that his colleague trusted his mathematics conceptual knowledge and would draw on this knowledge as a way of learning. However, teaching is a very complex process, and one cannot apply linear reasoning. Having a high content knowledge in mathematics does not guarantee the effective teaching of learners.

Pedagogical Competence

When responding to the questionnaire about his perception of his competence relating to these TPACK components, Mr Tsebo perceived himself to be competent in PK and PCK. He strongly agreed with all statements mentioned in these components. However, concerning the TPK component, he perceived himself to be somewhat in between. Out of the eight statements which he was asked to rate himself, he agreed with four statements and disagreed with the other four statements. The statements he agreed with were: “I use technologies that enhance the teaching approaches for a lesson;” “I use technologies that enhance learners’ learning;” “I use technology that support learner–centred strategies in mathematics teaching” and “I provide leadership in helping others in the use of technologies in teaching”. The statements Mr Tsebo disagreed with were: “I use technologies that address the diverse needs of learners in mathematics;” “I manage a technology-rich classroom effectively;” “I evaluate the appropriateness of a new technology for teaching and learning;” and “I use technology to motivate learners”.

Mr Tsebo’s observation lesson was conducted in the mathematics laboratory. When I arrived in his class, I found the laptop and the data projector ready. The teaching time for the next class had not yet started, and he was having a free period. When the period started learners came from their classroom to the mathematics laboratory for their mathematics lesson. He was teaching a grade 12 mathematics lesson. When all the learners were in the laboratory, he greeted them and introduce the topic they were going to discuss.

Mr Tsebo adopted a teacher–centred approach when using the laptop in his classroom. However, he saw the computer as helping him to improve his teaching. He pointed out:

> *Normally I display my lessons on a screen so that it become easier and time saving to copy activities and whatever, it is simply displayed. So, I think my teaching is improved.*

Projecting the lesson for the learners with them as passive viewers does not improve teaching. Teaching is improved when learners are actively involved in the projected lessons. Mr Tsebo assumed that the computer had contributed towards restructuring his classroom practice.

He further indicated how this engagement had contributed to mathematics learning. However, the engagement involved learners solving problems on the chalkboard individually as indicated in figure 6.5. Each learner had a turn to work from the chalkboard provided they volunteered by raising their hands. Mr Tsebo was guiding the process by asking other learners if the volunteer learner was on the right track. As soon as a fellow learner realised that the volunteer learner had made a mistake, their chance to participate started. They would go to the front, take away the chalk from the learner who was solving the problem, correct the mistake and complete solving the problem without any verbal communication. Mr Tsebo gave feedback when there were no more learners at the chalkboard. In one instance he allowed two learners to work on the chalkboard at the same time. After having solved the problems, the class started comparing the solutions of the two learners. Although he was using whole class teaching, Mr Tsebo encouraged his learners to participate in the discussion even though they were not in groups.

This was made possible because content was projected onto the screen and the chalkboard afforded more space for the learners. Also, learners had more time to solve the problems because they were not copying the problems, as they were projected onto the screen. However, learners were restricted to working in the chalkboard space only. They could not work from the laptop, as it was the only one being used. Trying to allow learners to use the laptop was going to create more work in classroom management. Besides, he had not taught learners how to operate the laptop.

Although Mr Tsebo had more space on the chalkboard because of the data projector, moving from the chalkboard to the laptop created a lot of movement for Mr Tsebo which at times distracted the learners. He did not realise the opportunity offered by the overhead projector for group discussion activities. What is more, the lesson aim was to dispel learners' misconceptions on arithmetic, geometric and quadratic sequences. It was also a revision lesson and learners had acquired some of the formulae and procedures for solving problems related to mathematics sequences. Figure 6.5 below shows a learner working on the chalkboard

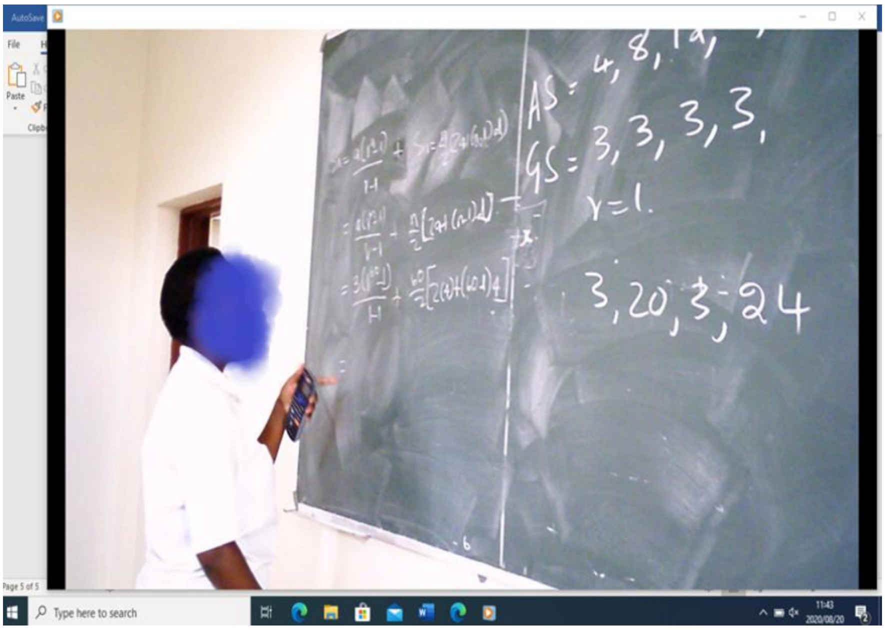


Figure 6.5. A learner working on a chalkboard space

This learner was solving a series problem. She wrote the formula and substituted values on the formulae. The learner then proceeded to use a calculator to operate the values. Her facial expression was stunned after she got the answer from the calculator. She was reflecting on her formulae as well as substitution. While she was reflecting another learner, who had identified the mistake, came to the chalkboard, grabbed the chalk, rectified the mistake, and completed the solution to the problem. All these activities occurred without the two learners communicating with each other. This did not come as a surprise because communication in the classroom was facilitated by Mr Tsebo asking questions and learners responding to his questions.

Mr Tsebo showed that he could use a laptop to create support for learners among themselves. Though he used one laptop only, the laptop gave him more time and space to enable learners to demonstrate their work to other learners. However, the school's socio-economic status dictated the tools he could use in his classroom environment. The way he used the laptop was to compensate for the resources the school did not have.

Mr Tsebo did not perceive himself as having a high knowledge level about the relationships among learners, teachers, content, practices, and technology. However, when he explained the benefits of using educational technology in his classroom, he showed awareness of the above-mentioned relationship. He explained:

> *Eh, I think it is a visual aid that usually learners learn much easier when they see and touch things. In mathematics being told how things are done eh it is not easy. If you simply show them by entering a formula on the system and it works itself out, they can see that sometimes things are possible.*

However, the above comment did not reflect what I observed in Mr Tsebo's classroom. During his lesson he was the point of focus. The projection of maths concepts on the data projector was a teacher-directed teaching strategy which characterised learners as vessels that needed to be filled with knowledge that the teacher had.

Mr Tsebo also indicated that the use of the laptop had affected learners' attitudes towards mathematics. He expressed his view in this way:

> *I can't say much, it is just that learners like using these technological tools and it is most of them (learners). Yes, in terms of attitudes they start to like doing mathematics, but I can't say it has affected their performance. I think yes it has improved their attitudes, they like using technological stuff; so when we bring them to their class they enjoy and like to be part of the lesson.*

This comment suggests that Mr Tsebo was aware that the technological tools did not improve learners' performance in mathematics. However, learners had become more interested in mathematics and were now enrolling for the subject. Thus, Mr Tsebo's competence in the use of educational technology in mathematics is represented in diagram 6.6 below.

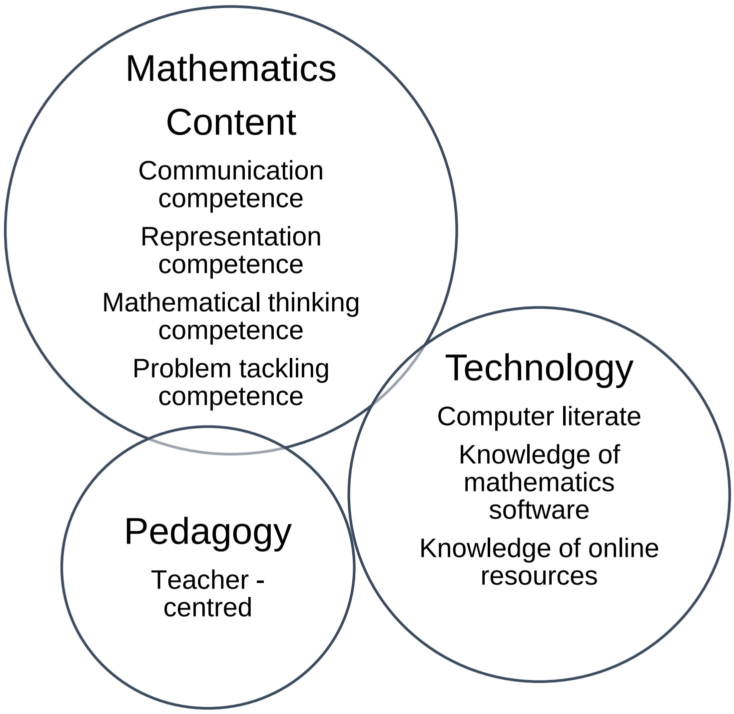


Figure 6.6. Mr Tsebo's use of educational technology in mathematics

The above diagram demonstrates that that Mr Tsebo had more confidence in his mathematic conceptual knowledge than either his technology knowledge or his pedagogical knowledge. However, the mathematical content knowledge did not have any influence on Mr Tsebo's use of technology. He lacked strategies of using educational technologies in his class. Though he had completed a course on the use of technology in mathematics teaching, he had never been taken to a class where he could apply the theoretical knowledge gained in that course. This is consistent with Polly's (2011) study which demonstrated that teachers' professional development contributes to teachers' TPACK competences and the ways in which they use technology in their teaching environment. Another possible explanation could be that Mr Tsebo was using one laptop for the whole class. The laptop was the only tool available to him because of the school's socio-economic status.

As indicated in 6.2 Mr Tsebo and Mr Lehlokwa were from the same school. Mr Tsebo was also the head of department (HOD) for mathematics. Thus, he was part of the team that was exerting pressure on teachers to use Microsoft Office software programmes. He was also an expert in these programmes thus his colleagues could draw knowledge from him as well (Frank et al., 2004).

Ms Makgona (School B)

Technological Competence

Ms Makgona's response to the questionnaire indicated that she did not own any technological tool and did not use any technology in the classroom.

Ms Makgona's further responses to the questionnaire indicated that she perceived herself to be competent on TK. She agreed with all the statements in the questionnaire about her technological knowledge except one. The statements she agreed with were: "always resolving ICT-related problems;" "being able to differentiate between software and hardware;" "familiarity with new technologies and their features" and "knowledge of several websites and social media platforms". The only statement she disagreed with was: "learning a new software program on her own". However, she perceived herself as not competent on TCK. She disagreed with all the statements in this component. The statements were: "use technologies to enhance learners' understanding of mathematics;" "facilitate equitable access to technological resources for all mathematics learners;" "develop class activities involving use of educational technologies;" "develop projects involving use of instructional technologies" and "use technologies in teaching to easily achieve the learning outcomes".

Despite indicating in the questionnaire that she did not own or use any technology, she mentioned during the interview that her favourite technological tools were a computer and a calculator. She indicated that she accessed computers at her workplace. Ms Makgona also mentioned that she did not use a computer in her teaching and learning environment. Like Mr Lehlokwa, she used a computer to type tests, make mark sheets and prepare schedules. A computer allowed her to edit her work easily and store the work for future use. As indicated above, teachers in her school were obliged by the school management to submit computerised assessment records and thus she had been compelled to learn how to comply with the school regulations. The school did not put pressure on teachers to use the computers in their classroom teaching. The reason could be that there were not enough computers for both the teachers and learners. Ms Makgona's access to the computer at school was also dependent on the free periods she had. She could only work on the computer during her few free periods – about 4 hours per week.

Ms Makgona further indicated that she also used the school's Wi-Fi to download previous question papers and discuss them with learners in the classroom. This was an indication of exam-orientated teaching. Ms Makgona was drilling learners in solutions to various mathematics problems, anticipating that if the questions were found in the exam, learners would be able to reproduce the solutions. This is not surprising in a system where the teaching focus is on the number of learners that exit a phase without consideration of the quality of learners' knowledge.

She had also enrolled at an institution and acquired a formal certificate in end-user computing; it did not come as a surprise that she was not using the computer in the classroom. The end-user computing qualification was in the use of different computer application systems for personal use, and no mathematics teaching and learning programs were included in the course. This indicated that she lacked confidence in using the computer in the classroom environment. She also, indicated that she had never attended any training in the use of educational technology in the classroom. She had therefore only learnt to use technology for her personal benefit.

Ms Makgona indicated that the main reason she was not using educational technology tools in her classroom was lack of knowledge and skills:

> *Eh, except using the computer for myself and calculators for both learners and me I think I don't have any other because I am not familiar in using the data projector. I don't usually use the data projector even though we have one.*

Ms Makgona did not describe any attempt to explore how the computer could process knowledge in mathematics. She used Excel spreadsheets to prepare her schedules but could not see the link with using spreadsheets in the classroom situation.

She was not restricted by anybody but had created boundaries for herself, based on her lack of technological capabilities. Not owning a computer could also have contributed to the fact she did not to use one in the classroom (Almerich, Orellana, Suárez-Rodriques & Diaz–Garcia, 2016). Very few teachers were using this kind of a tool and thus she could not rely much on her colleagues to help her. This is seen in her description of the challenges she had encountered in the use of educational technology. She said:

> *The challenge is that you as a teacher you have, first you want, prepare, and plan whatever you want to do with the learners in the class. If you get stuck there is no one nearby to help you at that precise moment, because at that moment you find those that can help you are either in class or not there. Then it means you must prepare your lessons here at school and so that they (colleagues) will be nearby. If you do that at home when you get stuck, then you are stuck.*

The above comment indicates that the school had no coordinated teamwork activities.

Mathematics Competence

Ms Makgona perceived herself to have a high knowledge of mathematics concepts. This was seen in how she responded to the TPACK questionnaire on statements that were focusing on the mathematics CK component. She agreed with all the statements.

Ms Makgona had an old teacher' training certificate. This was a qualification acquired before democracy when the pre-democratic government introduced the diploma system as a qualification for pre-service teachers. A prospective teacher would need to have obtained a grade 12 qualification to be accepted into this two-year programme to qualify as a teacher. Prospective mathematics teachers would have passed their mathematics in grade 12 when they were accepted into the programme. The time required to obtain this certificate was shorter than the diploma programme and thus most of the content was dedicated to classroom practice and teaching and learning methods. Thus, the programme did not offer any post-grade 12 mathematics content. This was done deliberately by the then apartheid government to deny blacks access to subjects that would open better opportunities in life. Blacks were meant to be subservient workers and not good enough to do subjects like mathematics, accounting, physical science, and so on. Thus, many teachers of this era did not like to teach mathematics. Ms Makgona later upgraded her qualification and now has an ACE in mathematics education as her highest qualification.

