Stocktaking to Support Information and Communication Technology Integration into Mathematics Teaching in Initial Teacher Education

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A research thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy

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Abstract

There is growing concern about pedagogically integrated information and communication technology (ICT) in the teaching of mathematics; however, this integration does not happen among all mathematics lecturers in and around Schools of Education in South Africa. There is an ICT knowledge gap between mathematics education lecturers and pre-service teachers. The current crop of students is part of the Net Generation, meaning they have access to digital technologies and in most cases use them for social purposes. On the other hand, lecturers still use their old methods of teaching and these needs to be improved to meet the demands of the 21st century. The literature revealed that most mathematics lecturers have difficulty in integrating ICT in their teaching because they lack the technological knowledge to use computer applications, especially software applications that can be used to prepare lessons and in classrooms. For successful integration of ICT in teaching and learning mathematics, the mathematics lecturers must be resourced with the needed technological knowledge first before upgrading and installing digital resources in schools and then expect ICT integration to happen.

The study used a qualitative approach. The instrument used was interviews with 12 mathematics education lecturers and 20 Further Education and Training B.Ed. fourth year mathematics major pre-service teachers in schools of education in South African. The interview was used to understand to what extent they pedagogical integrate ICT in teaching. The findings obtained assisted to ascertain the reason for low ICT pedagogical integration by mathematics lecturers. At the same time, the digital competency of pre-service teachers was established. The findings revealed that the slow integration was caused by a lack of professional development, a knowledge sharing space and an operational policy or framework that guides ICT integration in teaching. These findings seem to be a barrier to the pedagogical ICT integration in the teaching of mathematics. The study concludes by discussing the findings that were later used to propose a working model/structure that can work within the South African education context. The Transformed Activity Theory (TAT) model was developed to assist mathematics education lecturers to adopt and appropriate ICT in their teaching. The results revealed the mathematics education lecturers' need for a knowledge sharing space that equips them with substantial knowledge to help them determine the type of ICT software to be used in teaching. This knowledge will help them fit into the 21st-century classroom and meet the expectations of the Net Generation students.

Key Words: Pedagogical ICT Integration, Mathematics Application Software, Transformed Activity Theory Model, Net Generation

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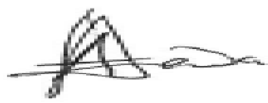
“Knowledge is power. Information is liberating. Education is the premise of progress, in every society, in every family.” **Kofi Annan**

Declaration

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



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List of Acronyms

CBAM—Concerns-Based Adoption Model

CoP—Communities of Practice

DoE—Department of Education

FET—Further Education and Training

HoD—Head of Department

IC—Innovation Configuration

ICT—Information and Communication Technology

LoU—Levels of Use

MRTEQ—Minimum Requirements for Teacher Education Qualifications

NCTM—National Council of Teachers of Mathematics

SoC—Stages of Concern

TPACK—Technological Pedagogical Content Knowledge Model

TAT—Transformed Activity Theory

CHAPTER 1: BACKGROUND OF THE STUDY

1.1 Introduction

Technology pervades almost every aspect of life in our rapidly evolving digital world. The teaching profession is facing challenges in this modern society where knowledge is growing due to modern Information and Communication Technology (ICT) that demand that teachers use ICT in teaching and learning. New concepts of teaching using computer software are evolving and pressure placed on teachers to facilitate teaching and learning using these tools to provide meaningful learning instead of just providing knowledge and skills (Jung, 2005). These new developments in ICT have provided the teaching profession with new possibilities while simultaneously placing the expectation on pre-service teacher educators to prepare teachers to upgrade their ICT skills and competency on how to integrate ICT in their teaching. Despite increases in technologies at universities, ICT is not being used to support pre-service teachers with the expected instruction that is believed to be beneficial and empowering in the teaching of mathematics (Ertmer & Ottenbreit-Leftwich, 2010).

Today's instructional technologies have made it possible to customise learning to suit the individual's needs and to allow students to pace their learning according to their abilities. Technologies have enabled today's students and instructors to spend less time to achieve their target learning goals. Instructors can communicate with their students more effectively using innovative teaching techniques, making the learning experience more interactive and effective. In today's world, though computers are not designed for educational purposes, they are influencing the educational domain to use them for teaching and learning, particularly in the development of learners' problem-solving and computational skills (Armah & Apeanti, 2012). The National Council of Teachers of Mathematics (NCTM, 2000) posits that mathematics teaching must emphasise mathematical procedures such as mathematical thinking, connections, communication and problem-solving. In South Africa, the majority of learners are performing badly in mathematics. This is alluded to by McCarthy and Oliphant (2013) who noted that South Africa is significantly underperforming in mathematics and is among the "worst on the world" (p. 1). Thus, with the potential ICT has in improving learning mathematics, it is expected that it may raise interest among learners and consequently improve mathematics results. Many previous studies conducted have shown that ICT encourages collaboration among students, sharing knowledge, and communication, and give instantaneous and accurate feedback to students, which consequently motivate students to like mathematics (Hook, 2008). Despite what ICT offer, many mathematics teachers in South African schools are facing challenges integrating ICT in the classroom. This challenge extends to teacher training institutions where these teachers are trained. Mathematics deserves attention because it is affected by computerisation and the machines follow some mathematics procedures and algorithms to work successfully. The role of mathematics is pervasive and tends to move together with the role of technology, because mathematics is at the centre of what computers do (Gravemeijer, Stephan, Julie, Lin, & Ohtani, 2017).

The need to provide meaningful ways of teaching and learning mathematics is quite imperative considering that mathematics is a crucial subject in society and for the growth of the economy at large. It acts as a critical filter to many educational and career opportunities: It is a gateway to careers in science, civil aviation, medicine, commerce, engineering, architectural studies and other key sectors. Given the importance of mathematics in our society, the low levels of achievement in this subject are of concern (Volmink & Van der Elst, 2017). Studies in South Africa report that mathematics is the subject most Grade 10–12 students fail. Adler and Sfard (2016) noted that there appears to be a shift from mathematics to mathematical literacy where learners drop mathematics in Grade 10 and opt for mathematical literacy because they find pure mathematics difficult and its language a challenge to understand. The tools of mathematics are abstraction, symbolic representation and symbolic manipulation (Schoenfeld, 2009). All these tools need to be applied when solving mathematical problems. ICT has the capability to augment learners' understanding of mathematical foundations and concepts. ICT affordances could help learners get past the blockages and alleviate problems associated with teaching mathematics using textbooks. This can be accomplished by harnessing ICT tools in the teaching of mathematics to simulate tasks, to discover and to experiment with concepts (Aslan & Zhu, 2016). However, to achieve ICT integration in mathematics, training to integrate ICT should start at teacher training institutions where mathematics lecturers play a prominent role in explaining and demonstrating how the subject matter must be taught. According to Fullan (2007) in Aslan and Zhu (2016, p. 360), “Educational change depends on what teachers do”. This shows that mathematics lecturers are the backbone in applying educational changes in their teaching practices.

ICT-supported learning in mathematics provides a plethora of opportunities that include: promotion of self-directed and self-regulated learning, autonomous learning, higher-order thinking, student-centred learning, cooperative learning and problem-solving (Mwalongo, 2011; Delfino, Dettori, & Persico, 2010). It is interactive and helps learners visualise abstract ideas (Kennwell, Tanner, Jones and Beauchamp, 2008). In cases where the mathematical concepts is very abstract in the textbook, ICT offers various methods to solve that particular mathematical problem and model processes that may help the student grasp the concept. Students can use the available mathematical software and YouTube videos to grasp the content.