Although Ms Makgona has qualifications in mathematics teaching, that does not imply competence in mathematics. However, during my data collection period at her school, a few teachers sought her assistance relating to mathematics concepts. One of them was Mr Lehlokwa, her colleague in the mathematics department. Mr Tsebo her HOD, hinted that she was giving extra classes on Saturdays for grade 12 mathematics learners in the community. The learners attending her extra classes came from different secondary schools in the area and the parents of the learners had requested her to offer their children extra tutoring. This indicated that her community had a trust in her mathematics conceptual knowledge. Ms Makgona also indicated that she helped colleagues in instances where her colleagues requested her assistance. She expressed her view in this way:

> *In other subjects you find that the teachers saying, "Hey! I'm stuck. When it comes to calculation in maths this is maths, it is your area. Help! how can I do it?" And then we help each other.*

This demonstrated her willingness to share her knowledge among her colleagues. Her colleagues regarded her as an expert from whom to draw resources (Frank et al., 2004). Ms Makgona contributed positively towards collective knowledge in mathematics. Both Ms Makgona's and Mr Tsebo's collective knowledge helped Mr Lehlokwa in his maths content knowledge development.

Pedagogical Competence

Ms Makgona perceived herself to have high knowledge on PK and PCK and low knowledge on TPK. This was seen in her response to the TPACK questionnaire on statements that were focusing on PK, PCK and TPK components. She agreed with all statements in PK and PCK components to support her perception. The PK statements focused on assessment, teaching and learning strategies, learning styles and classroom management while the PCK statements focused on planning for mathematics teaching, connecting mathematics with other subjects and making mathematics accessible to all the learners. However, she disagreed with all the statements in the TPK component of the TPACK framework. The TPK statements focused on choice and use of appropriate technology in mathematics, management of technology in mathematics classroom and the motivational factor of the technology.

As mentioned, Ms Makgona had been teaching mathematics for 34 years and was teaching mathematics in grades 10 and 11. As a mathematics teacher she was supposed to ensure that all her learners proceeded to do mathematics up to the grade 12 level. Ms Makgona's long experience gave her flexibility when dealing with learners. As she explained:

> *When we do some calculations then we show the slow ones how it is done, and then you will have more time with them and because they are using something different (calculator) to what they have used previously then they have interest and then gain confidence in whatever you would have shown.*

This explanation indicated that Ms Makgona was aware of the different types of learners she had in the classroom and was trying to cater for all their needs. However, her explanation was inconsistent with her response to the questionnaire about her pedagogical use of educational technology as indicated above. She disagreed with the statement: "I use technologies to address learners' diverse needs in mathematics."

Ms Makgona did not allow me to have a look at her lesson plans. I posit that as an experienced teacher she did not develop lesson plans. Instead, she was teaching from the textbook (Walshaw, 2012). Thus, it was not possible to see how much mathematics content was generally covered in a lesson, or the coherence and connections of mathematics concepts. By looking at a lesson plan, one can establish whether the lesson is focusing on content coverage or addressing learners' needs based on the mathematical tasks indicated, the resources to be used, and the teachers' and learners' activities that are to be done in the classroom. It is also easier to follow and understand how concepts are represented to learners by their teacher and how learners are assisted in developing a grounded understanding in mathematics.

Ms Makgona provided reasons for using educational technologies in her class:

Sometimes when you teach you found that learners eh! do not understand. Especially when you are dealing with graphs. When they use the calculators, they see how the graphs shifts and changes. It makes the learning a reality and they can understand easier.

From her explanation it was evident that she was aware that she can draw from a range of representations and tools to support learners' understanding. However, her explanation was inconsistent with her response to the questionnaire about her pedagogical of educational technology as indicated above. She disagreed with the statement: "I choose technologies that enhance learners' learning."

Ms Makgona's competence in the use of education technology is summarised by Figure 6.7 below:

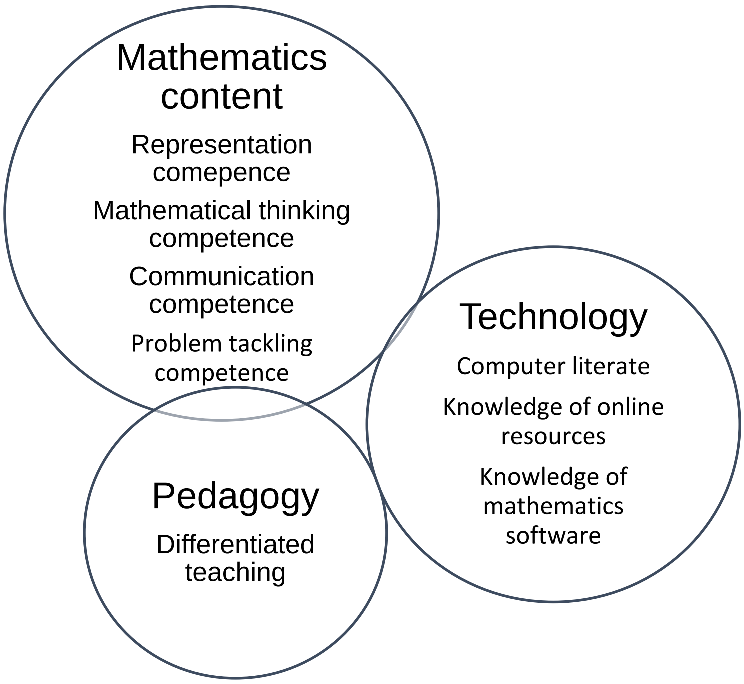


Figure 6.7. Ms Makgona's use of technology in mathematics

The above diagram indicates that Ms Makgona's mathematical content knowledge was more developed than either her technology knowledge or her pedagogic knowledge. However, the mathematics content knowledge did not have any influence on Ms Makgona's use of educational technologies. She had demonstrated confidence in mathematics content knowledge but lacked confidence in using computers in her class. Thus, Ms Makgona's technological knowledge was the least developed component. This is consistent with a study by Joo, Park and Lim (2018), which showed that teachers with a high TPACK competence find it easier to use technology in their classrooms. Thus, Ms Makgona's low TPACK competence influenced her use of educational technology in the classroom.

As indicated in 6.2 Ms Makgona and Messrs Tsebo and Lehlokwa were from the same school. Ms Makgona trusted her colleagues and relied on them for support and access to expertise. Also, the initiative that Ms Makgona had taken to upskill herself in technological skills was in line with the shared expectations in the school regarding the use of Microsoft Office for administration purposes.

As indicated above neither Mr Lehlokwa nor Ms Makgona used computers or laptops in their classrooms. They indicated that they used calculators with learners in the classroom. However, they used a computer to search for previous examination question papers, prepare assessment records and keep records of documents. On the other hand, Mr Phetole and Mr Tsebo both owned a smartphone and a desktop computer, and both used a laptop in their classroom. Both Mr Lehlokwa and Ms Makgona had access to the laptops in their school, but they chose not to use them. On the other hand, both Mr Phetole and Mr Tsebo were younger than Mr Lehlokwa and Ms Makgona. This is consistent with a study conducted by Alampay (2006) in the Philippines which found that the use of ICT in the classroom was more pronounced in the younger generation of teachers. Also, the fact that both Mr Lehlokwa and Ms Makgona did not own a smartphone, a laptop or a computer could have influenced their non-use of educational technology in the classroom (Basak & Govender, 2015).

Ms Makgona had a qualification in end user computing which was very helpful when she was preparing learners' assessment records and typing question papers because she used her computer literacy skills. Mr Lehlokwa had not undergone any training in the use of Microsoft Office programmes but has learnt from colleagues and was using the programmes for typing question papers and preparing learners assessment records. On the other hand, Messrs Phetole and Tsebo taken a formal course on the use of educational technology in mathematics involving Microsoft Office programmes. Thus, all the teachers in this study were competent in the use of various Microsoft Office programmes and had acquired skills of using these programmes in different ways.

All the schools' laptops and computers had Microsoft Office, but none of the teachers ever used the Excel programme in mathematics. None of the mathematics teachers in the two schools knew how to use it in mathematics teaching. The Department of Basic Education (DBE) has advocated for the creation of communities of practice as part of in-service training for the use of technology in teaching and learning (DBE, 2011b). This would have helped teachers to access expertise from outside their school communities, enabling schools to obtain more resources while extending their social capital. However, the department's idea was never cascaded to school level.

The fact that both Mr Phetole and Mr Tsebo had completed a full-year's formal course in the use of technology could have been a contributing factor that encouraged them to use laptops in their classrooms (Mouza, 2011). However, Mr Phetole's and Mr Tsebo's laptop use was limited to demonstration purposes. The findings confirm the fact that using laptops for presentations does not lead to effective use of technology in mathematics (Lassak, 2015a). Effective use of technology in mathematics teaching depends on the teacher's ability to select and create mathematics tasks that take advantage of the technology being used (Attard & Holmes, 2020).

6.3.1.2 Teachers' classroom practices

Mr Phetole (School A)

The lesson was conducted in a science laboratory because the computer laboratory was too small to accommodate the learners. All the teachers who usually used the science laboratory as a staffroom were also teaching at the time. So, there was no in-and-out movement during Mr Phetole's lesson. Before the learners arrived in the science laboratory, I requested a lesson plan from Mr Phetole, but he told me that he did not have one. The learners arrived and found Messrs Thupa (not his real name) and Phetole in the laboratory. Mr Phetole requested Mr Thupa to be his assistant in his lesson presentation. The learners greeted Messrs Thupa and Phetole. Mr Phetole started grouping the learners into groups of five or six, after which Messrs

Thupa and Phetole started distributing laptops to the learners. Each group shared one laptop. There were about 58 learners in his class and 10 laptops.

As Mr Phetole did not have a lesson plan, it was difficult to see the goal of the lesson. In his lesson he first used the Encarta software program which just gave information about mathematics concepts without specifying the goals of the information. Mr Phetole went straight into the concepts. This is how he introduced his lesson:

> *Let us check the topic we were doing last. We were doing analytical geometry… We were doing colinear in class. Are we together? Let us click on colinear and see what it has. If you have opened the colinear link, there is information written for us there. To prove that you have all opened the colinear link, I am going to request someone to read for us. Who can read for us? (Asked in the local indigenous language.)*

There was no background given to learners about the purpose of the lesson or a recap of what had happened in the previous lesson. He also did not link the lesson he was presenting to any of his previous lessons. However, he mentioned in what I consider the introduction to his lesson that the lesson was a continuation of a previous lesson. Thus, learners were learning concepts without being informed about the purpose of learning them.

During my observation of his lesson, learners never wrote anything in their books or scribblers. He also wrote minimally on the chalkboard. The laptops provided learners with information that would have taken him a long time to write on the chalkboard. The explanation of colinear was about three sentences long and it would have taken him too long time to write it on the chalkboard.

While giving learners instructions on how to access the concepts of the lesson, Mr Phetole was also working on the laptop keyboard. However, learners could not see which keys he was pressing as the laptop was facing him. The lesson was not projected for the learners and the laptop screen obscured the learners' view. Mr Phetole's instructions were also a bit long. Learners had to click five links before they could access concepts that were presented in that lesson. Although writing time was saved, a lot of time was wasted giving instructions on how to access the maths concepts that were discussed in the lesson.

The challenge that Mr Phetole was facing was to ensure that every learner was doing what was expected of them. As indicated above, Mr Phetole had the assistance of Mr Thupa to ensure that learners were doing the right thing. Mr Thupa moved around among the groups to check if learners had opened the correct content on their laptops. Although Mr Thupa was assisting, some learners could still not follow Mr Phetole's instructions. What is more, Mr Thupa did not communicate with Mr Phetole at all during the lesson. Figure 6.1 shows the screen display that Mr Phetole instructed the learners to open.

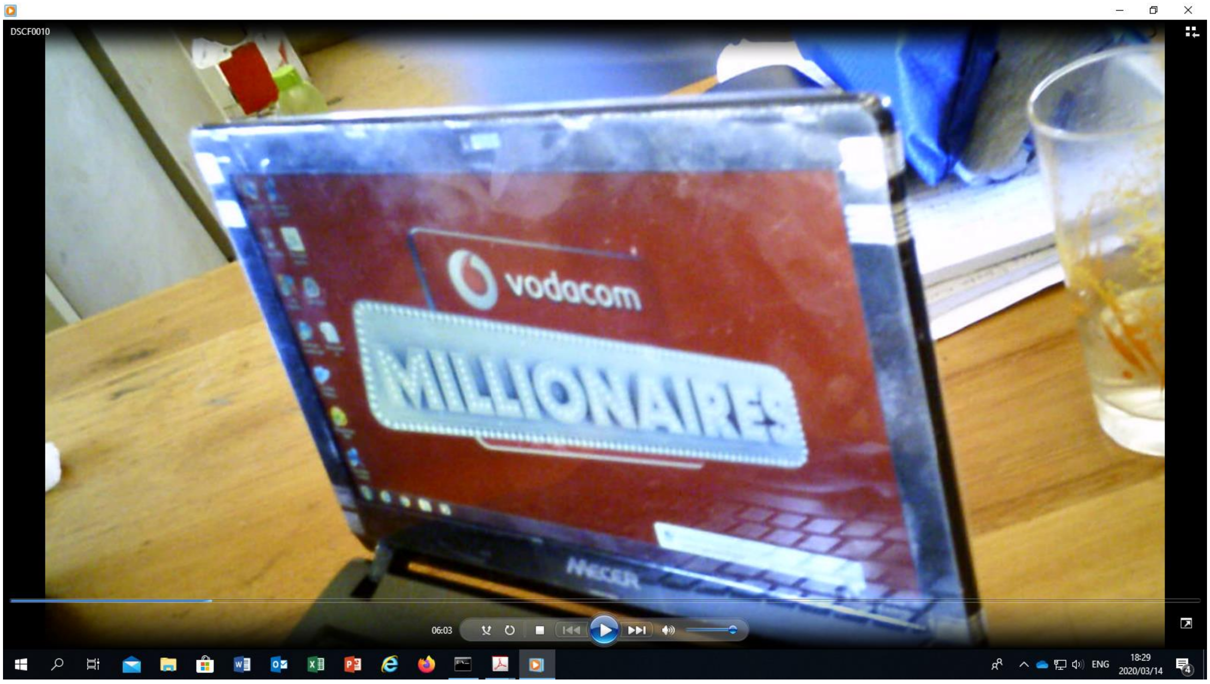


Figure 6.8. Screen display of Vodacom Encarta and Secondary Content for schools based on Mr Phetole's instructions

However, there was one group which did not follow Mr Phetole's instructions. Below is Figure 6.9, which shows the screen display of a different program. Another learner within the group can be heard in the background asking the learner who was operating the laptop what he was doing. This distracted learners in their learning but would not have happened if Mr Phetole had been able to monitor learners' laptop' activities from his laptop using a program like ebeam. The ebeam program allows the teacher to connect all the learners' computers to his computer and monitor the activities of each connected computer. However, the school could not afford the software program and thus an assistant was sought.

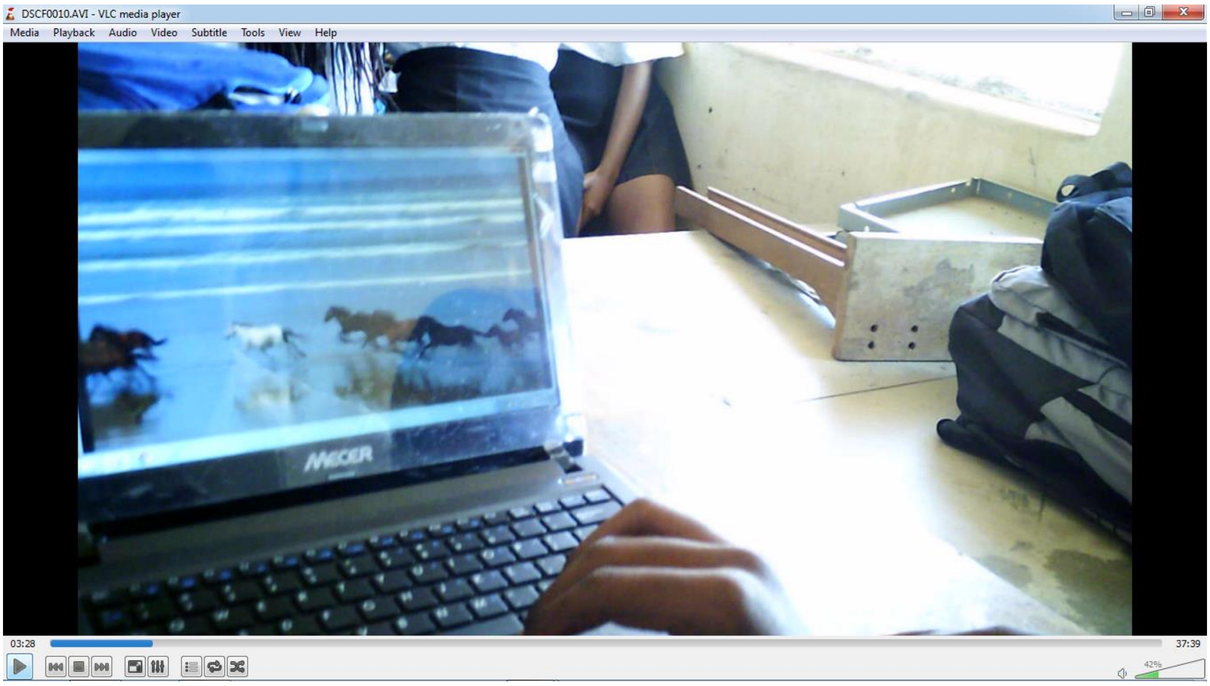


Figure 6.9. A screen display of a different program from Mr Phetole's instructions

Furthermore, Mr Phetole's presentation provided no opportunity at all for learners to interact among themselves. The interactions he had with the learners involved asking questions from them, their responses to his questions, him giving learners instructions and them following his instructions and him reprimanding learners for their misbehaviour. It was one-directional interaction.

Based on the above discussion, I conclude that Mr Phetole used a teacher-centred approach in his lesson. The traditional teaching patterns are not challenged or disturbed by his use of technology in the classroom. Mr Phetole could have brought his long experience of using educational technology outside the formal teaching environment into his classroom. Instead, the laptops were used as electronic versions of learners' textbooks as indicated above.

Furthermore, the way the content was presented to learners was more like Mr Phetole 'filling' learners with knowledge of mathematics concepts and navigation skills of the laptop. He chose two application programs to present his lesson and used Encarta to allow learners to read the concepts he was teaching. He could have approached this differently by giving learners homework or out-of-class work. The learners could read have about the concepts in Encarta from any source as homework before the lesson. Learners could have brought different perspectives on the mathematics concepts they have read, based on their resources. This could have helped Mr Phetole to identify errors, misconceptions, and misunderstandings that learners had and would have provided opportunities for them to interact among themselves and to interact with him in a bidirectional way.

The other application program he used was the secondary content for schools. In this program content for all subjects is found. The content is CAPS aligned and structured according to age cohort. However, this was not part of what he envisaged doing in his classroom. This is supported by what he said before he instructed learners to open the program:

> *So basically, what we did in class is wrapped by what you have seen in the laptops. We still have some time. Let us move on to another program.*

In this part of his presentation, he did not give many instructions. He instructed learners to click on mathematics, then on content for ages 17-18, then on the lesson about coordinate geometry. This lesson had six objectives. Mr Phetole focused on objective 1 which was: Understand and plot points on the Cartesian plane. He did not make any link or connection between the mathematics concepts he had presented from the Encarta program and the concepts from the secondary school content.

During the post-observation interview, I asked Mr Phetole the difference between the lesson I had observed and the one I had not observed, in which he was teaching the learners the same topic. His response was:

> *The lessons are the same. The difference is that in this lesson (observed lesson) we are using laptops. I wanted the learners to see how computers can be used in mathematics and to check if they are able to use the computers.*

From Mr Phetole’s response I could posit that his goal had more to do with learners acquiring knowledge of how to use the laptops than with their mathematics conceptual knowledge. As a mathematics teacher his paramount goal should be to develop learners’ mathematics conceptual knowledge.

He viewed the role of the teacher in class as someone with all the knowledge. Hence, the role of the learners in the classroom was to acquire this knowledge from their teacher. This view was captured in how he explained the contribution of technology to his classroom teaching:

> *I will be in the classroom instructing them (learners). I will be showing them what they need to do and which programs they should open. Then I walk around to monitor and check if they are doing what I instructed them to do. I will also assist learners who are having problems. Some learners are computer literate and others are not.*

In this case, the laptops have taken the place of the chalkboard

Mr Phetole further demonstrated that educational technology can also take the place of the teacher in the classroom, in a positive way. This was evident in his response when he said he would have appreciated the opportunity to show some mathematics videos to his learners by projecting them onto the screen. He said the video offered both voice and visual learning opportunities simultaneously, an aspect that human beings could not do. As a teacher, he could not talk and demonstrate concepts simultaneously; he could only perform the activities sequentially. However, in a video, animations of concepts are accompanied by voice explanations during the animation process. In addition, he also argued that:

> *Some of the videos explain themselves, thus you can just do a lesson without saying much and the learners will be understanding and learn from it.*

He supported the fact that educational technologies tools were machines that could do the work of teachers. However, he did not take into cognisance the context in which the tools are developed, and the way mathematics concepts are represented by these tools.

Mr Phetole also allowed learners to use their smartphones in his classroom even though the school did not allow learners to have cell phone on the premises. He said the school did not allow this because learners were using the cell phones for wrong reasons. Learners' use of smartphones was confined to using the technology as a way of replacing the textbooks that they did not have. Learners who did not have the prescribed textbook had downloaded a copy of this book and used their cell phones to follow what was happening in the classroom. However, because of the large numbers of learners in the classroom, it was difficult to monitor and control whether learners had opened the textbook or were doing other things on their cell phones. During the focus group interview with learners, they also confirmed that they used their smartphones to download the mathematics textbook. They further indicated that they downloaded the textbook because the school did not have enough hard copies for all the learners. However, they mentioned that they rarely used their cell phones in the classroom.

The above analysis demonstrated Mr Phetole's approach to teaching mathematics using the laptops. From the analysis, I can deduce that Mr Phetole did not recognise the affordances of the laptops. Thus, he was unable to employ appropriate pedagogical strategies when using the laptops in his class. This is consistent with the study by Wong et al. (2008). Andyani et al., (2020), in their quantitative study found that teachers' TPACK competence had a direct influence on their classroom practices in the use of technology.

Mr Lehlokwa

As indicated in 6.2 above, Mr Lehlokwa did not allow me to observe him in his teaching. In this section I present only Mr Lehlokwa's interview data. Mr Lehlokwa indicated that he used teacher-centred approach when using calculators in his teaching; however, when explaining his use of a calculator, Mr Lehlokwa perceived himself as the master of all. Learners were drilled into mastering concepts by means of a calculator. He seemed not to understand that a calculator was a tool and not the mathematics curriculum. He emphasised that learners should be competent in the use of the calculator, and he seemed to conflate competence in the use of a calculator with competence in mathematics concepts. He explained:

> *Well, in most cases when learners do not know how to use a calculator then they will be lost, they are lost, they will be lost. If learners do not know that the 'how' part of the calculator is not correct, the calculator will not tell them that they are wrong or right.*

He explained how he identified learners' errors in the use of a calculator:

> *… is only when I see the, the incorrect answers from learners when they are using the calculators, then I have just realised that lack of knowledge on how the calculator is used is misleading the learners towards the correct solutions to the problems.*

It was interesting to notice how Mr Lehlokwa emphasised incorrect solutions to mathematics problems as an indication of inappropriate calculator use by the learners. Sometimes an incorrect answer was lack of mathematics conceptual knowledge and thus it could not be inferred that it was due to the incorrect use of a calculator.

Mr Lehlokwa saw some potential benefit in using technologies in the classroom. Though he used only a calculator in his classroom, he saw the functional aspect of the calculator as the basis for using it in his classroom. He noted.

> *Mmm, ah, I think it is when it is needed. Then I really do say take out your calculators and check if this sine is the sine of or an angle cosine is the cosine of the same thing we are doing.*

Mr Lehlokwa further described what he saw as the benefit of using a calculator in his classroom:

> *Well, it really gives the correct answers if used quite well. If used properly then it will give the correct thing.*

Based on the above views, Mr Lehlokwa appeared not to plan for the use of the calculator in his lesson. A calculator seemed to be used impulsively or by chance because the concepts he was dealing with suddenly required learners to use calculators. Learners were expected to have their calculators on hand. However, there was no indication from Mr Lehlokwa that he had told learners to bring their calculators to school. Mr Lehlokwa assumed that learners would bring their calculators every time they came to school, but he conceded that this did not always happen. Furthermore, some of the learners did not have calculators. In these cases, he explained that he allowed the learners to share the calculators. He also indicated that learners should practice using calculators to master maths concepts.

Sharing of resources can create an opportunity for cooperative learning. However, Mr Lehlokwa did not see the opportunity. Despite using a calculator regularly in his classroom, he did not acknowledge that a calculator might affect his way of teaching. He commented:

> *Oh, oh I am not actually affected. Like, like using the calculator, I usually don't, don't, need it to change my way of teaching. When I teach, I do give the how part of doing, solving a problem. I know that the calculator will only come up with answers but not exactly showing how that answer came to be that answer.*

The above comment demonstrates that Mr Lehlokwa was using a simple scientific calculator cannot store data. However, as an experienced mathematics teacher he could have developed mathematics games that learners could play using calculators. The games could have contributed to learners' conceptual understanding of mathematics.

The above discussion indicates how Mr Lehlokwa approached his teaching in his classroom. His teaching was focused on drilling the learners to the correct answers and showing them how to do so. Procedures were the focus of his teaching at the expense of conceptual understanding. Learners made very little or no contribution at all to the lesson. From the analysis I posit that Mr Lehlokwa did not recognise the affordances of a calculator. This influenced his practices when using calculators in his class.

Mr Tsebo

During my observation Mr Tsebo introduced his lesson by mentioning a clear and articulate goal of his lesson:

> *This morning I want us to revisit the concepts sequences and series. When I was going through your books, I discovered that some of you were using formulae for arithmetic sequences in geometric sequences and vice versa. Also, some of you were using the formula for quadratic sequences in geometric sequences.*

The above view also indicated the mathematics skills that learners should have acquired because the lesson was addressing learners' misconceptions relating to arithmetic, quadratic and geometric sequences and series. Mr Tsebo then proceeded by projecting his lesson onto the screen for the learners to see and read. He then showed learners the relation between sequences and mathematical patterns. Mr Tsebo also showed the learners the different types of sequences and represented the mentioned sequences with formulae. After explaining these to the learners, he again explained the goal of the lesson again to the learners. Then he asked them to differentiate between a sequence and a series. By asking learners questions he was guiding them towards the achievement of the learning goal.

It was also interesting to observe Mr Tsebo's interaction with his learners in the classroom. Although he used whole class teaching, when asking oral questions, he asked volunteers to respond to his questions as well as whole class simultaneous response. Asking for volunteers discouraged shy learners from volunteering. Also, lazy learners might have been hiding behind learners who always contributed to the lesson. Figure 6.10 below bears testimony this fact. The two learners that showed enthusiasm were the ones who were volunteering to respond to Mr Tsebo's question. The other learner who looked like he was hiding behind his school bag never volunteered. Judging from the picture, this learner was doing other things. Thus, some of the learners were left out in the lesson. I think Mr Tsebo should have chosen learners who were not volunteering to respond.

Figure 6.10. Learners who volunteered to respond to Mr Tsebo's question and the other learner who did not volunteer

Mr Tsebo repeated and expanded on his learners' responses. In doing so he was trying to highlight ideas that the learner respondent had raised, help all learners to develop their understanding implicit in the ideas that had been raised, negotiate meaning with the learners, and add new ideas or move the discussion in another direction (Anthony & Walshaw, 2009). He also gave feedback to all his questions after learners responded. The feedback confirmed to the learners the appropriateness, or otherwise, of their responses.

No disruptions were experienced in Mr Tsebo's lesson. This indicated that optimal mathematics learning occurred in the learning environment. Optimal learning environments may result in an increase in the number of learners in mathematics classrooms.

Mr Tsebo also mentioned that the type of content he was to present informed his decision of which technology to use. However, his focus was on how he could present content in such a way that he would save time when presenting his lessons. The focus was hence more on him as a teacher than addressing learners' needs. The focus was not on the potential and opportunities offered by the technologies in the classroom, namely, to enhance learners' understanding of mathematics concepts (Pierce & Stacey, 2010). He explained:

… we are normally dealing with problem solving, so you may find that the time you are spending to copy the problem might affect the time you spend in order to copy the problem to solve them.

The above response indicated that Mr Tsebo's concern was to reduce his routine work. By projecting problems onto the screen, he did not have to copy them out. As long as learners were not his point of departure in the use of technology, using it was no better than not using it. He should have been using the tools for the learners' benefit, not his own. In his statement above, the technology helped him not to have to write on the chalkboard and gave him more time to on work problems for learners. The statement reveals an instructional practice that he followed in his classroom: his teaching seems to focus on pumping information into the learners' heads. The technology allowed him to achieve this objective because it reduced his routine work. The screen took the place of the chalkboard, and the laptop was his automated writing. This is usually a problem in instances where teachers are chasing the completion of the syllabus. There is pressure from the departmental officials to fulfil what is expected from teachers and to enable learners to regurgitate the information they were fed during the year.

Mr Tsebo could cover quite a substantial amount of work during that period. Learners also seemed to be in tune with what he was doing. They took out their calculators and used them without being directed by their teacher. The calculator usage was mainly for routine work, like calculating the sum of sequences. This was confirmed by Mr Tsebo when asked why learners were using the calculators during the lesson:

Eh I think it was part of working, somehow a calculator is essential for this type of a lesson because they (learners) need to make calculations of bigger values, so a calculator might be necessary.