According to Jung (2005), prospects for ICT integration in mathematics instruction are inspiring; however, it creates challenges for teachers and teacher training institutions. The challenges facing teacher training institutions are that graduating teachers do not have the combination of technological and pedagogical knowledge to meet the demands of the 21st century classroom which include among other things “critical thinking, problem-solving, communication, collaboration, initiative, imagination and analysing information” (Gravemeijer et al., 2017, p. 107). Despite the affordances ICT offer in teaching and learning, mathematics lecturers’ use of ICT is rarely linked to the student learning outcomes (Ertmer & Ottenbreit-Leftwich, 2010). ICT training for teachers should model effective teaching practices (Infodev, 2015) and mathematics lecturers’ role is to model ICT integration during their lectures. As the mathematics lecturers are the central point in initiating the instructional potential offered by ICT, institutions of teacher training have a big role to play in preparing pre-service teachers to develop digital fluency so that they, in turn, adopt and apply digital pedagogies in the classroom.

Several countries worldwide have realised the significance of ICT in teaching and learning and have provided ICT teacher training in various forms (Jung, 2005). Countries like Tanzania, Kenya and Uganda are calling for ICT integration at public teacher training colleges, however, the uptake is still low (Luhamya, Bakkabulindi, Muyinda, & Mpoza, 2017). Tikly et al. (2018) found that there are few qualified lecturers in Africa who can teach mathematics using ICT and there is a severe shortage of ICT specific skills and subject knowledge among both pre-service and qualified practising teachers. However, recently pre-service teachers in Nigeria have established the critical role played by ICT in improving the grade of students studying mathematics at the university level, especially through distance education (Reju & Jita, 2017). Similarly, Liebenberg, Chetty, and Prinsloo (2012) noted the positive role ICT plays in distance education for South African and Ghanaian students, respectively. Pre-service teachers are trained in how to use ICT in the classroom, for example, "selecting appropriate ICT tools and supporting students in the use of those tools, using ICT to promote learning activities and developing new methods of facilitating learning..." (Jung, 2005, p. 95). There is a growing need to provide pre-service teachers with skills to use ICT in teaching and learning (Du Toit, 2015). In this regard, the onus is placed on mathematics lecturers to create opportunities for pre-service teachers to acquire the needed skills and knowledge to model integration of ICT in mathematics classes.

As mathematics education lecturers model and demonstrate ICT integration in their lectures, there is a possibility that pre-service teachers will master the concepts taught. The learned skill can be easily transferred to their future practices. This is alluded to by the International Society for Technology in Education (1999, cited by Bowers, Barron, & Goldman, 1994) who say teachers teach as they were taught. Thus, mathematics lecturers need to model meaningful use of ICT in their own classes (UNESCO, 2002). For the pre-service teachers to adopt ICT in the classroom, they need to acquire appropriate skills and knowledge that can be learned through their teacher training programmes (Agyei & Voogt, 2011; Tondeur, Van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012).

Figure 1 provides a road map of what will be presented in this chapter to give the reader a better understanding of my motive in the study.

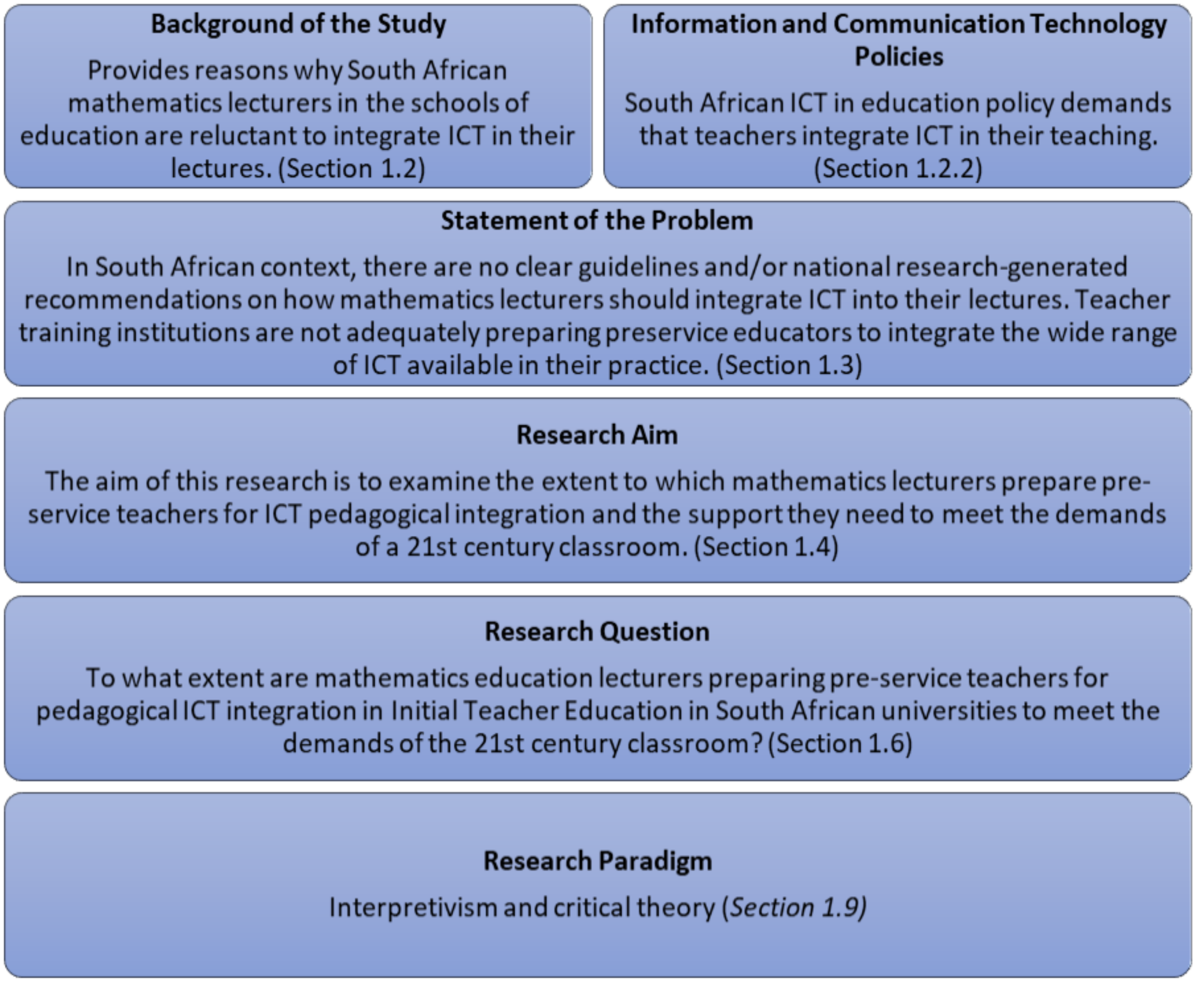


Figure 1: Arguments presented in Chapter 1

1.2 Background of the Study

The background to this research is documented in two sections. The first section describes the rationale of my interest in this research area and how it developed. The second section outlines some international and South African policies on pedagogical ICT integration in the teaching of mathematics; further reasons why the research is meaningful in the contemporary society.

1.2.1 Research Interest

My research interest stem from being a mathematics and computer science advanced level teacher at a high school with a passion for programming in C#, C++, Java, SQL and Delphi. I noted that there are plenty of computer software and other ICT materials that can be used in the teaching of mathematics that my colleagues could not use. I used mathematics software to explore the innovative ways that ICT can be used in the teaching of mathematics to pre-service teachers. In addition, I noted that Microsoft Excel and other mathematics software have abundant platforms that can be used to solve mathematical problems.

The literature I engaged with indicated that the use of ICT is not used to its fullest potential in educational settings as many teachers have no idea on how to use ICT for pedagogical purposes (Prestridge, 2012). In South Africa, ICT are part of many aspects of people's day-to-day activities, teachers included. Teachers are experiencing challenges as to when to start teaching using ICT coupled with their limited ICT skills. They have limited knowledge on how to use ICT in the teaching except in ICT literacy, which they use for administrative purposes. South African pre-service teacher education in mathematics is still dominated by textbook teaching. Education mathematics lecturers hardly integrate ICT into their lecture rooms, either because they do not have sufficient skill to integrate ICT in their teaching or they lack a guide to direct them on how to integrate ICT. Makonye (2017) noted that it is a challenge for education mathematics educators to embed ICT in their regular teaching and learning situations. He went further by saying, "some staff members see no need to use ICT as they are coping well without them" (p. 204). Valencia-Molina, Serna-Collazos, Ochoa-Angrino, Caicedo-Tatayo, Montes-González, and Chávez-Vescance (2016) were of the opinion that "it is vital for institutions and all educational agencies to recognise that teacher training must be based on data from research and practice …" (p. 15). In other words, teacher training institutions have the ability to transform the way they prepare pre-service teachers to cope with the society that is already flooded with ICT in their pedagogical practice to promote meaningful construction of knowledge in their students. Thus, mathematics lecturers are to view ICT as affordances or resources that could be used in enhancing teaching and learning. Future teachers need to be equipped with skills on how to teach mathematics with ICT. The use of multimedia during content development can improve learners' higher cognitive skills. Pre-service teachers may be trained on how to use simulations, graphics, GeoGebra and videos to explain what would be hard to explain in a lesson without ICT. ICT stimulates learners' thinking, giving them the chance to construct their own knowledge.

1.2.2 ICT Policies

In South Africa there are limited ICT policies that spell out how mathematics can be taught by integrating ICT. The existing policies (such as Minimum Requirements for Teacher Education Qualifications (MRTEQ) (2015) and Survival Guide to the FET Curriculum and Assessment Policy Statements (CAPS), Longman, 2013) are not clear on the integration of ICT in the teaching and learning mathematics to pre-service teachers. There is no clear policy on the adoption and implementation of ICT in the classroom. The MRTEQ (2015) recognises ICT as a fundamental learning area that all graduating South African teachers are required to be competent in, however, it does not explain how ICT can be used in teaching and learning. Thus, the existing policies seem to contain a general statement about 'ICT integration' but does not explain how to implement and monitor ICT integration. Nevertheless, contemporary teachers are expected to learn to live and work in an information rich society and to use ICT in a wide range of ways.

In spite of the availability of ICT, the adoption of ICT by mathematics lecturers is still relatively low (Kerckaert, Van der Linde, & Van Braak, 2015). The pressure is on teacher training institutions to prepare pre-service teachers to be hands-on in using ICT for pedagogical use and to have a theoretical understanding of how to use ICT in learning and teaching (Chai & Lim, 2011; Haydn, 2014).

Preparing pre-service teachers to use ICT in their teaching practices has been a perpetual challenge in many countries (Jung, 2005; Teo, 2011; Angeli & Valanides, 2013). The New Zealand Ministry of Education report in Bolstad et al. (2012) noted that a range of areas in the use of ICT still need to be taken into account in education. Teachers should be able to understand the importance and affordances of ICT tools and have the ability to support an innovative curriculum that responds to the needs of 21st century learning that includes thorough knowledge of technical skills needed by real world and use of technology to strengthen content knowledge (Kaufman, 2015). The affordances provided by the use of ICT signals the importance of mathematics lecturers to ensuring that their mathematics teacher graduates are confident, competent users of ICT.

In developed countries like the United States, through the International Society for Technology in Education, standards have been used as guidelines for teachers to integrate ICT in teaching and learning processes (Tondeur, Aesaert, Prestridge, & Consuegra, 2018). In Australia ICT is used as implicit (embedded) within pedagogy. There are three domains used as guiding frameworks: professional knowledge, professional practice and professional engagement. Each domain in ICT is both implicit and explicit (Tondeur et al., 2018, p. 33). ICT has to be implemented as a teaching strategy to demonstrate the skill of solving challenging problems in the teaching fraternity.

The South African ICT in Education Policy (Department of Education [DoE], 2004), though outdated, focuses on teaching and learning for a new generation of young people who are growing up in a digital world. This means that South African universities, as teacher trainers, have an obligation to prepare pre-service teachers with the knowledge and skills needed to fulfil these expectations. However, despite these expectations of the Department of Education (DoE), the policy does not specify how these expectations can be fulfilled. ICT in the South African education system is mainly taught as a subject instead of being integrated as a pedagogical tool for teaching and learning in other subject areas (Kafyulilo, Fisser, Pieters, & Voogt, 2015). ICT pedagogical practices by mathematics lecturers may have a major impact on pre-service teachers, particularly in the areas of solving mathematical problems and mathematical logic that will sustain both learning and effective functioning in life (Abbasi, 2014). In addition, integration of ICT may be used to support the learning environment by providing tools for discourse, discussions and collaborations and by providing support to scaffold learners' cognitive growth (UNESCO, 2002). It is important, however, that pre-service teachers be provided with various opportunities to learn and use ICT during their training, especially during their teaching experiences.

In South African and other sub-Saharan countries' higher education institutions—whether poor in ICT infrastructure or not and whether mobile and social media is used or not—teaching and learning practices remains largely unchanged (Brown, Bozalek, Gachago, & Wood, 2016) and technology remains at the periphery of most teachers' practices (Hofer & Grandgenett, 2012). Despite the abundance of technology, mathematics lecturers often do not make optimal use of it (Stols et al., 2015) for teaching and learning purposes. Integrating ICT in mathematics can equip pre-service teachers with strategies to solve a range of complex mathematical problems. Mathematics lecturers have a critical opportunity to expose their students to practical as well as pedagogic ICT competencies during lectures. Mathematics lecturers are often seen as the key drivers in the preparation of pre-service teachers to integrate ICT into their teaching practice.

Technological knowledge and competency are now mandatory for productive participation in education and the workforce. The complexity of teaching in the 21st century constantly calls on teachers to make decisions about activities to engage learners and instructional strategies that not only meets their needs but also provides them with ways to interact in a technologically-driven society. Therefore, it becomes increasingly important to provide pre-service teachers with opportunities to develop their ICT or technological knowledge and competencies. Mathematics lecturers in the schools of education are expected to teach their content through technology and in the process model and teach technology during content delivering to meet the demands of the economic, social and cultural imperatives that face South Africa. The demands of the global and knowledge society place teachers in a difficult position, and to a certain extent they are forced to adopt new learning technologies to accommodate contemporary learners.

1.3 Statement of the Problem

The policy guidelines for teacher education programmes in the Department of Higher Education and Training (DHET) (2013) and the South African Revised Policy on the MRTEQ (2015) recognise ICT as a fundamental learning area that all graduating South African teachers are required to be competent in. Despite the policy's pronouncement, to date, there are no clear guidelines and/or national research-generated recommendations on how mathematics lecturers should integrate ICT into their lectures. Jita (2016, p. 15) wrote that, "there is thus a clear gap in terms of how mathematics lecturers are expected to break the ‘digital divide’ in their preparation of prospective teachers”. Kaufman (2015) and Sang and Guoyuan (2010) noted that teacher training institutions are not adequately preparing pre-service educators to integrate the wide range of available ICT in their practice. It seems that mathematics lecturers need ICT skills to pedagogically integrate ICT in the lecture room. Tondeur et al. (2018) realised the importance of teacher training institutions to prepare future teachers to integrate ICT in their classrooms. The adoption to develop pre-service teachers’ competencies to use ICT and harness its potential can enhance teaching and learning. Nonetheless, it is still not clear how teacher training institutions can get a comprehensive and systematic way to teach using ICT (Baran, Canbazoglu Bilici, Albayrak Sari, & Tondeur, 2017; Tondeur, Aesaert, Pynoo, Braak, Fraeyman, & Erstad, 2017; Drummond & Sweeney, 2017). Using ICT reinforces learning and the setup should first take place in the teacher education lecture rooms. It is against this background that this study seeks to stocktake how mathematics lecturers prepare pre-service teachers to integrate ICT in the teaching and learning of mathematics with the aim of developing a framework to support pedagogical integration of ICT by mathematics lecturers in initial teacher education programmes.