From his response I could deduce that his learners knew when they were supposed to use the calculators without his guidance. The fact that he did not consider how the laptop represented concepts in a simpler and more meaningful way was a flaw.

Ms Makgona

Although Ms Makgona did not allow me to observe her, the interview data indicated that she used a learner-centred approach when using a calculator in her classroom. She indicated this when explaining how she used calculators with learners in the classroom.

> *Let's say where they (learners) must do some calculations, I let the learners do the calculations themselves and sometimes I let them do trial and error so that they discover. There after I show them how to use it (calculator).*

As indicated, this was self-reported data and thus the explanation was her perception of calculator usage in the classroom.

Ms Makgona acknowledged the advantage of using a calculator in mathematics. This was evident in her response to the item about the contribution of calculators in mathematics:

> *Always we use calculators, nowadays when you want the children to do some calculations, they use a calculator. They will always pick a calculator and do that, and it makes maths easier for them. They can draw graphs, they can do some complex calculations on them, it makes working with maths faster.*

She further mentioned that educational technology allowed easier access to information like downloading mathematics question papers for the learners, enabled easier calculation of numbers, and aroused learners' interest in mathematics. The use of a calculator made her feel motivated in her classroom. She explained:

> *A calculator makes me confident, confident in teaching the subject because if you just talk to the learners, they tend not to listen, but if they are hands on, and you engage them, then they participate, then they will concentrate and not do other things and do what you want them to do.*

Ms Makgona was using the word 'confidence' in relation to learners' behaviour in the classroom. Learners' full participation, engagement and concentration are what will result in her having confidence in learners. It is her responsibility as a teacher to develop these behaviours in the learners. The technology cannot do that for her.

However, she could not use the technology in such a way that it could assist her in developing these behaviours in the learners.

As indicated above, Ms Makgona's use of a computer did not directly benefit the learners. The computer was mainly used for downloading information (for example previous years' question papers) for the learners. However, for her to conduct a fair and valid assessment of her learners, she should base her assessment on her classroom practices. Thus, the computer was used to provide her with information that she would use to feed her learners in her classroom.

6.3.1.3 Discussion

Teachers viewed calculators and smartphones as tools that can engage learners with drill and practice activities. The laptops were used as presentation tools. All these activities are teacher-centred. This is consistent with findings from other studies which demonstrated that, when technology is used in the mathematics classroom, it is most often used to support teacher-centred teaching approaches (Eickelmann et al., 2017; Law, 2009; Tay et al., 2012). Pelgrum and Voogt (2009) indicated that this was more pronounced in countries with a low rate of technology use. South Africa is one of these countries with a low rate of technology use (Howie & Blignaut, 2009).

However, GTTP-ICT (DoE, 2007) and the e-education policy (DoE, 2004) stipulated that by 2013 teachers should be able to use educational technology to develop learners' critical thinking, informed decision making, higher order thinking skills and collaborative and experiential learning. These competences can be developed if teachers use the technology to support learner-centred strategies (Keengwe & Onchwari, 2011; Sang et al., 2010). However, teachers in the two investigated schools were not aware of these policies. Thus, it can be posited that the GTTP-ICT and e-education policies are far from being realised in these schools.

The above discussions on the classroom practices of the four teacher participants showed that they are oriented towards a transmissive classroom practice. This is consistent with the study by Stoilescu (2015) which found that teachers TPACK contributed to how they used technology in their classrooms. Teachers with a high

TPACK were able to redesign their pedagogical practices and used the technology for learner-centred pedagogy to support the learners.

6.3.2 What Learners Do with Technology in Mathematics

Here the focus was on learners' experiences in the use of technology, which the first part of the questionnaire focused on. Also, the interview protocol for the focus group interview had some questions on learners' experiences on the use of technology (see appendix H). I will present the questionnaire data first followed by the focus group interview data. As indicated in 5.5.2, the questionnaire had three sections – section A, B and C. Data presentation in this section came from section B. Section B had three parts. The first part asked participants' information about technology ownership, the second part focused on technology used in mathematics and an explanation of how the technology was used, and lastly participants were requested to rate their regular use of technology based on certain given activities. In this section I first present learners' technology ownership, followed by learners' use of technology and lastly learners' regular use of technology.

6.3.2.1 Learners' technology ownership

Learners can have experiences of using technological tools if they have access to these tools. One form of access to educational technology tools is through ownership. If learners own the technologies, they can use them at any time. Learner participants indicated that they owned different technological tools. Most of them owned a smartphone. The second most owned technology was a calculator; however, for this the ownership percentage was not overwhelming, as it was less than 60 percent. Other tablets (iPad) were owned by fewer than ten percent of participants. Although the schools were no-fee schools, technology ownership is misleading because most of the participants indicated that they owned different technological tools. Below follows table 6.1 which gives a percentage of learner participants' technology ownership of both schools A and B.

Table 6.1

Learner participants' technology ownership of Schools A and B combined

	Ownership		Non-ownership	
	Percentage	Frequency	Percentage	Frequency
Smartphone	81	64	19	15
Tablet	20.3	16	79.9	63
Other Tablet(iPad)	3.8	3	96.2	76
Laptop	24.1	19	75.9	60
Desk top Computer	31.6	25	68.5	54
Calculator	58	46	41.8	33

Tables 6.2 and 6.3 below show learners' technology ownership per school.

Table 6.2

Learner participants' technology ownership in school A

	Ownership		Non-ownership	
	Percentage	Frequency	Percentage	Frequency
Smartphone	93.1	40	6.9	3
Tablet	32.6	14	67.4	29
Other Tablet(iPad)	4.7	2	95.3	41
Laptop	37.2	10	62.8	33
Desk top Computer	46.5	20	53.5	23
Calculator	55.7	24	44.3	19

Table 6.3

Learner participant's technology ownership in school B

	Ownership		Non-Ownership	
	Percentage	Frequency	Percentage	Frequency
Smartphone	69.4	25	30.6	11
Tablet	5.6	2	94.4	34
Other Tablet	2.8	1	97.2	35
Laptop	8.3	3	91.7	33
Desktop Computer	11.1	4	88.9	32
Calculator	61.1	22	38.9	14

When comparing the two schools in terms of technology ownership, tables 6.2 and 6.3 show that learners in school A have a higher percentage of technology ownership than those in school B. Also, more learners in school A own different types of technologies. Though the school are classified under the same quantile it can be posited that the learners in school B come from a poorer community than those in school A.

6.3.2.2 Learners' use of technology

Learners may have access to some of the educational technologies they do not own. The school and the community can provide access to learners if they have the facilities. School A had laptops that were connected to the internet through Wi-Fi. On the other hand, school B had both desktop and laptop computers that were connected to the internet through Wi-Fi. Table 6.4 below displays learner participants' percentage of technology usage.

Table 6.4

Percentage of learner participants' use of technology in Schools A and B combined

Smartphone		Tablet		Other tablet(iPad)		Laptop		Computer		Calculator	
Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
70	88.6	21	26,6	4	5.1	26	32.9	34	43	51	64.6

Note. Freq = Frequency

A comparison of Tables 6.1 and 6.4 revealed that not all learners who own smartphones use them. Also, learners have access to other technologies they do not own. In table 6.1, 25 learners indicated that they owned a desktop computer. However, table 6.5 revealed that 34 learners were using a desktop computer. In exploring the relationship between technology ownership and technology use, a chi-square test was used. The test was done on smartphone ownership and smartphone use, and calculator ownership and calculator use. Smartphones and calculators were chosen because of an overwhelming percentage of use by learners. The critical value (p) for test of independence was set to 0.5. Tables 6. 5 and 6.6 give the null hypothesis rejected by the chi-square test of independence.

Table 6.5

The null hypothesis rejected by the chi square test of independence on smartphone ownership and smartphone use

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	32.265[a]	1	<,001		
Continuity Correction[b]	27.340	1	<,001		
Likelihood Ratio	25.004	1	<,001		
Fisher's Exact Test				<,001	<,001
Linear-by-Linear Association	31.856	1	<,001		
N of Valid Cases	79				

Table 6.6

The null hypothesis rejected by the chi square test of independence on calculator ownership and calculator use

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	19.688[a]	1	<,001		
Continuity Correction[b]	17.629	1	<,001		
Likelihood Ratio	20.227	1	<,001		
Fisher's Exact Test				<,001	<,001
Linear-by-Linear Association	19.439	1	<,001		
N of Valid Cases	79				

Tables 6.5 and 6.6 show that the p-value is less than the chosen significant level of α=.05, the null hypothesis was rejected and therefore smartphone ownership and calculator ownership have an influence on smartphone use and calculator use respectively. In this study this showed that there is a significant relationship between smartphone ownership and smartphone use as well as calculator ownership and calculator use.

Participants further indicated how they use the technologies. The responses were categorised into four types of technology usage: communication, learning, entertainment and other. Table 6.7 below shows the percentages of different types of technology usage responses.

Table 6.7

Learner participants' types of technology use outside the school in Schools A and B combined

	Smartphone		Tablet		Other tablet(iPad)		Laptop		Computer		Calculator		TV	
	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
Communi-cation	35	32.4	1	5	1	14.3	1	3.2	1	2.6	0	0	0	0
Learning	37	34.3	14	70	3	42.9	17	54.8	27	69.2	28	100	6	100
Entertain-ment	19	17.6	4	20	2	28.8	9	29	7	17.9	0	0	0	0
Other	17	15.7	1	5	1	14.3	4	12.9	4	10.3	0	0	0	0
Total	108	100	20	100	7	100	31	100	39		28	100	6	100

Note. Freq = Frequency; Perc = Percent

Comparing tables 6.4 and 6.7 there is some form of consistency. Smartphones, calculators, and computers had the most responses in table 6.7. Also, looking at Table 6.4, smartphones, calculators, and computers had the highest percentages in terms of usage. Computers and calculators were used mostly for learning. Learners also indicated the activities they were engaged in when using the smartphones and computers to learn. The activities included downloading previous question papers and memoranda, watching online mathematics lessons, researching difficult mathematics topics, and downloading mathematics application programs. All the mentioned activities required connectivity to the internet. Learners also mentioned the activities they were engaged in when using calculators. The activities involved among others solving mathematics problems, doing calculations, and drawing graphs. Learners further indicated that a calculator was mostly used in sequences and series, logarithmic and trigonometric functions, and statistics. All these concepts involved operating very large or very small numbers. Thus, they used the calculator to relieve themselves from mathematics routine work.

In the focus group interview, some of the participants indicated the types of technology used. Some of the participants commented as follows:

> *(School A) Tipa: I use a calculator to do calculations that involve solving mathematical problems and check if the answer that I have worked out is correct.*

> *(School B) Rapelo: I go to Google Chrome and download an app for mathematics. If there is any mathematics problem that I need to solve, the app will show me. Like PhotoMaths shows you exactly how to solve maths problems. It guides you step by step.*

These views showed that participants had confidence in using calculators and smartphones. They could use these tools to support their learning.

6.3.2.3 Learners' regular use of technology

Learners' use of technology is not confined to a specific space. Different spaces afford learners opportunities to use different tools. In this section the focus was on learners' use of technology within the two important spaces in which they find themselves. The two spaces that were focused on in this analysis were outside and within the school environment. These two spaces can either constrain or permit learners' use of educational technology. Irrespective of the space in which learners accessed technological tools, learners are also influenced by different tools when they are learning. Thus, it was important to understand the different activities that learners were engaged with when using educational technologies within these two spaces. The regularity rate that the learners preferred in performing these activities, indicated the impact the technology had on learning. Tables 6.8 and 6.9 indicate the percentages of regular use of technology to perform different activities within and outside the school premises respectively.

Table 6.8

Learner participants' regular use of technology within the school in schools A and B combined

Items	Never		Yearly		Monthly		Weekly		Daily	
	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
Talk and share ideas about maths	16	20.3	21	26.6	10	12.7	20	25.3	12	15.2
Make maths practical	9	11.4	12	15.2	16	20.3	28	35.4	14	17.7
Persist to solve difficult problems	12	15.2	15	19	18	22.8	25	31.6	9	11.4
Apply different approach to solve problems	11	13.9	16	20.3	15	19	18	22.8	19	24.1
Deep maths understanding	6	7.6	14	17.7	16	20.3	19	24.1	24	30.4
Improve technology skills and knowledge	6	7.6	10	12.7	11	13.9	32	40.5	20	25.3
Improve maths skills and knowledge	11	13.9	5	6.3	18	22.8	18	22.8	27	34.2

Note. Freq = Frequency; Perc = Percent

Table 6.8 shows that most of the learners use educational technologies more regularly for learning. In this study more regularly was considered in terms of weekly and daily use of technology. The table also shows only four items having a percentage above 50 on more regular use of technology in school. The four items are: "improve maths knowledge and skills," "improve technological knowledge and skills," "use technology for deep maths understanding" and "connect content to daily life." The percentages are 66, 57, 55 and 53 respectively.

Table 6.9

Learner participants' regular use of technology outside the school in schools A and B combined

Items (use of technologies outside the school)	Never		Yearly		Monthly		Weekly		Daily	
	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
Learn mathematics	12	15.2	12	15.2	17	21.5	22	27.8	16	20.3
Play games	13	16.5	17	21.5	17	21.5	13	16.5	19	24.1
Communicate with friends and family	3	3.8	7	8.9	12	15.2	18	22.8	39	49.4
Design and produce artefacts	40	50.6	14	17.7	5	6.3	10	12.7	10	12.7

Note. Freq = Frequency; Perc = Percent

Table 6.9 above shows an overwhelmingly high percentage of participants who used technology more regularly outside the school premises to communicate with friends and family and play games.

During the focus group interview some participants commented on the different places where they used the technology.

> *(School A) Pulane: Ok, at school we have laptops, but we don't have access to use them…and again we go to the community library for the computer and the Wi-Fi.*

> *(School B) Taola: I use my mother's smartphone at home because she allows me to use it there and at night it is quiet, I can learn without disturbance.*

These views emphasised the convenience of using the different tools outside the school environment. School A did not have library. However, the community of school A had a library. Therefore, learners in school A had access to the community library. It is posited that these participants were using smartphones to communicate. Participants were not prohibited from using smartphones outside the school premises. Moreover, nobody prescribed to them how they were to use their smartphones. They were also not monitored or supervised by parents or guardians during their use of smartphones. There was also an insignificant percentage of participants who used technology more frequently for learning outside the school premises.

Tables 6. 10 and 6. 11 below show learner participants' percentage of frequent use of technology within the school per school.