A significant criticism has been made that pre-service teacher education fails to prepare initial mathematics teachers to use ICT in the classroom (Starcic, Cotic, Solomonides, & Volk, 2016). In view of the above assertion, it is observed that ICT uptake by mathematics lecturers is still low (Kafyulilo et al., 2015) and lecturers’ ability to teach using technology to their students is still limited (Kaufman, 2015). To benefit from ICT affordances, mathematics lecturers have a bigger role to play in helping pre-service teachers develop technological knowledge and digital competencies to model integration of ICT in their future classrooms. Hence, Chemwei, Kiboss, and Njagi (2016) viewed teacher educators as key players if effective learning is to be achieved.

The DoE (2004; 2007) reported that South Africa lacks a theoretical framework for ICT pedagogical integration in all the levels of its educational system. In addition, the South African educational technology policy for higher education also affirms that there is a lack of theoretical framework informing the discourse on pedagogical ICT integration in teacher training institutions (Council on Higher Education, 2006). Hence, Howard and Maton (2011) and Saxena (2017) argued a theoretical foundation needs to be established to inform any discourse. From the statement above it seems that current teaching methods informed by existing frameworks are not sufficient in explaining how innovation configurations (IC) can be integrated in the teaching of mathematics to enhance students' understanding of abstract mathematics concepts. Considering this, the researcher views it as imperative to conduct a study to explore how mathematics lecturers prepare pre-service teachers for ICT pedagogical integration in the classroom.

1.4 Aim of the Research

The aim of this research is to examine the extent to which mathematics lecturers prepare pre-service teachers for ICT pedagogical integration and the support they need to meet the demands of a 21st century classroom. The findings will help to develop an ICT pedagogical model that has the potential to be appropriated and adopted by mathematics education lecturers when preparing pre-service teachers for an effective pedagogical ICT integration.

1.5 Objectives

The research objectives are as follows:

1. To examine the extent to which mathematics lecturers prepare pre-service teachers to integrate ICT to meet the demands of the 21st century contemporary classroom.
2. To investigate the kind of support mathematics education lecturers need to adequately prepare pre-service teachers to integrate ICT in teaching and learning of mathematics to meet the demands of the 21st century classroom.
3. To investigate how the pre-service teachers are prepared to meet the demands of the 21st century classroom.
4. To determine what kind of ICT pedagogical model is suitable for preparing pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

1.6 Main Research Question

To what extent are mathematics education lecturers preparing pre-service teachers for pedagogical ICT integration in Initial Teacher Education in South African universities to meet the demands of the 21st century classroom?

1.7 Sub-questions

1. How do mathematics lecturers prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?
2. What ICT tools does mathematics lecturers need to adequately prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?
3. To what extent are the pre-service teachers being prepared to meet the demands of the 21st century classroom?
4. What ICT pedagogical model/structure is suitable for preparing pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

1.8 Significance of Study

The study researches on how lecturers in mathematics education use ICT in teaching and learning of mathematics and use the results obtained from the data to develop a model/structure that will help with the integration of ICT at university level. The model is envisaged as a tool that will expand their knowledge of integrating ICT in mathematics education, if effectively adopted. There is massive need for mathematics education, especially in South Africa, to effectively use ICT in teaching.). For the successful ICT integration, mathematics lecturers should be step ahead of their pre-service teachers with regard to the use of ICT in teaching and learning. They act as a resource that serves as a catalyst for change, in an effort to harness ICT in the education system. This is critical in contemporary education as pre-service teachers desperately need this knowledge and skills. The study focus on the skills lecturers need to have to equip pre-service teachers with the necessary ICT skills and competencies. In addition, it will provide insights for mathematics lecturers as to how and when ICT can be used to benefit the pre-service teachers at any stage of their education. Pre-service teachers will acquire skills and knowledge on how to integrate ICT to enhance student learning and to reflect on their own experiences on their student. Once lecturers realise the fact that the metaphor of acquisition that underlies their thinking about using ICT in teaching and learning mathematics, the probability could be that they may become immediately aware of its presence in almost every common utterance on learning. In addition, it may equip pre-service teachers with the appropriate skills to independently use ICT in the classroom. Mathematics lecturers, heads of teacher training institutions, in-service teachers and policymakers may also benefit from the necessary digital knowledge (technology and pedagogy) needed to facilitate learning in the digital knowledge society and structuring pedagogical ICT curriculum that create opportunities for the use of ICT in the teaching and learning of mathematics. The study hopes that mathematics lecturers will contribute to the knowledge of integrating ICT in their lectures, and in turn, this knowledge will be passed on by pre-service teachers to their future classes. ICT skilled graduating educators entering the teaching profession will be equipped to meet the MRTEQ (2015) standard for ICT endorsement.

The absence of information detailing how ICT should be used in teaching mathematics begs attention, hence the schools of education at universities in South Africa need to ensure that the teachers who leave their institutions are themselves ICT capable and are adequately prepared to effectively use ICT in the teaching of mathematics and other subjects across the curriculum. With pressure being placed on initial teacher education to produce teachers that are ICT capable, there is an urgent need for mathematics lecturers to improve their ICT skills so that they may use it in the teaching. Thus the value of my research lies in its efforts to conduct stocktaking on how mathematics lecturers are preparing pre-service teachers, especially those that are in their final year, for pedagogical ICT integration to meet the demands of the 21st century. Findings from my study, such as identifying factors that impact low use of pedagogical ICT integration in the teaching of mathematics, can assist in determining the best ways to support mathematics lecturers to improve their digital competency to help pre-service teachers harness ICT for their future students.

1.9 Research Paradigm Underpinning the Study

Logical positivism has been the main research paradigm for several centuries. This paradigm centres on scientific theories and undermines beliefs and practices that are based on superstition. Ontologically, this paradigm is concerned with establishing causal, scientific laws, and statistical or probabilistic relationships to arrive at the conclusion. However, it has some weaknesses when applied to social sciences where some contextual variables (such as beliefs, attitudes, culture) need to be considered (Scotland, 2012). This research adopted the interpretivism paradigm approach. Scotland (2012) asserted that interpretive epistemology (subjectivism) is “based on real world phenomena” (p. 11). Human beings have some knowledge about the world they live in. The meaning of the world cannot be discovered; however, it can be constructed through interaction with the world. Thus, knowledge and meaningful reality are constructed through the interaction between humans and the world they live in (Crotty, 1989). The study aims to understand the ICT integration in the South African context with the hope that the integration of ICT will add value to the schools of education and contribute to a positive change. In terms of critical theory, the concern is with the emancipation of mathematics lecturers to a level where they can teach using ICT with enthusiasm. ICT has changed the landscape and are reforming teaching practices and practitioners need this knowledge in their teaching practices. Lecturers are grappling to embrace these opportunities that can add value to their 21st century teaching practices.

Interpretivism and critical theory approaches rely on the qualitative method. It incorporates methods such as interviews (open-ended interviews and semi-structured interviews), observations and document analysis to unpack how participants see and know things. This study used qualitative tools to quantify the levels of mathematics lecturer’s knowledge of ICT integration. Audio recordings were used as the data-collection method. Research that falls into the interpretive/critical theory paradigm is conducted in more natural or contextual setting to collect data. In this study, university mathematics lecturers in the schools of education were interviewed in their normal setting without manipulating their environment in any way.

Research designs associated with these paradigms provide opportunities for knowledge to emerge without manipulation of the environment and proceed by testing a priori hypothesis.

1.10 Conclusion

In conclusion, the chapter provided a background of the challenges faced by mathematics lecturers in harnessing ICT in preparing pre-service teachers. In addition, the research statement problem has been identified and the context in which the research will be carried out has been highlighted.