Table 6.10

Learner participants' regular use of technology within the school in school A

Items (use of technologies at school)	Never		Yearly		Monthly		Weekly		Daily	
	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
Talk and share ideas about maths	3	7	12	28	11	26	10	23	7	16
Make maths practical	1	2	7	16	12	28	14	33	9	21
Persist to solve difficult problems	3	7	10	23	8	19	11	26	11	26
Apply different approaches to solve problems	0	0	6	14	7	16	14	33	16	37
Deep maths understanding	2	5	4	9	7	16	10	23	20	47
Improve technology knowledge and skills	1	2	5	12	4	9	18	42	15	35
Improve maths knowledge and skills	10	23	4	9	7	16	11	26	11	26

Note. Freq = Frequency; Perc = Percent

Table 6.11

Learner participants' regular use of technology within the school in school B

Items (use of technologies at school)	Never		Yearly		Monthly		Weekly		Daily	
	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
Talk and share ideas about maths	9	25	10	28	6	17	8	22	3	8
Make maths practical	10	28	4	11	7	19	13	36	2	6
Persist in solving maths problems	7	19	6	17	4	11	14	39	5	14
Apply different approaches to solve problems	10	28	5	14	6	17	7	19	8	22
Deep maths understanding	7	19	7	19	8	22	5	14	9	25
Improve technology knowledge and skills	7	19	5	14	6	17	12	33	6	17
Improve maths knowledge and skills	10	28	1	3	7	19	11	31	7	19

Note. Freq = Frequency; Perc = Percent

The two tables show that school A has a higher percentage of regular use of technology on all items than school B. This is consistent with tables 6.2 and 6.3

Learners in school A were initially given access to the school's Wi-Fi login PIN. This could have contributed to learners' being able to access the school's Wi-Fi daily. However, the learners did not use the internet for their schoolwork. Thus, access to the internet was discontinued. Shibu (pseudonym) from school A focus group explained:

> *The school used to provide us with login details for the school Wi-Fi. It has stopped providing us with login details for the Wi-Fi. The school informed us that we use internet for wrong reasons like chatting on social media and downloading music and video.*

Thus, the school found it reasonable to stop providing learners access to Wi-Fi. There are other ways that they could have used to solve the problem. Developing a school policy on the use of technology and monitoring the implementation of the policy are some of the constructive approaches that could have helped the school to resolve the problem.

6.3.2.4 Discussion

The above analysis confirmed that learners' socio-economic context contributes to what learners do with technologies in mathematics learning. Most of the learners used smartphones and calculators. These tools are mostly used for computational purposes and relief from computational burdens (Lassak, 2015a). Learners used the tools for basic calculations when solving mathematics problems and checking the correctness of their calculations. These activities did not foster deep mathematics learning (Parrot & Leong, 2018). The mathematical competences demonstrated by the learners were problem solving competence and aid and tool competence (Niss & Jensen, 2002). Tools that support acquisition of deep mathematical conceptual knowledge include among others Dynamic Geometry System (DSG), Computer Algebra System (CAS), Cabri and Geometer's Sketchpad (Albaladejo, et al., 2015; Granberg & Olsson, 2015; Oldknow, 2009). These tools were never used in either school A or school B because they were not available.

Also, the learners' use of technology was consistent with their teachers' use of technology (Lai, 2015). Mr Lehlokwa and Ms Makgona from school B mentioned that they downloaded past years question papers from School B computers. Learners also mentioned that they use their smartphones to download previous years question papers. On the other hand, Mr Phetole from school A and Mr Tsebo from school B mentioned that they use the laptops for presenting mathematics lessons. Learners also mentioned that they watched online mathematics lessons on their smartphones. Thus, the technology was taking the place of their teachers.

6.4 Benefits of Using Technology in the Teaching and Learning of Mathematics

In this section the focus is on the benefits of technology for teaching and for learning. The benefits of technology for teaching involved how teachers perceived the value of technology in teaching. The benefits of technology for learning focused on how teachers and learners perceived the value of technology in learning. I first give an analysis of the benefits for technology for teaching, followed by an analysis of the benefits of technology for learning.

6.4.1 Benefits of Technology for Teaching

The teachers' questionnaire and the interview schedule were used to source information about the benefits of technology in mathematics teaching. I present the questionnaire data then the interview data.

Section C of the teachers' questionnaire under the Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Technological, Pedagogical and Content Knowledge (TPACK) of the TPACK components solicited information on the benefits of technology in teaching. The TCK component had one item which was "I use technology in my teaching to easily achieve the learning outcome." The TPK component had two items which were: "I use learner-centred strategies in teaching mathematics" and "I use the technologies that address the diverse needs of all learners in mathematics." The TPACK component had three items which were: "I use technology to adjust instructional strategies," "I evaluate and reflect on the effective use of technology to enhance to enhance mathematics teaching" and I take advantage of the new and emerging technologies to improve on my teaching practices in mathematics."

Mr Phetole

Mr Phetole agreed with the item in the TCK component, which implied that he felt technology was assisting him in teaching. He also agreed with one item in the TPK components: "I use technologies to support learner-centred strategies." However, he neither agreed nor disagreed with the other item in the TPK component. Mr Phetole agreed with all the items in the TPACK component.

When responding during the interview to questions about the benefits of technology in teaching, Mr Phetole explained as follows:

> *The benefits are that you teach easy since there is a machine that will be doing most of the work for you. You just explain. In some videos, they explain themselves, you just do a lesson without saying much and the learners will be understanding and learning from it.*

The response above showed that Mr Phetole viewed the technological tool as having the ability to replace him for some time in a lesson. This left him with a minimal facilitation role. From his response I can posit that the technology had designed the learners' task for him. Also, he did not provide time for learners to pose questions while watching the videos, as the videos were doing the teaching. These activities equipped learners with basic computer skills and basic mathematics knowledge.

Subsequently, when asked what motivates him to use technology in his classroom, he responded in this way:

> *Eh, it (technology) makes lesson planning and teaching easier. We are moving from the old way of using the chalkboard to write all day and learners copying from the chalkboard. So, through ICT you can do the lesson on a computer in an easy way, so it is helping in this way.*

This response showed that his conception of easy planning and teaching had little to do with being effective and efficient in his classroom. Nor did he explore a variety of technologies that could assist him in presenting different mathematics concepts. He pointed out that:

> *We are not using them (technologies like Geogebra, smart boards and headphones) because of lack of resources. Educational technologies would have contributed to our classroom teaching if we were using them. But now it is just a little bit.*

He could only use laptops, calculators and smartphones with learners in the classroom. Although he mentioned lack of resources, Geogebra is a free software. When I probed further about free software his response was:

> *We are not allowed to install new programs on those donated laptops.*

The above response illustrated the limited support offered by the school in terms of technology use in teaching. Thus, this behaviour did not help the school to benefit from the use of technology. Despite Mr Phetole's agreeing with almost all items on benefits of technology in mathematics in the questionnaire, his interview data gave a different picture. The interview data showed that the technology was beneficial in teaching when it automated his teaching tasks.

Mr Lehlokwa

Mr Lehlokwa strongly disagreed with the item in the TCK component. This implied that the technology was not assisting him in teaching. He also neither agreed nor disagreed with the two TPK component items. In the TPACK component Mr Lehlokwa disagreed with two items and neither agreed nor disagree with one item. The two items he disagreed with were: “I use technology to adjust instructional strategies” and “I evaluate and reflect on the effective use of technology to enhance mathematics teaching.” The item he neither agreed nor disagreed with was: “I take advantage of the new and emerging technologies to improve on my teaching practices in mathematics.”

In responding during the interview Mr Lehlokwa described the benefits of technology in his teaching in this way:

> *Well at times it happened that we had some lessons from a certain company, but now they are no more working. It (software program) was working well because we were presenting the lessons through the data projector, however it has been stopped, the number has been stopped, I don’t know what happened … What we were actually doing … somewhere there will be people who are presenting, and I will be talking to the learners, explaining to the learners, about what is being presented. Well somewhere they will be showing calculations and I will keep on explaining and give them the answers and/or examples.*

From his description I got the sense that he saw those software programs as tools that would do the teaching on his behalf. The programs had mathematics concepts; thus, all he had to do was to project the lesson to the learners.

Mr Lehlokwa also seemed to believe that the use of technology in the classroom would always assist the teacher to present the concepts better. He expressed this view in this way:

> *Well, it actually shows that what the teacher is teaching is also in the lesson and it strengthen what the teacher is doing.*

I then probed to find out how the technology strengthened what the teacher was doing, and he responded in this way:

> *Like if they see it (mathematics concepts) in the data projector and when you tell them that they match, they are able to have trust in the teacher and say that the teacher is teaching us the truth.*

The above explanation demonstrated that Mr Lehlokwa's view does not consider how the technology was used in the lesson. Projecting mathematics concepts over the data projector does not assist in enhancing the teaching process. The interview data confirmed his questionnaire response about his perception of the benefits of technology in mathematics teaching.

Mr Tsebo

Mr Tsebo strongly agreed with all the items in the TCK component. This implied that the technology was assisting him in teaching. He further agreed with one out two items of the TPK component. He agreed with the item: "I use technology to support learner-centred strategies" and neither agreed nor disagreed with the other item which was: "I use technology to address the diverse needs of learners."

When responding to the interview Mr Tsebo described the benefits of technology in teaching in this way:

> *I think most of the things is about time saving and how the mathematics equations can be used to develop graphs.*

From his comment it appeared that the technology helped him to reduce the administrative and routine tasks involved in mathematics teaching. He also referred to the administrative and routines tasks that are reduced in his teaching. These included copying problems onto the chalkboard, waiting for learners to open their textbooks, and moving around the classroom to check if ever learners had opened the correct pages. The second part of the sentence indicated that the technology assisted him in representing mathematics concepts.

He further indicated that the technology assisted him in presenting diagrams that are up to scale and accurate, compared to free hand drawn diagrams. He expressed this view as follows:

……another way when drawing graphs at least they become better and easier for them(learners) to see the shape of the graph when using the tool.

He also indicated that all the above-mentioned activities had contributed towards improvement in his teaching. However as indicated above, he neither agreed nor disagreed with the item; “I evaluate and reflect on the effective use of technology to enhance mathematics teaching.” This was an inconsistence.

Ms Makgona

Ms Makgona disagreed with the item in the TCK component. This implied that the technology was not assisting her in teaching. She also disagreed with the two TPK component items.

When responding to the interview questions, Ms Makgona described the benefits of technology in her teaching as follows:

It makes me excited in teaching the subject because I can do more complex calculations with the learners.

Ms Makgona’s response to the questionnaire indicated that she did not see the technology as benefiting her teaching. However, the interview data gave contrasting information.

6.4.1.1 Discussion

All the teachers saw the technology as benefiting them in their teaching. Messrs Phetole and Lehlokwa saw the technology as replacing them in their teaching and hence making it easier. This demonstrated that both Messrs Phetole and Lehlokwa saw the technology as an educational add-on to their teaching. Thus, they have not yet used technology effectively in their classrooms.

Both Mr Tsebo and Ms Makgona saw the technology as assisting them in performing the administrative tasks in teaching. Mr Tsebo further indicated that the technology helped him to represent concepts better to the learners, and this had improved his teaching. Using the technology to relieve teachers from administrative is beneficial, as teachers have more time to focus on the other aspects of teaching. However, this should be done in conjunction with technology use in the classroom where both teachers and learners use the tools. This demonstrated that Mr Tsebo and Ms Makgona are “teaching with the technology” (DoE, 2004). Thus, they have not used technology effectively in their classrooms.

The above discussion is consistent with Howie and Blignaut (2009) and Law and Chow (2008). These studies showed that South African teachers have not yet integrated technology into the teaching of mathematics.

6.4.2 Benefits of Technology for Learning

In this section I first present the analysis of teachers’ perceptions of the value of educational technology in learning, followed by learners’ perceptions of the same. The teachers’ questionnaire and the interview schedule were used to source information about the benefits of technology in mathematics learning. I present the questionnaire data, followed by the interview data.

6.4.2.1 Teachers’ perceptions

Section C of the teachers’ questionnaire under the Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) of the TPACK components solicited information on the benefits of technology in teaching. The TCK component had one item which was: “I use technologies to enhance learners’ understanding of mathematics.” The TPK component also had one item which was: “I use technologies to motivate learners.”

Mr Phetole

Mr Phetole neither agreed nor disagreed with the item in the TCK component, which implied that he felt the technology was not assisting his learners in their learning. Mr Phetole agreed with the item in the TPK component.

When responding during the interview, Mr Phetole indicated that learners get access to use the laptops. If learners get access to use the laptops, the laptops help them to learn. This is how he explained it:

> *We do have lessons whereby learners will be using laptops. It is just that they (laptops) are limited…and they will be sharing a laptop, so it is helping them because they can do a lesson using that laptop.*

He later mentioned that the technology made life easier for learners because calculators help learners to get answers more easily. His interview responses were consistent with the questionnaire responses.

Mr Lehlokwa

Mr Lehlokwa neither agreed nor disagreed with the item in the TCK component, which implied that he saw the technology as not assisting his learners in their learning. Mr Lehlokwa disagreed with the item in the TPK component.

When responding to the interview he indicated that most learners in school B were not given access to the computer room. This is how he explained the situation:

> *Learners are not given the opportunity to go in the cyberlab, … only those who are doing grade 12 are given a chance to search for information from the internet and apply for their studies for the following year.*

I probed further to find the kind of information learners were searching, but he did not know because he never assisted learners when they were in the computer laboratory. Both the questionnaire and the interview were consistent with Mr Lehlokwa's perception of the benefits of technology in mathematics learning.

Mr Tsebo

Mr Tsebo neither agreed nor disagreed with the item in the TCK component, which implied that he did not view the technology assisting his learners in their learning. Mr Tsebo neither agreed nor disagreed with the item in the TPK component.

When responding during the interview, Mr Tsebo indicated that learners are actively involved in the lesson when the technology is used. He expressed this view in this way:

> *Learners are normally engaging themselves in the lesson and … they are always hands on.*

He further indicated that the technology made mathematics concepts concrete for the learners. He expressed this view in this way:

Usually, learners learn much easier when they see and touch things, also in mathematics, being told how things are done eh, it is not easy. If you simply show them (learners) by entering a formula on the system and it work itself out they can see that sometimes things are possible.

The questionnaire response of Mr Tsebo was not consistent with his interview response. The questionnaire response indicated that he did not view the technology as assisting his learners. However, in the in the interview he indicated how his learners benefited from his use of technology in mathematics.

Ms Makgona

Ms Makgona disagreed with all the items in the TCK component, which implied that technology in her view was not assisting her learners in their learning. She also disagreed with all the items in the TPK component.

When responding to the interview questions Ms Makgona indicated that the technology assisted learners by relieving them of the routine calculation work and representing concepts. She expressed this view as follows:

When you want the learners to do some calculations, they use a calculator. It (calculator) makes maths easier for them (learners) because they can draw graphs and do some complex calculations, it makes working with maths faster.

The questionnaire response by Ms Makgona was not consistent with her interview response. The questionnaire response indicated that she did not view the technology as assisting her learners. However, in the in the interview she indicated how her learners benefited from her use of technology in mathematics.

6.4.2.2 Learners' perceptions

The learners' questionnaire and the interview schedule were used to source information about the benefits of technology in mathematics learning. I present the questionnaire data followed by the interview data.

Section C of the learners' questionnaire solicited information by means of four items on the benefits of technology in mathematics learning. Table 6.12 shows percentages in terms of learners' perceptions on the benefits of technology in mathematics learning.