1.11 Outline of Chapters

Chapter 1: Introduction and Background of the Study

This chapter describes how ICT is used in teaching mathematics to pre-service teachers in the schools of education as revealed by previous studies. The opportunities and potential that ICT have in teaching and learning mathematics are explained and thus provided the base for the background of the study. The problem statement and the research questions are included.

Chapter 2: Literature Review

This chapter provides the literature review on opportunities and affordances that come with ICT in teaching mathematics. The extent to which ICT is used in the teaching of mathematics to pre-service teachers is explored across the African continent and South Africa. Social and cultural capital and connectivism are included to help develop an argument that can help engage with data in the context of this study.

Chapter 3: Models and Theories

This chapter informs the reader on models and theories that can be adopted in teaching mathematics. These are discussed in detail and the strengths and weaknesses of each unpacked. One theory is selected to form the basis of the study.

Chapter 4: Research Design and Methodological Approach

The research methods appropriate for the study are presented and justified. Methodological paradigms and metacognition paradigms are discussed and their usefulness to the study justified.

Chapter 5: Mathematics Education Lecturers' Use of ICT in teaching

The data from the chosen 12 mathematics education lecturers are presented and interpreted. Some emerging themes are grouped.

Chapter 6: Mathematics Pre-service Teachers' Use of ICT in Learning

The data from the chosen 20 mathematics pre-service teachers are presented and interpreted. Some emerging themes are grouped.

Chapter 7: Discussion of the Findings

Themes from Chapters 5 and 6 and the findings are discussed in this chapter. This chapter discusses a proposed model, the Transformed Activity Theory that can be used to appropriate and adopt ICT in the teaching of mathematics.

Chapter 8: Conclusion and Implications

This chapter outlines the overall reflection of the study. The summary of the key findings addressing the main research question is discussed. Finally, the contribution, limitations and recommendations are presented.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter examines the literature in the ICT teacher education field and the justification for its use in the teaching of mathematics, especially by mathematics lecturers, in order to gain in-depth understanding of how mathematics lecturers in the schools of education use ICT for pedagogical purposes. I further explore some conceptual frameworks that are implemented in the preparation of pre-service teachers and to identify the gaps and potential areas for research. The review considered the main themes in Table 1 related to the ICT and teacher education discourse for a sustainable and knowledge society development.

Table 1: Main themes related to ICT integration in teaching

Teaching and learning with ICT
Methods for effective ICT integration by mathematics education lecturers
Global ICT integration in the teaching of mathematics in schools of education
Inclusivity and ICT—enhancing learning in a diverse classroom
ICT integration in the teaching of mathematics in schools of education in Africa
ICT in schools of education
Significance of ICT in teacher training institutions
ICT policies in education and supported conceptual framework
Learning theories in ICT environment
ICT affordances and teaching of mathematics

2.2 Teaching and Learning with ICT

Future mathematics teachers are expected to use computerised gadgets as tools to solve mathematical problems. The increasing availability of ICT and its use have made some mathematics topics easer to teach and learn. According to Gravemeijer et al. (2017), 21st century classroom skills are necessary for future teachers to be relevant in the classroom. These skills include “critical thinking and problem solving, networking, initiative, effective communication, accessing and analysing information" (p. 108). These skills contribute to mathematics pre-service teachers being independent, being more strategic in selecting appropriate, effective materials to help accomplish tasks, and recognising that knowledge is not transmitted but that they support students to construct mathematical concepts. Contemporary mathematics learning is supported by a lot of mathematical software, unlike in the past when textbooks and teachers were the only sources of information. Computer software applications such as MATHEMATICA, GeoGebra, MathsExpert, Statistica, Wolfram MATHEMATICA, Fathom, etc. have the potential to facilitate an active approach to learning by creating an environment where students become involved in discovery and consolidate their own knowledge, thus developing conceptual, geometrical and statistical understandings and a deeper approach to learning. The emergence of these mathematical tools and their ability to help pre-service mathematics teachers cannot be ignored by mathematics education lecturers.

ICT supports many activities in our modern society such as knowledge management, communication, business, entertainment and commerce (Wilson & Boateng, 2014). The 21st century has witnessed a drastic change in the way people conduct their day-to-day business activities because of ICT. Education cannot avoid this change; however, it is not quick to harness the implementation of ICT in teaching and learning. Technologies can be used to teach and deliver lessons. The role of mathematics education lecturers is to play the role of modelling, explaining, coaching and scaffolding the concept. The challenges facing educational institutions is how to transform the existing operational curriculum to one that will include harnessing ICT in teaching so that it provides students with the needed skills to fit into this dynamic, information rich, and continuously changing the environment. Mastering ICT skills is not the prime concern; however, acquiring skills that will be used to teach using ICT is of paramount importance. The infusion of ICT in pedagogy enhances learning and knowledge acquisition. In addition, it promotes collaboration, fosters enquiry and exploration, motivates and engages learners (Wilson & Boateng, 2014). Teaching and learning using ICT encourage learners to be independent, autonomous, creative and critical in thinking. For pre-service teachers to be equipped with all these skills they need training that should start at their teacher training institutions. Therefore, their lecturers should have a diverse knowledge of and innovative ideas for using ICT.

Teaching is about making the taught concept clear and effective; this skill helps students develop a deeper understanding of the learned phenomena. In contemporary teaching, using ICT can make explaining the concept easier because of its interactive nature. Hidden concepts can be instantiated, simulated and modelled using ICT. Pre-service teachers might benefit from teaching that uses technology. Yusuf (2005) stated that the education field has been affected by the infiltration of ICT, which in turn has affected teaching, learning and research. UNESCO (2011) also alluded that instructors need to use ICT in their pedagogy which is relevant for acquiring needed knowledge in our modern societies. Stoyle and Morris (2017) viewed teaching using multimedia being "rich in information and afford the potential to generate many opportunities for explaining information and connecting to prior knowledge, particularly for low prior knowledge learners" (p. 115). ICT platform provides facilities such as social interaction (group chat, forums) to foster communities for learning mathematics. Learning in an ICT-rich environment has the potential in engaging students in constructing new ideas and help them collaborate in solving complex problems. The use of ICT assists pre-service teachers acquire in-depth knowledge of the subjects and understanding the 'know-how' of generating new knowledge (Sanmi, 2016). ICT are important tools used to enhance new ways of teaching and learning mathematics. Therefore, there is a need for the education mathematics lecturers and pre-service teachers to acquaint themselves with ICT tools (mathematics software) to enhance effective teaching and learning of the subject. Gilakjani, Ismail, and Ahmadi (2011) believed that the use of ICT provides teacher training programmes the prospect to create rich learning environments for their pre-service teachers, supported by the wide range of technologies coupled with resources available on the Internet. Advancement of ICT provides diversity in the way knowledge, concepts and ideas can be presented. Education mathematics lecturers need to be mindful in considering such resources for pedagogical purposes to facilitate effective learning.

Mathematics educational software has the possibility of making teaching and learning more interesting and goal-oriented. These software provide mathematics pre-service teachers with platform to solve mathematics problems with hints/clues available in the event they face some challenges. In addition, it ignites interest and curiosity among pre-service teachers when solving a mathematics problem that needs critical thinking either individually or in a group.