Table 6. 12

Percentage of learner participants' perceptions on the benefits of technology in mathematics learning

Items	Strongly Disagree		Disagree		Not sure		Agree		Strongly Agree	
	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
Experience of enhanced maths learning	2	2.5	4	5.1	11	13.9	25	31.6	37	46.8
Boosting of maths confidence through technology usage	1	1.3	5	6.3	15	19	31	39.2	27	34.2
Checking maths procedures			10	12.1	17	21.5	25	31.6	27	34.2
Routine use of technology in maths			14	17.7	10	12.1	34	43	21	26.6
Ability to link maths ideas with the help of technology	3	3.8	8	10.1	14	17.7	33	41.8	21	26.6

Note. Freq = Frequency; Perc = Percent

Table 6.12 indicates that the item with the highest percentage of agreement by far is: "experience of enhanced maths learning." This implies that learners see the technology as being beneficial to them. The second highest percentage of agreement is: "boosting maths confidence through technology use." Their percentages are 84.4 and 73.4 respectively. The remaining items also show high percentages on agreement, but the percentages are not overwhelming. Thus, learners perceive technology in mathematics as benefiting their learning.

During the focus group interview participants confirmed the above data in this way:

> *(School A) Chego: You gain more knowledge, and you are exposed to more methods to use to solve different mathematics problems. You also get tips on how to approach some of the topics. There are more examples as compared to examples given in the textbook.*

(School B) Nsovo: In most instances I do not understand trigonometric functions when they are taught at school. When I have downloaded them (trig functions) on my cell phone I can practice and revise them more at home for better understanding.

When comparing teachers' and learners' perceptions on the benefits of technology in mathematics, learners showed that technology benefited them in their learning and that they were motivated to use the technology in their learning. However, teachers did not see the technology as benefiting the learners in mathematics learning. This could be because the teachers did not use the technology regularly in their teaching.

6.4.2.3 Discussion

The above discussion illustrated that, teachers perceived the laptops and the calculators beneficial to their teaching. However, they did not consider the pedagogical use of these tools. Hence the use of the laptops and calculators did not benefit the learners. This is consistent with Pierce and Stacey (2010). Pierce and Stacey (2010) study proposed a taxonomy of pedagogical opportunities created when a mathematics analysis software was used in the classroom. Teachers may be able to identify these created opportunities if they have a high developed TPACK level (Stoilescu, 2015).

6.5 Factors that Influence Learners' Use of Technology in Learning Mathematics

This section reports data on the factors affecting learners' use of technology in mathematics. Data in this section was sourced using the learners' questionnaire and the interview schedule for the focus group. I will start by presenting the questionnaire data followed by the interview data.

6.5.1 Learners' Competence in the Use of Technology

Technological competence was part of section C of the learners' questionnaire. The technological competence section had three questions. The questions involved participants rating themselves on their technological skills, commitment to technology usage and the ability to solve their technical problems using a Likert scale. Table 6.13 indicates learner participants' technological competence.

Table 6.13

Learner participants' technological competence in schools A and B combined

Item	Strongly Disagree		Disagree		Not Sure		Agree		Strongly Agree	
	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
I am good at using technology	2	2.5	5	6.3	12	15.2	38	48.1	22	27.8
I am committed to using technology	5	6.3	14	17.7	9	11.4	37	48.6	14	17.7
I solve technical problems myself when using technology	4	5.1	17	21.5	25	31.6	21	26.6	12	15.2

Note. Freq = Frequency; Perc = Percentage

From Table 6.13 it is evident that, out of 79 learner participants 60 rated themselves highly on technological skills, 51 highly on commitment to technology usage, and 33 highly on the ability to solve technical problems. This indicated that most learner participants have confidence in their technological skills. As indicated in 6.3, the most owned technology devices were the smartphone and the calculator. Tables 6.14 and 6.15 show learners' competence in terms of smartphone and calculator ownership respectively.

Table 6.14

Learner participants' technological competence according to smartphone ownership in schools A and B combined

Item		Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
I am good at using technology	Smartphone owned	1	3	9	31	20
	Smartphone not owned	1	2	3	7	2
I am committed to technology usage	Smartphone owned	2	1	5	39	17
	Smartphone not owned	0	3	3	4	5
I solve technical problems myself when using technology	Smartphone owned	3	12	7	30	12
	Smartphone not owned	2	2	2	7	2

Table 6.15

Learner participants' technological competence according to calculator ownership in schools A and B combined

Item		Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
I am good at using technology	Calculator owned	2	4	7	20	13
	Calculator not owned	0	1	5	18	9
I am committed to technology usage	Calculator owned	1	4	4	24	13
	Calculator not owned	1	0	4	19	9
I solve technical problems myself when using technology	Calculator owned	2	7	7	22	8
	Calculator not owned	3	7	2	5	16

From table 6.14, out of 64 participants who owned smartphones, 51 rated themselves highly on technological skills, 56 on commitment to technology use and 52 on the ability to solve technical problems. These results are consistent with table 6.13 which shows learner participants' technological competence. However, out of 15 participants who did not own smartphones, nine participants rated themselves high on all items on technological competence. As the items on technological competence were not specified for a specific technology, participants who do not own smartphones could have skills in using other technological tools or having access to smartphones even though they do not own one.

When looking at table 6.15, out of 46 participants who owned calculators, 33 rated themselves highly on technological skills, 37 on commitment to technology use and 30 on the ability to solve technical problems. Table 6.15 is also consistent with table 6.13 which shows learner participants' technological competence. However out of 33 participants who did not own calculators 27 rated themselves highly on technological skills, 28 on commitment to technology use and 21 on the ability to solve technical problems. Participants who do not own calculators could have skills in using other technological tools or having access to calculators even though they do not own one.

When comparing table 6.14 and 6.15, the item: "I am committed to technology usage," had the highest rating for both tables. The assumption was that learners acknowledged the importance of the calculator and the smartphone to learn mathematics, and they did not have challenges to use them to learn.

6.5.2 Teachers' Influence on Learners' Use of Technology

Learners spend most of their day with their teachers who become their role models. Learners' learning practices are likely to be influenced by their teachers' teaching practices. Learners look up to their teachers to help them succeed in their studies. The way their teachers use educational tools in school is likely to influence learners' use of educational technologies.

In both schools, learners were not allowed to bring their smartphones to school. However, Mr Phetole recognised the need for learners to access the mathematics textbook, so he allowed his learners to use their smartphones in his mathematics class. However, owing to lack of resources, he had no way of monitoring learners' use of smartphones, so he did not incorporate smartphone use effectively into his lesson. It is difficult for learners to use a smartphone appropriately if they have not been exposed to the different uses of the smartphone in their classroom.

In school B, Mr Tsebo used educational technology to cover large amounts of mathematics concepts rather than encouraging or guiding learners in the classroom on how to use educational technology tools. Also, as indicated above, learners did not use the laptop in his classroom as the laptop was used mainly to share mathematics concepts. However, learners used calculators without being instructed to do so.

In both schools there were no guideline on how technology could be used to enhance the teaching and learning environment. On the other hand, learners see their relatives using smartphones for other purposes not related to teaching and learning. This is confirmed by Table 6.8. The table reveals an insignificant difference in responses to smartphone usage between the learning type and the communication type. The responses are 37 and 35 respectively.

Learners also indicated during the focus group that they are influenced by their teachers in their use of technology in learning. Comments by two learners are provided here:

> *(School B) Moshikara: I was not aware about e-school. We were informed about it by our physical science teacher, Mr Hlompho (pseudonym).*

> *(School A) Tebello: Mr Tau (pseudonym) at learning centre X usually invites us to the computer centre to watch mindset video.*

It is evident from the above views that motivation and encouragement by word of mouth contributed to influencing learners' use of technology.

6.5.3 Discussion

As described above, learner-centred teaching and learning strategies are essential for effective use of technology. Learners' effective use of technology requires an understanding factors which influence their use of technology. The above discussion demonstrated that most learners owned a smartphone and a calculator. Learners did not rely on their respective schools to have access to these gadgets. The school socio-economic status limited them from accessing laptops, computers, and Wi-Fi. This is consistence with Kim and Park (2018) study which demonstrated that learners' ability to use technology for learning determine their persistent to its use. Ainley (2018) further indicated that learners' experience in the use of technology also contributes to their competence to its use.

Most learners used their smartphones for the internet. This demonstrated that connectedness helped them to gain more information on mathematics concepts. The online resources offered learners the opportunity to create more networks. This showed that learners' use of technology was consistence with their teachers' use of the technology. This is consistent with Lai (2015) study which found that teachers' encouragement and guidance also contributed to learners' persistence in using technology in learning.

6.6 Chapter Summary

This chapter presented and analysed the data for this study. Based on the results from the analysis I found that technology access had an influence on what teachers and learners do with technology in mathematics. Teachers regarded the benefit of technology being greater for them than for the learners. This also influenced what the teachers did with technology in the classroom. Teachers' use of technology also influenced learners' use of technology.

Chapter 7

Summary, Conclusions and Recommendations

7.1 Introduction

The previous chapter presented the findings and discussions of the study. This chapter concludes the thesis by presenting a summary of the key findings. The chapter also addresses the significance of the study and contribution to the body of knowledge as well as implications for practice. Finally, the chapter outlines some recommendations for further research, and the limitations of the study.

7.2 Summary

The aim of my study was to investigate the influence of teachers' pedagogical practices and competence in mathematics on the use of educational technologies in their classrooms. The study further established the factors that influence learners' use of educational technology in mathematics learning based on the schools' informal social processes and socio-economic status. A mixed methods approach was used to investigate two schools in Mopani District of Limpopo province in South Africa. The study sought to answer two overarching questions:

How do teachers' pedagogical practices and mathematics competence influence their use of educational technology in mathematics teaching and learning?

and

What factors influence learners' use of educational technology in learning mathematics?

To answer the above questions, the following sub-questions were pursued:

1. What do teachers and learners do with educational technology in mathematics instructions?
2. What benefits do teachers and learners appreciate in using educational technology in mathematics?

3. What are teachers' and learners' attitudes towards the use of educational technology in mathematics
4. How does the use of educational technology affect teachers' pedagogy?

Mr Phetole demonstrated a basic competence in the use of laptops in mathematics. This was illustrated by how he used the laptops for mathematics teaching. As indicated in 6.3.1.1 the laptops were used as instructional tools. There were instances in the lesson that created opportunities for Mr Phetole to use the laptops as tutors (Taylor, 2003). However, he did not seize the opportunities. This demonstrated that his pedagogical competence was limited. Mr Phetole also demonstrated a profound mathematics concepts competence. However, this competence did not influence his use of laptops in the classroom. Furthermore, Mr Phetole did not use the laptops regularly in his lessons.

Mr Lehlokwa indicated his views on the use of a calculator in his classroom demonstrating a basic knowledge of calculator use. This was illustrated by his explanation of how he saw the use of a calculator in the classroom. He emphasised the routine use of a calculator in mathematics classrooms. Mr Lehlokwa had access to the school's computers and laptops and used these tools for his teaching-related, administrative tasks, but he chose not to use them in his classroom. This indicated that Mr Lehlokwa lacked confidence in the use of laptops or computers in the classroom. This implied that he had limited pedagogical competence in the use of calculators, laptops and computers in mathematics teaching.

Mr Tsebo also demonstrated a basic competence level in the use of a laptop in mathematics. He used a laptop to project maths concepts for the learners, but he did not seize the opportunity created by the laptop to develop collaborative activities among the learners. This indicated Mr Tsebo's limitations in terms of his pedagogical competence. Mr Tsebo also demonstrated a profound mathematics concepts competence. However, this competence did not influence his use of laptops in the classroom.

Ms Makgona described her views of the use of a calculator in her classroom, which demonstrated a profound knowledge of the use of a calculator in mathematics. She indicated that the calculator was used to strengthen learners' mathematics conceptual knowledge. Ms Makgona had access to the school's computers and laptops, and she used these tools for doing her teaching-related administrative tasks, but she chose not to use them her classroom. This indicated that Ms Makgona lacked confidence in the use of laptops or computers in the classroom, implying that she had limited pedagogical competence in the use of laptops and computers in mathematics teaching.

The school social's structure also contributed to the use calculators, laptops and computer in the two schools. In school B teachers worked as team. This helped teachers to learn from one another about using laptops and computers to perform their administrative teaching tasks. The school also exerted pressure on teachers to use these tools for that purpose. Thus, all the mathematics teachers used either laptops or computers to perform their administrative teaching tasks. However, in school A there was no teamwork, and the school did not exert pressure on teachers to use laptops or computers. Hence, Mr Phetole carried out the teaching administrative tasks for some of the teachers in his school.

Overall, the teachers demonstrated a teacher-centred classroom practice. The interaction between the teacher and the learners was one-directional. The teacher asked questions and learners responded to the teachers' questions. Collaborative opportunities did emerge during the lessons, but the teachers were not able to exploit these opportunities. The school socio-economic status and teachers' support or lack of it contributed to how often laptops were used in teaching. Mr Tsebo occasionally used a laptop while Mr Phetole rarely used one in his classroom.

Learners' technological skills were shown to be important in their use of educational technologies for learning. Technological skills were dependent on learners' access to various educational technologies. In both schools most learners had access to smartphones and scientific calculators. In school A, 39 learner participants out of 43 had access to smartphones, and in school B, 29 participants out of 36 had access to smartphones. In terms of participants' access to calculators, school A had 30 participants with access to calculators, while school B had 21. Thus, more learners had access to smartphones than calculators. Learners' socio-economic context contributed to how they used the technological resources in mathematics learning. Most learners used smartphones and calculators. Thus, they were used for purposes of computation and relief from computational burdens. This was consistent with how their teachers used the laptops in their classroom. The laptops were used for low level teaching, and the learners used smartphones and calculators for low level learning.

Mr Lehlokwa had a negative perception on the benefits of calculators in mathematics teaching and learning, while Ms Makgona had a positive perception of the same. Mr Phetole's and Mr Tsebo's use of laptops in their classroom benefited them as teachers, but learners did not benefit from the use of the laptops in the classroom. However, learners mentioned that they benefited from using smartphones, computers, and laptops in their learning. The benefits mentioned were access to online resources and flexible study time. This also indicated low level learning.

The contributing factors that influenced learners' use of technology were found to be, the type of technology used, proficiency in using the technology and their teachers' use of technology contributed to the learners use of technology in mathematics.

7.3 Implication for Practice

The study has implications for the practice of mathematics teachers in secondary schools. It is envisaged that the results of the study may help offer evidence-based recommendations for enhancing the use of educational technology in school contexts that are similar to those of the investigated schools. The finding pointed to a low level of technology usage in both schools. Thus, the following recommendations are made with the hope of fostering meaningful technology integration.

Professional development of teachers in how to use educational technologies is key to fostering technology integration. Such a programme should focus on the pedagogical use of technologies and be conducted in the schools where teachers work. It should include modelling activities that will constitute vicarious learning. This will help teachers to see how others are using technologies based on their context.

In the case of the schools studied, an online programme would be ideal, as the two schools are from low socio-economic communities and thus cannot afford the services of consultants. Both schools have access to Wi-Fi; thus, connectivity is not a challenge. There are nonprofit organisations offering these services at little or no cost. Thus, creating partnerships with these organisations would benefit the schools.

However, schools need to develop some guidelines that will exert pressure on teachers to use these tools in their classroom. As indicated, in school B the school management team did not accept hand-completed mark sheets, schedules or learners' progress reports. Hence, all of the teachers in school B submit computerised assessment records to their SMTs.