2.3 Methods for Effective ICT Integration by Mathematics Education Lecturers

Generally, mathematics is a subject that is full of abstract concepts or ideas that might be hard for students to grasp. The use of teaching and learning aids is important to support students' understanding of concepts, because it allows visualising abstract concepts while linking them to objects students are familiar with in their everyday world. ICT has the potential to make abstract concepts concrete (real). Integrating ICT in teaching needs a lot of demonstrations and illustrations. The teacher has to demonstrate and monitor the task given to the learners. This is similar to trade apprenticeship training where learning occurs as experts and novices interact socially while focused on completing a task (Dennen, 2012). In this study, the experts are the mathematics lecturers and the novices are the initial teachers. The lecturing method used in this situation is a cognitive apprenticeship. The cognitive apprenticeship allows students (initial teachers) to learn through interactions, sharing knowledge and constructing knowledge with their colleagues (UNESCO, 2002). This type of lecturing method assists in developing the cognitive skills of the student in authentic learning experiences. ICT provides new powerful tools to support cognitive apprenticeships such as collaborating to develop artifacts and intellectual products. In cognitive apprenticeships, mathematics lecturers can act as coaches and mentors by offering assistance to students. Laurillard (2013) saw learning through practice linked to the theory, abstraction to instantiations and discussion to experience. ICT integration in the classroom, by its nature, involves a lot of practice. Thus, it is my opinion that "work-based or vocational" learning is best for ICT integration, as it happens in authentic and situated learning. It is noteworthy that the "curriculum succeeds in linking theory with practice" and should not divorce from its contextual use (Laurillard, 2013, pp. 20, 29).

Mathematics is one of the subject areas affected by ICT when training pre-service teachers (Akkaya, 2016). The use of ICT in mathematics instruction contributes to the development of the teaching concept and skills such as problem-solving, abstraction and reasoning. In addition, the use of ICT in mathematics instruction increases the quality and permanence of the concept (Önal & Demir, 2013). ICT tools that are useful in teaching mathematics include computer algebra systems, dynamic geometry software, virtual learning objects, interactive boards, and graphing calculators. Using these technological tools is important in making sense of mathematical concepts: "Dynamic geometry software has provided opportunities, especially in teaching geometry, in visualisation, dynamic drawing of geometric shapes and exploring various geometric relationships" (Tatar, Zengin and Kağızmanlı, 2013). However, integrating ICT into the teaching-learning process is still a challenge to mathematics lecturers. Pre-service teachers need to be equipped with technological competence to meet the needs of their students while they are doing their pre-service education (Zhou, Zhao, Hu, Liu, & Xing, 2010). Thus, Yıldırım (2000) suggested that it is important for pre-service teachers to learn ICT integration during their training in their pre-service education period and their profession. This will help them to meet the requirements of the '*Net Generation'* learners who are described as 'a homogenous group with wide experience and advanced skills in using information and communication technologies' (Kennedy, Judd, Dalgarno, and Waycott, 2010; Tapscott, 2009).

Pedagogical approaches used by mathematics education lecturers are one of the important factors that affect the effective use of ICT. In the South African university context, mathematics lectures are conducted using the traditional approach with textbooks and presentation slides. However, the use of ICT in the lecturing process requires significant changes in the planning, implementation, and evaluation of instruction. Mathematics lecturers should consider the content to be taught and the activities to be implemented while integrating ICT. Thus, it is crucial to equip mathematics lecturers with combined knowledge on technology, content knowledge and pedagogical knowledge (Mishra & Koehler, 2006).

2.4 Inclusivity and ICT—Enhancing Learning in a Diverse Classroom

The South African government through the Department of Basic Education has tried to increase the pass rate in mathematics for the National Senior Certificate Assessment and Examination, however many students are still performing below the required levels. The few that pass mathematics and proceed to train as teachers at the university level had passed it with minimum requirements; students that pass mathematics at higher grade prefer to do other courses at university. Students with learning disabilities are heavily affected. They are given less attention because of the high demand of the curriculum and the ever-increasing lecturers' workload. The trend is similar for those who would have chosen teaching as their career.

Currently, many young people with disabilities (deaf, blind, or physically challenged) are undertaking tertiary education. However, because of the lack of facilities to meet their needs in mainstream teaching and learning environments, students with disabilities are more likely to quit university than abled students (Pacheco, Yoong, & Lips, 2017). ICT offers new ways of supporting the learning of physically and mentally challenged students by providing support arrangements, collaboration, and participation to manage the transition, develop new skills and see themselves as independent students and self-determined young adults. Tom, Mpekoa, and Swart (2018) noted that the South African Council of the Blind confirmed that there are special schools in the country. These special schools are supposed to play a pivotal role in ensuring that the individual needs of the physically and mentally challenged students in the country are met. Inclusive education was introduced to remove barriers to learning for disadvantaged groups. The individual needs of these students are met in special schools. But the moment they leave secondary education to go to tertiary institutions, these marginalised students' needs are going unmet. They need to adapt to a new environment where their individual needs are no longer accommodated. There is an emerging hope that ICT technologies can cater for the needs of these disabled young people and give them universal access to education and enable them to participate equally in the learning environment with their disabled colleagues (Bouzid & Jemni, 2017). Teaching mathematics with ICT technologies that come with infrared systems, visual communication devices, sound and speech-to print software, virtual reality environments, and interactive smartboards could convey information visually and enhance auditory and visual information (Bouzid & Jemni, 2017). Mathematics education lecturers can use these advantages to support inclusive education by providing multimedia platforms that combine text, sound, and animation. Shifting beyond traditional modes of education, the integration of ICT has become an advantage for students with specific needs. ICT brings forth a flexible and accessible mode of education. Furthermore, the use of ICT bridges the gap of learning across borders. Students can have the access to other universities and mathematics academic resource materials from other countries, thereby expanding their knowledge base. With such advantages, it is critical to deliberate upon the development of pedagogical ICT use in the classroom.

2.5 ICT Integration in the Teaching of Mathematics in Schools of Education Globally

With the digitisation of communities, mathematics education lecturers need to develop competencies required by the 21st century world. Students graduating from teacher training institutions should be equipped with ICT skills set that can be used in teaching mathematics and to participate in modern society and work-life that uses information super-highway. Many governments across the globe expect ICT to be integrated into the teaching of mathematics to support the learning processes and improving the quality of education. Despite these expectations, "research reports a gap between expectations and actual usage" (Utterberg, Lundin, & Lindström, 2017). ICT types of equipment are mostly used outside teaching and learning spaces. Many students at teacher training institutions, particularly is South Africa, tend to spend most of their time playing games and watching videos instead of using ICT for academic purposes. Mathematics education lecturers seem to be struggling to use mathematics software applications (for example, Statistica, GeoGebra, MathsExpert, SPSS Statistics, Fathom, Excel, etc.) in the teaching of mathematics. Generally, some on the public domain consider integrating ICT in teaching and learning time-consuming while others consider it as an added curriculum on top of the overburdened curriculum. Yet, the contemporary students are expected to teach using ICT and for them to be able to do that, ICT integration in teaching of mathematics should start at teacher training institutions.

On-campus teaching exposes pre-service teachers to several opportunities concerning integrating ICT in their subject areas. In teacher training, there are methodology courses that prepare pre-service teachers for the theoretical part of how to teach the subject. It is these courses that education mathematics lecturers can take advantage to demonstrate how to integrate ICT and give pre-service teachers a chance to practice the skills taught and be evaluated on their performance and application during teaching practice (Jita, 2016). Teaching experience provides pre-service teachers with an excellent opportunity to test and experiment with their knowledge and skills (Kabilan & Izzaham, 2008). Teaching practicum is an ideal platform for pre-service teachers to learn about ICT for pedagogical purposes through repetitive practice. In order to develop competent pre-service teachers, support systems need to be established that includes the use of topic-specific application software during lectures.

ICT is gaining ground as a learning tool in European countries and the USA. Many educational institutions have expanded the ICT infrastructure in classrooms (Gil-Flores, Rodríguez-Santero, & Torres-Gordillo, 2017). Countries like the UK, USA, Japan, and Australia have also invested in mobile and classroom-based technologies such as portable devices and interactive whiteboards. Despite this advancement of infrastructure in schools, McGarr and Gavaldon (2018) stated that “research indicates that pre-service teachers’ use of ICT is often less than expected, even though they express positive opinions of its benefits” (p. 1). This might be because there are limited training on how to integrate ICT during pre-service teacher training. Thus, it is a challenge for schools of education to show professional competence that will ensure the pre-service teachers will embrace ICT in their teaching.