In addition to teachers' professional development, there are also some recommendations for further study. In this study the focus was on low socio-economic schools. The schools were found in the same district. It would be interesting to see what the findings would reveal if the study could be extended to other low socio-economic schools in a different district and see whether the recommendations made for this study would be feasible. Also, the two schools had differing support structures within their schools Thus it would be interesting to explore roles played by a school's support structures in technology integration.

7.4 Limitation of the Study

The fact that I am not a staff member of either of the two schools where I conducted the study is a limitation as I experienced cooperation problems, especially given that interviews were conducted after school hours. Self-completed questionnaires raise concerns about the clarity of the questions. In ensuring clarity of the questions, both the teachers' and the learners' questionnaires were pretested before they were administered to the respondents. Also, one of the shortcomings of using a questionnaire was that I did not get all the questionnaires back, especially the ones distributed to learners. All the learners who did not return their questionnaires were hence withdrawn from the study.

In this study I used a mixed methods approach. I merged the two data sets during the analysis, discussion, and interpretation phase to avoid the divergent of data sets.

The fact that the study focused on mathematics classrooms in the two schools cannot be generalized beyond these classrooms. Thus, the findings may not apply to either teachers or learners of different subjects and grades. They may also not apply to either teachers or learners of mathematics at different schools. However, teachers and learners with similar contexts to those in my study may benefit from my study findings if they put them into practice.

In both schools, learners used smartphones and calculators for mathematics learning and teachers used laptops. Thus, the findings are limited to teachers' laptop usage and learners' smartphone and calculator usage.

7.5 Chapter Summary

This chapter concluded the investigation into the influence of teachers' pedagogical practices and competence in mathematics on their use of educational technology in the classroom and the factors that influence learners' use of educational technology in mathematics learning. The findings in this study paint a bleak picture for schools in a low socio-economic context. Relying on government to assist in accelerating integration of technology in teaching and learning will result in a more pronounced digital divide. The affected communities should take it upon themselves to come up with mechanisms that will assist them.

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Appendices

Appendix A: Consent Letters

Appendix A 1 Teachers' consent letter

Dear sir/madam

My name is Moila Mathomo Meriam and I am a PhD student in the School of Education at the University of the Witwatersrand.

I am doing a research on the use of Information and Communication Technology (ICT) in mathematics teaching and learning. My focus is on attitudes, behavior and practices of both teachers and learners in their use of ICT in mathematics teaching and learning.

My research involves giving you a questionnaire at your school which you will complete at your own time. I will come back to collect it within three days. The questionnaire requires 15 minutes of your time. I will also interview each one of you individually in a secluded room for about 30 minutes outside the normal schooling hours starting from 14h45 to 16h00. I will also use a tape recorder to record your responses as this will save time for writing responses and will also help me in recording the exact spoken words, verbal inflections, interjections, giggles and long silence. I will also come and observe you during a mathematics lesson for only one lesson. The duration of the observation is dependent on the duration of the mathematics period. I will use a video recorder during the observation to assist me in capturing some of the moments that I am likely to mis during my observation and to capture movements and facial expressions. I will also analyze your mathematics file.

The reason I chose your school is due to the stocked computer laboratory your school has. You are also using computers for mathematics teaching and learning. I want to understand how and why you are using these tools in mathematics and the benefits they provide in mathematics teaching and learning.

I was wondering whether you would mind if I invite you to take part in the research. I need your help with observation, interview questionnaire, audiotaping, videotaping and document analysis of the research.

Your name and identity will always be kept confidential and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed between 3 – 5 years after completion of the project. You will not be advantaged or disadvantaged in any way. Your participation is voluntary, so you can withdraw your permission at any time during this project without penalty. There are no foreseeable risks in participating and you will not be paid for this study.

Please let me know if you require further information. Thank you vey much for your help

Yours sincerely

Moila MM

Email Mathoo1@yahoo.com

Cel 0836674856

Appendix A 2 Learners' consent letter

Dear learner

My name is Moila Mathomo Meriam and I am a PhD student in the School of Education at the University of the Witwatersrand.

I am doing a research on the use of Information and Communication Technology (ICT) in mathematics teaching and learning. My focus is on attitudes, behavior and practices of both teachers and learners in their use of ICT in mathematics teaching and learning.

My investigation involves giving you a questionnaire at your school which you will complete at your own time. I will come back to collect it within three days. The questionnaire requires 15 minutes of your time. I will also interview you for about 30 minutes outside the normal schooling hours starting from 14h45 to 16h00.I will interview in groups of fives in a secluded room. I will also use a tape recorder to record your responses as this will save time for writing responses and will also help me in recording the exact spoken words, verbal inflections, interjections, giggles and long silence. I will also come and observe you during a mathematics lesson for only one lesson. The duration of the observation is dependent on the duration of the mathematics period. I will use a video recorder during the observation to assist me in capturing some of the moments that I am likely to mis during my observation and to capture movements and facial expressions. I will also analyze your mathematics file.

I was wondering whether you would mind if I invite you to take part in the research. I need your help with observation, interview questionnaire, audiotaping, videotaping and document analysis of the research.

I will not be using your own name, but I will make one up so none can identify you. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely and destroyed between 3 – 5 years after I have completed my project.

Your parents have been given an information sheet and consent form, but at the end of the day it is your decision to join us in the study.

I look forward to working with you. Please feel free to contact me if you have any questions.

Thank you

Moila MM

Email Mathoo1@yahoo.com

Cel 0836674856

Appendix A 3 Parents' consent letter

Dear parent

My name is Moila Mathomo Meriam and I am a PhD student in the School of Education at the University of the Witwatersrand.

I am doing a research on the use of Information and Communication Technology (ICT) in mathematics teaching and learning. My focus is on attitudes, behavior and practices of both teachers and learners in their use of ICT in mathematics teaching and learning.

My research involves giving your child a questionnaire at their school which you will complete at your own time. I will come back to collect it within three days. The questionnaire requires 15 minutes of their time. I will also interview them in groups of fives in a secluded room for about 30 minutes. I will also use a tape recorder to record their responses as this will save time for writing responses and will also help me in recording the exact spoken words, verbal inflections, interjections, giggles and long silence. I will also come and observe them during a mathematics lesson for only one lesson. The duration of the observation is dependent on the duration of the mathematics period. I will use a video recorder during the observation to assist me in capturing some of the moments that I am likely to mis during my observation and to capture movements and facial expressions.

The reason I chose your child's school is because they are doing mathematics as one of their subjects and are in grades 10.11 or 12. Grade 10, 11, and 12 mathematics learners are the focus of this study. Also, their school is using computers for mathematics teaching and learning. I was wondering whether you would mind if I invite your child to take part in the research. I need their help with observation, interview, questionnaire, audiotaping and videotaping of the research.

Your child will not be advantaged or disadvantaged in any way. S/He will be reassured that s/he can withdraw her/his permission at any time during this project without penalty. There are no foreseeable risks in participating and your child will not be paid for this study.

Your child's name and identity will always be kept confidential and in all academic writing about the study. His/ Her individual privacy will be maintained in all published and written data from the study.

All research data will be destroyed between 3 – 5 years after completion of the project. Please let me know if you require any further information. Thank you very much for your help.

Yours sincerely,

Moila MM

Email Mathomo1@yahoo.com

Cel. 0836674856

Appendix B: Ethical clearance certificate

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa. Tel: +27 11
717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

19 February 2016

Student Number: 772413

Protocol Number:

2015ECE026D

Dear Mathomo

Moila

Application for ethics clearance: Doctor of Philosophy

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate, has considered your application for ethics clearance for your proposal entitled:

Attitudes, behaviours and practices on the use of educational technology in Matheatics teaching and learning

The committee recently met and I am pleased to inform you that **clearance was granted**.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

Wits School of Education

011 717-3416

Appendix C: Permission letter from department of education in Limpopo Province

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

Ref: 2/5/6/1 Enq: MC Makola PhD Tel No: 015 290 9448 E-mail:MakolaMC@edu.limpopo.gov.za

Moila M M
Box 7341
TZANEEN MALL
0855

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal: **"ATTITUDES, BEHAVIOUR AND PRACTICES IN THE USE OF ICT IN MATHEMATICS TEACHING AND LEARNING."**
3. The following conditions should be considered:

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

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

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

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

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

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

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

Request for permission to Conduct Research: Moila MM

CONFIDENTIAL

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

Best wishes.

29/02/16

MUTHEIWANA NB
HEAD OF DEPARTMENT (ACTING)

DATE

Request for permission to Conduct Research: Moila MM

CONFIDENTIAL

Appendix D: Learners' interview schedule

Learners' Interview schedule

1. Where do you mostly use ICT tools?
2. Why do you use these tools at the indicated places?
3. What do you use ICT tools for?
4. Which ICT tools do you generally use for learning?
5. How do you use ICT tools in your learning?
6. Which ICT tools do you enjoy most and why?
7. In which content area of mathematics do you normally use your most enjoyable ICT tool and why?
8. Which ICT tools do you enjoy least and why?
9. In which content area of mathematics do you normally use your least enjoyable ICT tool and why?
10. Are you being helped in the use of ICT?
11. Do ICT tools make you work differently?
12. Explain how the use of ICT has affected your role as a learner in mathematics learning.
13. Who influence your decision to use ICT tools?
14. What are the benefits of using ICT in mathematics learning?
15. What challenges do you face when using ICT in mathematics?
16. How do you address these challenges?
17. How does the school support you in the use ICT in your learning?
18. What motivate you to do mathematics?

Appendix E: Teachers' interview schedule

Teachers Interview schedule

1. What do you know about the White paper on e – learning?
2. Is there a policy on the use of ICT in your school?
3. Who were involved developing the ICT policy?
4. What guided the decision to develop the school ICT policy?
5. Is there a relation between your school's ICT policy and the white paper on e-learning? Explain?
6. How is implementation of ICT policy monitored?
7. What is your favourite ICT tool?
8. How long have you been using this tool?
9. Briefly describe your initial experience of using this tool in Maths teaching and learning.
10. Has your initial experience affected the way you use ITCs now?
11. How has your favourite ICT tool contributed to learners' learning?
12. How has your favourite ICT tool contributed to maths classroom teaching?
13. What motivates you to use ICT tools in mathematics?
14. In which mathematics content areas do you use ICT tools?
15. How do you plan a lesson where in you are going to use ICT tools?
16. Which other ICT tool do you use in teaching mathematics?
17. How are these tools used in your mathematics lesson?
18. What percentage of your lesson are the mentioned tools used?
19. What guides your decision to use a particular ICT tool in your teaching?
20. How does the use of ICT in Mathematics affect your teaching role?
21. What are the benefits of using ICT in mathematics?
22. What are the challenges of using ICT in mathematics?
23. How have tried to address the challenges?
24. How do you use ICT to cater for different types of learners in mathematics?
25. Do you ensure equitable access to ICTs for all learners in your classroom?
26. How did you acquire the skills of using ICTs in teaching and learning?
27. Do you get any support from your school on the use of ICT in teaching and learning?

28. Briefly explain how you use ICT tools for collaboration purposes to support teaching and learning.
29. Briefly explain how proficient your colleagues are on the use of ICT for teaching and learning.
30. Do you request for assistance on the use of ICT in your teaching?
31. Has the use of ICTs affected learners’ attitudes towards mathematics?

Appendix F: Mr Tsebo's lesson plan

MODULE 1: Sequences and Series

a - first term	d - common difference
n - number of terms or	r - common ratio
- position of term	l - last term
T_k - value of k th term or	T_n - value of n th term

Arithmetic (common difference... d)

$T_3 - T_2 = T_2 - T_1 = d$

Sequence: $a\ ;\ a+d\ ;\ a+2d\ ;\ a+3d...$

Sequence

General term:

$T_k = a + (k-1)d$ or

$T_n = a + (n-1)d$

Series

Sum of:

$S_n = \frac{n}{2}[2a + (n-1)d]$ or

$S_n = \frac{n}{2}(a + l)$

Geometric (common ratio... r)

$\frac{T_3}{T_2} = \frac{T_2}{T_1} = r$

Sequence: $a\ ;\ ar\ ;\ ar^2\ ;\ ar^3\ ;.....$

Sequence

General term:

$T_k = ar^{k-1}$ or

$T_n = ar^{n-1}$

$a \neq 0, r \neq 0$

Series

Sum of:

$S_n = \frac{a(r^n - 1)}{r - 1}\ ;\ r > 1$

$S_n = \frac{a(1 - r^n)}{1 - r}\ ;\ r < 1$

1

$\sum$ **Sigma notation - Sum of**

$\sum (2k-1)$ ..... 8 terms $\qquad \sum (2k-1)$ ..... 5 terms

Number of terms:

$\sum_{k=p}^{l}$ ..... $n = (l - p) + 1$ $\qquad$ use sum formula

NB: $\mathbf{T_n = S_n - S_{n-1}}$ $\qquad$ e.g. $\mathbf{T_8 = S_8 - S_7}$

Infinite geometric series

Converging series: $-1 < r < 1$

$$S_\infty = \frac{a}{1-r}$$

More series.

Find the general term of:

A. 1; 4; 9; 16

3 5 7

2 2

2nd difference → quadratic

$\therefore T_n = an^2 + bn + c$

1. Let $2a$ = 2nd difference

$\therefore 2a = 2$

$\therefore a = 1$

2. c = term before 1st = T_0

0 1 4 9

1 3 5

2 2 $\qquad \therefore$ **c = 0**

$\therefore T_n = 1n^2 + bn + 0$

but $T_1 = 1$

$\therefore 1 = (1)^2 + b(1)$

$\therefore b = 0$

$\therefore T_n = n^2$

B. 7; 19; 37; 61

12 18 24

6 6

2nd difference → quadratic

$\therefore T_n = an^2 + bn + c$

1. $2a = 6$

$\therefore a = 3$

2. c = term before 1st = T_0

1 7 19 37

6 12 18

6 6 $\qquad \therefore$ **c = 1**

$\therefore T_n = 3n^2 + bn + 1$

but $T_1 = 7$

$\therefore 7 = 3(1)^2 + b(1) + 1$

$\therefore b = 3$

$\therefore T_n = 3n^2 + 3n + 1$

The questions in the worksheets are very easy at the beginning and can be used as examples.

Round answers off to 2 decimal places.

Worksheet 1 A

Find the general term for each of the following sequences:

1. 3; 8; 13; .....
2. 1; 5; 9; 13; .....
3. −2; 0; 2; 4; .....
4. −15; −11; −7; .....
5. 20; 23; 26; .....

Worksheet 1 B

Determine the 12th term of the following:

1. 3; 5; 7; .....
2. −1; 2; 5; .....
3. 16; 21; 26; .....
4. 5; 7; 9; .....
5. 13; 16; 19; .....

Worksheet 1 C

1. Which term in the sequence 36; 25; 14; ... has a value of −52?
2. Which term in the sequence 1; 6; 11; .... has a value of 26?
3. Which term in the sequence 19; 16; 13; ...has a value of −44?
4. Which term in the sequence $-2a$; $-5a$; $-8a$; .... has a value of $-32a$?

Worksheet 1 D

1. Given: 27; 23; 19; ..... Determine:

1.1 the 11th term

1.2 which term = −53.