The USA, Australia, the UK, Brazil, Singapore, and New Zealand have national policies that make ICT integration mandatory (Cuban, Kirkpatrick, & Peck, 2001; Ng & Gunstone, 2003; Priest, Coe, Evershed, & Bush, 2004; Lai & Pratt, 2004). Governments have to inject a large amount of capital to make technology in the classroom possible. Thus, these countries have invested a lot of money with the hope that ICT will enhance teaching and learning, prepare learners for a technology-driven world, and equip students to meet the demands of a society that is rich with information so that they may use it for creativity and innovative purposes (Drent & Meelissen, 2008; Kozma, 2008). Following international trends, the South African government has also invested a lot of money in ICT in all its educational systems with the hope of enhancing the quality of learning to emancipate its citizens to contribute to its economic and social growth (DoE, 2004; Kozma, 2008). The government has succeeded in equipping universities with the necessary ICT infrastructure (computers, Internet connections, Wi-Fi, interactive boards, tablets, overhead projectors); however, the uptake of ICT use by mathematics lecturers in the schools of education is still very low. This goes against the requirement in the MRTEQ (2015) that ICT is a prerequisite skill that all graduating South African teachers must be competent in.

2.6 ICT Integration in the Teaching of Mathematics in the Schools of Education in Africa

Research conducted by Adler (2017) indicated that "there is increasing agreement that there is specificity to the mathematical knowledge that is required and used in the work of teaching". This implies that this kind of knowledge should be included in pre-service education and augmented with ICT. Appropriate knowledge of ICT and mathematics is of paramount importance, and pedagogical training in ICT integration of mathematics is essential. However, the skill of integrating ICT in teaching mathematics is a challenge among sub-Saharan African countries.

Despite the positive promises that ICT offers in enhancing understanding of mathematics, there is very limited evidence to suggest that mathematics lecturers in the schools of education in sub-Saharan Africa are training their pre-service teachers on how to teach mathematics using ICT. Governments in sub-Saharan Africa countries have invested heavily in ICT with the hope of developing teachers to effectively use ICT in their classroom and raise educational standards but to no avail. Hennessy, Harrison, and Wamakote (2010) noted that the reason for the low uptake of ICT in schools of education in many African countries is the lack of qualified personnel. This problem is further exacerbated by teaching staff's negative beliefs and attitudes towards ICT. Many practicing teachers, especially those that were trained before the era of technology are technophobic (fear to use technology), which hinders the use of ICT in classrooms (Hennessy et al., 2010). Teaching with ICT tools such as mathematical educational software makes the teaching relevant to students because today's generation of students live and breathe ICT.

Another major obstacle common in sub-Saharan African countries is the lack of ICT framework policies that talk to ICT integration across the school curriculum. Most schools of education treat ICT as a discrete subject either called computer science, computer studies or information technology and it is examined by the national examination boards (Hennessy et al., 2010). Outside this subject, it is known as basic ICT skills, to which many students are exposed. Du Plessis and Webb (2012) suggested that integrating ICT in teaching is not the norm in South African schools and the pattern has cascaded upward to teacher training institutions.

2.7 ICT in Schools of Education

In a field where expectations for academic outcomes to adapt to any societal change is high, pre-service education systems play a pivotal role in preparing teachers to use ICT in the classroom (Chai, Koh, & Tsai, 2010). Kaufman (2015) asserted that education is under pressure to "respond to a technically driven society and the broad use of information communication technology" (p. 2). With an influx of ICT gadgets, teachers can use these modalities (such as smartphones and computer applications) to engage with students and disseminate new information. This section gives an overview of some of the challenges faced by schools of education with a particular interest in how mathematics lecturers prepare pre-service teachers to use ICT for pedagogical purposes. First, I unpack the influence of sociocultural capital on ICT integration in teaching and then look at the responsibilities of mathematics lecturers who prepare student teachers to effectively use ICT in their teaching.

2.7.1 Social and Cultural Capital on ICT Integration

Social capital theories are classified into individual social capital and collective social capital based on the level of analysis that the corresponding theories involve. However, social capital as described by Bourdieu (1986) highlights the importance of social interaction in building and maintaining social capital. Sociocultural views of learning in teacher training institutions are the socialisation and sharing of learning cultures, leading to shared knowledge through human interactions (Smidt, 2009). Pre-service teacher learning is influenced by social interactions (or engagement) with their lecturers and peers. Mathematics education lecturers in this study are seen as change agents who bring pre-service teachers into the culture of teaching with the rightful knowledge required by the society they serve. The premise behind the notion of social capital is the investment in social interaction with expected returns (Lin, Cook, & Burt, 2001). This view forms a base to link social capital, at both individual and collective levels, and ICT, which enables human beings' greater capability for social interaction than before.

Kakihara and Sorensen (2002) argued that ICT is continuously reshaping human interaction. This interaction is the precondition of social capital maintenance and recreation at both individual and collective levels (Lin, 2017). Social capital is productive but it can be depleted if it is not renewed (Coleman, 1990). It depends on social networks, which are the structure of relations among actors. Social networks, however, are not a nature given and must be constructed and renewed through investment strategies oriented to the institutionalisation of relations (Bourdieu, 1986). Social interactions are effective strategies for constructing social networks and creating trustworthiness and norms of reciprocity. Mobility facilitates and transforms social interaction. It is central to gluing social networks together and avoiding social exclusions that reduce social proximity and social capital (Urry, 2002). It is, therefore, noted that using ICT is a mechanism through which ICT affects social capital. For instance, institutions of learning have broken down the barrier of who has what or who can afford what. Mathematics pre-service teachers within the institution of their training have equal access opportunities to ICT technology and can do their research in a manner that suits them. Learning mathematics in the 21st century relies on learning with fellow students and learning with a skilful partner such as a teacher or mathematics computer software.

Social capital is both individual and collective (Lin, 2017). Thus, institutionalised social relations with embedded resources are expected to benefit both the collective and the individuals in the collective. Therefore, the impact of ICT could change individual social capital as well as collective social capital. However, these changes do not happen at the same time. Components of ICT, such as the Internet and mobile phones, are first used by individuals and progressively diffused to a larger population. Similarly, these ICT gadgets started as business utilities, but now they can be used for educational purposes and help enhance learning. Their impact on social behaviours and phenomena, including social capital, tends to be progressive. How individuals react to ICT use confirms that this technology has an influence upon our society.

2.7.2 The Role of Mathematics Education Lecturers

The preparation of pre-service teachers is the responsibility of mathematics education lecturers and schools of education as the providers of the knowledge. Teo, Chai, Hung, and Lee (2008) argued that it is the role of teacher education to ensure that pre-service teachers are provided with tools and experience that will enable them to use technology in the classroom. Thus teacher training programmes should be designed in such a way that it includes opportunities for pre-service teachers to learn about embracing ICT in their teaching. However, the current teacher training programmes do not seem to be preparing the 21st century teachers who need ICT skills to enhance learning in mathematics. A number of teachers graduate from their universities without adequate skills to harness technology in their instruction.

Brun and Hinostroza (2014) noted that the use of technologies is still on the periphery of core teaching and learning activities. Mathematics education lecturers are hesitant to solve more complex pedagogical activities using ICT. It is evident that for pre-service teachers to appropriate and integrate ICT into their teaching practices, it is essential that learn it at the schools of education. Pre-service teachers should understand the need to use ICT in the first place in order to create opportunities for them to use ICT as part of their teaching practice. To realise this, the use of ICT should become a routine part of their lives for them to gain skills and confidence to use ICT. The use of ICT tools has the potential to enhance teaching and learning of mathematics, by engaging students in instructional activities to increase their learning, and by helping them to solve complex problems in mathematics to enhance their cognitive skills.