2. Given: $3\frac{1}{2}$; 5; $6\frac{1}{2}$; ..... Determine:

2.1 the 25th term

2.2 which term = 11.

Worksheet 1 D

3. The first term of an arithmetic series is 25 and the 7th term is 115. Determine the first 3 terms of the sequence.

4. The 4th term of an arithmetic series is −8 and the 8th term is −24. Determine the first 3 terms of the sequence as well as the 11th term.

5. Determine the first 3 terms of the sequence as well as the 15th term if:

5.1 the 11th term = 81 and the 4th term = 25

5.2 $T_5 = 17$ and $T_{10} = 32$.

Worksheet 1 E

1. $T_k = 16 + (k - 1)(5)$ Determine:

1.1 the common difference

1.2 the 15th term.

2. $T_{19} = 11$ and $T_{31} = 5$ Determine:

2.1 the first 3 terms

2.2 the 10th term

2.3 which term = 14.

3. The 2nd term of an arithmetic sequence is 1 and the 8th term is −11. Determine:

3.1 the first term

3.2 the common difference

3.3 the twentieth term

3.4 which term equals −23

Worksheet 1 F

1. $a + 2$; $4a$; $6a + 4$ form an arithmetic sequence. Calculate the value of a and determine the first 3 terms of the sequence.

Appendix G: Rationale for teachers' interview schedule

Interview questions	Research questions addressed	Rationale for question
School context		
1. What do you know about the white paper on e-learning? 2. Is there a policy on the use of educational technologies in your school? 3. Who were involved in developing such a policy? 4. What guided the decision to develop the school ICT policy? 5. Is there a relation between your school's ICT policy and the white paper on e-learning? Explain? 6. How is the implementation of the ICT policy monitored in your school?	1 and 2	Identify teachers' knowledge in terms of ICT in education legislation and the role played by the school to inform teachers about the legislations on the use of ICT as well as supporting teachers on the use of ICT in teaching and learning. Establish the influence of context on teachers' use of IC in the school.

7. What are the challenges of using ICT tools in mathematics classrooms? 8. How have you tried to address the identified challenges? 9. How does your school support you on the use of ICT in teaching and learning?		
Experience		
1. Briefly describe your initial experience of using ICT tools in mathematics teaching and learning environments. 2. How has this initial experience affected the way you use ICT tools now? 3. What is your favourite ICT tool? 4. How long have you been using this tool? 5. Which other ICT tools do you use?	1	To get more information on teachers' competences and their experiences on the use of ICT as well as potential barriers in the use of ICT in their classrooms.

6. How often do you use these tools in your classroom? 7. How are these tools used in your mathematics classroom? 8. In which mathematics content are do you use ICT tools? 9. How do you ensure equitable access of ICT tools to all learners in your classroom? 10. What percentage of your lesson are ICT tools used?		
Value of educational technology use		
1. How has your favourite ICT tool contributed to learners' learning? 2. How has your favourite ICT tool contributed to mathematics classroom teaching? 3. What motivates you to use ICT tools in mathematics	2	To establish teachers' knowledge on the affordances and constrains of ICT in their classroom and appropriate/effective use of ICT. To identify informal learning processes occurring as a result of the use of ICT within and outside the classroom. To triangulate learners' competence in the use of educational technology in mathematics.

teaching and learning environment? 4. What are the benefits of using ICT tools in mathematics? 5. What guides your decision to use a particular in your teaching?		
Pedagogy		
1. How do you plan a lesson wherein ICT tools will be used? 2. What guides your decision to use a particular ICT tool in your teaching? 3. How are these tools used in your mathematics classroom? 4. How does the use of ICT affect your role as a teacher in your mathematics classroom? 5. Briefly explain how you use ICT tools for collaboration purposes to support teaching and learning.	1 and 3	To establish teachers' knowledge on selection and use of ICT tools and teacher's pedagogical orientation on the use of ICTs in their classroom. To identify the interaction between technology, learners and teachers

6. How do you use ICT tools to cater for different types of learners in mathematics? 7. Has the use of ICT tools affected learners' attitudes towards mathematics? Explain.		
Confidence in the use of educational technology		
1. Briefly explain how you use ICT tools for collaboration purposes to support teaching and learning 2. What percentage of your lesson are the mentioned tools used by the learners? 3. How did you acquire the skills of using ICT tools in mathematics teaching and learning? 4. How do you use ICT tools to cater for different types of learners in your	1	To establish teachers' confidence level in the use of ICTs,

mathematics classroom? 5. Briefly explain how proficient your colleagues are on the use of ICT for teaching and learning. 6. Do you request for assistance on the use of ICT in your teaching? (From whom, in what form and how often)		

Appendix H: Rationale for learners' interview schedule

Interview questions	Research questions addressed	Rationale for question
Access		
1. Where do you mostly use ICT tools? 2. Why do you use these tools at the indicated places? 3. How does the school support you in the use of ICT in your learning? 4. . Which ICT tools do you generally use for learning?	1 & 2	To identify ways in which learners access different technological tools and the role played by the school to support leaners' access o educational technologies.
Skills	1	
1. What do you use ICT tools for? 2. How do you use ICT tools in your learning? 3. Are you being helped in the use of ICT?		To establish learners' competences in the use of educational.
Attitude		
1. Which ICT tools do you generally use for learning? 2. Which ICT tools do you enjoy most and why?	1 and 2	To establish learners' persistence and commitment on the use of educational technology in mathematics

3. In which content area of mathematics do you normally use your most enjoyable ICT tool and why? 4. Which ICT tools do you enjoy the least? 5. In which content area of mathematics do you normally use your least enjoyable ICT tool and why? 6. Do ICT tools make you work differently? 7. What challenges do you face when using ICT in mathematics? 8. How do you address these challenges?		
Value		
1. Explain how the use of ICT has affected your role as a learner in mathematics learning. 2. What are the benefits of using ICT in mathematics learning? 3. Who influence your decision to use ICT tools? 4. What motivate you to do mathematics?	2	To establish learners' effective use of technology. To establish factors that affect learners' use of technology.

Appendix I: Teachers' questionnaire

TEACHERS' QUESTIONNAIRE

A: DEMOGRAPHIC INFORMATION

NAME OF SCHOOL: ……………………….   TEACHERS' AGE: …….

EXPERIENCE IN MATHEMATICS TEACHING: ……   TEACHERS' SEX: …….

HIGHEST QUALIFICATION IN MATHEMATICS: ……………………………………….

B: USES OF TECHNOLOGIES

1. Indicate the technology you own be means of a cross in the box next to the tool's name
   1.1 Smartphone ☐
   1.2 Tablet ☐
   1.3 Other Tablet ☐
   1.4 Laptop ☐
   1.5 Computer ☐
   1.6 Programmable calculator ☐
2. Indicate the technology(ies) that you usually use in teaching mathematics and give a brief explanation of how you use the technology. Mention as many as you use.

Technology	Use

C: TPACK MEASURE

Please complete the following by placing a tick in one of the five boxes next to each statement indicating the extent of your agreement to each of the statements. If you are uncertain or neutral about your response you may always select “Neither Agree nor Disagree”. Technology is a broad concept that can mean a lot of different things. For the purpose of this questionnaire, technology is referring to digital tools which include tools such as computers, laptops, Other tablets, Smartphones, Interactive White boards, Software programs, etc.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
TK (Technological Knowledge					
1. When I encounter ICT technical problems, I can resolve them.					
2. I can differentiate between hardware and software					
3. I can learn new software on my own.					
CK (Content Knowledge					
4. I always use algorithms when I do mathematics					
5. I am good in Geometry					
6. I am good in Trigonometry					

7. I am good in Algebra					
8. I have strategies of developing my understanding of mathematics					
9. I develop class activities in mathematics that are meaningful to the learners					
10. I develop projects in mathematics that are meaningful to the learners					
11. I follow recent developments and applications in mathematics					
12. I follow up to date (e.g, books, journals) in mathematics					
13. I keep up to date with conferences and activities in mathematics					
PK (Pedagogical Knowledge)					
14. I assess learners' performance in mathematics					
15. I adapt my teaching based on current learners' understanding or misunderstandings					
16. I adapt my teaching style to different learners					
17. I use a wide range of teaching approaches in a classroom setting.					
18. I use a wide range of different learning theories in a classroom setting					

19. I organise and maintain classroom management.					
PCK (Pedagogical Content Knowledge)					
20. I use effective teaching approaches that guide learners' thinking and learning in mathematics					
21. I use appropriate and effective teaching strategies for my topics in mathematics					
22. I develop assessment strategies and tools in mathematics					
23. I prepare lesson plans in mathematics					
24. I always meet objectives described in my lesson plans in mathematics					
25. I make connections between mathematics and other subjects					
26. I support mathematics with outside (out of school) activities.					
TCK (Technological Content Knowledge)					
27. I use technologies to enhance learners' understanding of mathematics					
28. I facilitate equitable access to technology resources for all the learners in mathematics					
29. I develop class activities involving the use of instructional technologies					

30. I develop projects involving the use of instructional technologies					
31. I use technologies in my teaching to easily achieve the learning outcomes					
TPK (Technological Pedagogical Knowledge)					
32. I choose technologies that enhance my teaching approaches in a lesson					
33. I choose technologies that enhance learners' learning in a lesson					
34. I use technologies to support learner – centred strategies in teaching mathematics					
35. I use technologies to address the diverse needs of all the learners in mathematics					
36. I manage a technology – rich classroom effectively.					
37. I provide leadership in helping others in the use of technologies in teaching					
38. I evaluate the appropriateness of a new technology for teaching					
39. I use technologies to motivate learners					
TPACK (Technology Pedagogy and Content Knowledge)					
40. I teach lessons that appropriately combine mathematics, technology and teaching approaches.					
41. I integrate appropriate instructional methods and					

technologies into mathematics					
42. I select contemporary strategies and technologies that help me to teach mathematics topics effectively					
43. My knowledge of the use of technology enables me to incorporate knowledge of all learners' understanding, thinking and learning of mathematics					
44. I facilitate a technology – enhanced mathematical experience that foster creativity					
45. I facilitate a technology – enhanced mathematical experience that encourage all the learners to develop higher order thinking skills					
46. I assess learners' appropriate and ethical use of technology resources in learning and communication in mathematics					
47. I use technologies to adjust instructional strategies					
48. I evaluate and reflect on the effective use of technology to enhance mathematics teaching and learning					
49. I exhibit leadership by demonstrating a research – based vision of					

integrating technology in mathematics teaching					
50. I promote safe, legal and ethical use of technology for teaching mathematics					
51. I promote safe, legal and ethical use of technology for exploring mathematics with learners and colleagues					
52. I use technology to communicate and collaborate with parents, colleagues and the larger community					
53. I use technology to nurture learners' mathematical learning					
54. I regularly participate and interact in ongoing professional activities that involve the use of technology					
55. I take advantage of the new and emerging technologies, to improve on my teaching practices in mathematics					
56. I am a leader in spreading the use of technological innovations in my teaching community					

D: ATTITUDES MEASURES

Please complete the following by placing a tick in one of the five boxes next to each statement indicating the extent of your agreement to each of the statements. If you are uncertain or neutral about your response you may always select "Neither Agree nor Disagree". Technology is a broad concept that can mean a lot of different things. For the purpose of this questionnaire, technology is referring to digital tools which include tools such as computers, laptops, Other tablets, Smartphones, Interactive White boards, Software programs, etc.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1. When I use technologies, I feel confidence in my teaching					
2. When I use technologies, I feel a sense of achievement					
3. When I use technologies, my work is more interesting					
4. I am motivated to use technologies in my class					
5. When I use technologies, my work is effective					
6. When I use technologies, I feel excited					
7. I do not have a fear of using technologies					
8. Using technologies in my class is encouraging					

9. I get a lot of satisfaction from using technology in my class					
10. Using technologies in my class make me confident					
11. When I want to use technologies, I always ask for advice from my colleagues.					
12. I feel confident in using technologies that I have had opinion(s) about their uses from colleagues					

Appendix J: Learners' questionnaire

LEARNERS' QUESTIONNAIRE

A: DEMOGRAPHIC INFORMATION

1. School name
2. Learner's grade: ………………….. Learner's age: ……….
3. Learner's sex: …………………….

B: USES OF TECHNOLOGIES

3. Indicate the technology you own be means of a cross in the box next to the tool's name

   3.1 Smartphone ☐

   3.2 Tablet ☐

   3.3 Other Tablet ☐

   3.4 Laptop ☐

   3.5 Computer ☐

   3.6 Programmable calculator ☐

4. Indicate the technology(ies) that you usually use in teaching mathematics and give a brief explanation of how you use the technology. Mention as many as you use.

Technology	Use

5. Please complete the following by placing a tick in one of the five boxes next to each statement. For the purpose of this questionnaire, technology is referring to digital tools which include tools such as computers, laptops, Other tablets, Smartphones, Interactive White boards, Software programs, etc.

1. I use technology at school to do the following	Never	Yearly	Monthly	Weekly	Daily
Talk to other leaners and teachers and share ideas about mathematics					
Connect mathematics to daily life					
Persist in solving difficult mathematics problems					
Apply different approaches when solving difficult mathematics problems					
Get a deep understanding of mathematics					
Improve on my technological skills					
Improve on my mathematics skills					
2. I use technologies at home to do the following					

Learn mathematics					
Play games					
Communicate with friends and family					
Design and produce artefacts					

C: ATTITUDES TOWARDS MATHEMATICS AND THE UE OF TECHNOLOGIES

Please complete the following by placing a tick in one of the five boxes next to each statement indicating the extent of your agreement to each of the statements. If you are uncertain or neutral about your response you may always select “Not Sure”. Technology is a broad concept that can mean a lot of different things. For the purpose of this questionnaire, technology is referring to digital tools which include tools such as computers, laptops, Other tablets, Smartphones, Interactive White boards, Software programs, etc.

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. I am good at using technologies					
2. I am committed to using technology					
3. I solve technical problem myself when using technologies					
4. I always understand mathematics easily					
5. I always get good results in mathematics					

6. I solve any mathematics problem in my grade					
7. I get excited when I do mathematics					
8. I am interested to learn new concepts in mathematics					
9. A good pass in mathematics opens one's door to a great future					
10. Learning mathematics is enjoyable					
11. I get a sense of satisfaction when I solve mathematics problems.					
12. I master any technology used in mathematics in my grade					
13. I like using technologies when learning mathematics					
14. Using technology in mathematics is worth the extra effort					
15. Mathematics is more interesting when using technological tools.					

16. Technological tools help me learn mathematics better					
17. I work with technological tools for long periods if I Know they will help me to solve the mathematics problem					
18. Using technological tools make me more confident about mathematics					
19. Using technological tools help me to check mathematics as I go.					
20. I feel confident to use technologies when faced with new problem in mathematics					
21. I find technologies useful when exploring unfamiliar mathematics problems					
22. Technologies help me to link mathematics ideas					
23. I prefer to learn mathematics first without the technology and learn the technology to do the					

mathematics more quickly					
24. I sometimes solve a mathematics problem using a technological tool, but realise afterwards that I do not really understand the problem					