In recent years, Aslan and Zhu (2016) wrote about teacher programmes and how they prepare pre-service teachers. They argued that schools of education should reflect their role as pre-service teachers' preparers. They added that lecturers should support their student teachers to integrate ICT into their teaching practice. In addition, they reiterated that pre-service teachers should be assisted to experience rich ICT learning environments, which will make them gain the needed skills and knowledge they will apply in their teaching practice. Mathematics education lectures in the schools of education need to demonstrate the use of ICT with their pre-service teachers in ways that will enhance their understanding of how to harness ICT for pedagogical purposes. Manning and Carpenter (2008) agreed that “Few teachers are adequately prepared to use technology themselves or to help students use technology in the classroom” (p. 48). They further argued that these issues must be addressed to ensure that pre-service teachers are prepared to use ICT effectively in their teaching practice. Many teacher education programmes do not prepare pre-service teachers for innovation and inventive teaching methods because most mathematics education lecturers’ ICT knowledge is basic (Goldstein et al., 2011). From the foregoing, it seems that most lecturers are limiting pre-service teachers from adequately using ICT. This study aims to coerce mathematics lecturers to use ICT in their teaching by providing a model that will provide them with an understanding of how they may pedagogically appropriate and integrate ICT into their lecturing practice. The model allows the lecturers insight into how they can appropriate and adopt ICT integration in innovative ways that will, in turn, help their pre-service teachers use ICT for pedagogical purposes.

2.8 Significance of ICT in Teacher Training Institutions

The proliferation of ICT has had an impact on the teaching curriculum and continues to create more challenges for education and training in the world. The challenges include participating in the information community and the integration of ICT in the learning and teaching process among other things (DoE, 2004). The DoE through the Curriculum and Assessment Policy Statement (CAPS) (2011) addressed the needs of the South African education system in the 21st century. The Department of Communications (2014) in the “National Integrated ICT Policy Green Paper” advocated “building a knowledge economy and information society that requires new capabilities, such as the ability and use of ICT”. All these policies are rather silent on how to integrate ICT in the teaching of mathematics in order to capacitate contemporary students with processes that enhance logical and critical thinking, accuracy and problem-solving that will contribute to decision-making. Mathematical problem-solving enables students to understand the world (physical, social and economic) around them, and most of all, empower them to think creatively. ICT improves the quality of education and training, and it is against this background that the South African government is called to embark on integrating ICT in the classroom (DoE, 2004). As I am writing this thesis, it has been over 10 years since the "White Paper on e-Education" (DoE, 2004) was published; however, there is no progress in integrating ICT in mathematics. In addition, there is no evidence that there is a revised white paper document that will explain how ICT may be integrated into the teaching of mathematics.

Policymakers play a unique part in bringing about change. The continuous emergence of new technologies in education challenges the roles of teacher education institutions on the new pedagogies and new approaches needed to prepare initial teachers. Accordingly, teacher training institutions will be a crucial component of this educational improvement (UNESCO, 2011). The "White Paper on e-Education" (DoE, 2004) highlighted the need to integrate ICT in the learning and teaching process. In addition, in 2004 the South African Department of Basic Education designed a policy on e-education to guide and support effective ICT integration in the classroom in South Africa. The White Paper (DoE, 2004) described education and ICT as two intertwined entities:

e-Education revolves around the use of ICTs to accelerate the achievement of national education goals. e-Education is about connecting learners and teachers to each other and professional support services and providing platforms for learning. e-Education will connect learners and teachers to better information, ideas and one another via effective combinations of pedagogy and technology in support of educational reform. It supports larger systematic, pedagogical, curricular and assessment reforms that will facilitate improved education and improved use of educational resources such as ICT. (p. 14)

This statement underscores the importance of the interface between learners and teachers in the teaching situation where both are key players in the field of learning and need to interact with one another in the teaching and learning process. Teachers need continual professional support services to be aligned with emerging ICT solutions. It is therefore necessary to craft a national framework for teacher development in ICT. Once the framework is developed, it will provide teachers, managers, and policymakers with the needed skill set to integrate ICT in the classroom. Teachers in the majority of South African public schools have been trained in basic computer skills (Ndlovu & Lawrence, 2012); however, this is inadequate to integrate ICT in the curriculum.

In his report Layard (2009), though debatable, indicated that the majority of South African teachers cannot go beyond using ICT to prepare their lesson plans. This is an indication that teacher training institutions are not playing a big enough role in preparing future teachers who can integrate ICT in their teaching practice, although ICT had permeated our societies since the early 1990s. The "White Paper on e-Education" (DoE, 2004) suggested that the DoE should collaborate with teachers, administrators, and managers in pre-service teacher training programmes delivered by higher education institutions to ensure the inclusion of ICT integration in schools was happening. The aim was that the teacher training institutions should provide initial teachers with the knowledge and skills required to integrate ICT into subjects of specialisation.

Tertiary institutions and schools have been given the responsibility of imparting ICT skills to South Africans. Knowledge of ICT is important in contemporary society. The policies spell out the crucial education system that prepares educators to meet their essential and demanding task to "continually enhance their professional competence and performance" in teaching (DoE, 2007, p. 17). Policies, curriculum and assessment are more related to governmental accountability to render services to its people. The government and provincial education departments provide an enabling environment (support and funding) to educational planners to develop or update the curriculum that will assist them to produce high-quality teachers. The Department of Higher Education and Training facilitates monitoring and makes a comprehensive and thorough evaluation of innovations for future curriculum development that supports diversity in skills.

The information-based society demands that the teacher training institutions continuously improve in preparing new generations of teachers to take full advantage of the new sociocultural and economic conditions (Brun & Hinostroza, 2014). Consequently, teacher training institutions should focus on transforming initial teachers to cope with the new demands of the 21st century that require integration of ICT in the classroom. UNESCO (2002) reported that pre-service teachers lack the confidence to integrate ICT in their classrooms because they lack previous practice in applying ICT into the curriculum.

Mathematics lecturers are required to cope with the new demands of the information age (that requires teaching that facilitates leveraging relevant ICT resources as meaningful pedagogical tools) to integrate ICT into their lecture rooms. Teacher training institutions, including those in South Africa, train pre-service teachers' basic ICT skills and competencies (UNESCO, 2002), however, very little is said on how they prepare them to integrate ICT in the classroom to meet the changing landscape of contemporary society (Lynch, 2015). The ICT policy (DoE, 2004) had advocated that every South African learner should be ICT capable (use ICT confidently) by 2013, however, the situation on the ground is not convincing. There is a possibility that South African schools will continue to produce students who are semi-competent in the use of ICT in this 21st century. Teacher education institutions have the challenge to prepare pre-service teachers to successfully integrate ICT into the teaching and learning process (Aslan & Zhu, 2016).

"The South African National Framework for Education and Development" (DoE, 2007) was crafted and developed to equip teachers with the 21st century skills set, and pre-service teachers should be taught to master a plethora of ICT integration strategies in the classroom. ICT capabilities should be integrated into the curricular and pedagogical content to prepare initial teachers to create new learning environments. Mathematics lecturers should, therefore, use these new learning environments in their lecture rooms (UNESCO, 2002). The curriculum for mathematics lecturers is generally rich with strategies for presenting subject content and pedagogy; however, it may be lean in terms of integrating technological tools for supporting that learning (UNESCO, 2002). Consequently, curriculum developers for educational programmes need to identify an appropriate framework that will be used to model ICT integration throughout the entire training of the pre-service teachers.

Teacher training institutions, as preparers for initial teachers on pedagogy, subject content mastery, classroom management skills and use of various teaching tools, including ICT, serve the following purposes (Du Toit, 2015):

- To prepare teachers to use ICT in pedagogy concerning competencies; and
- To prepare teachers to teach ICT-related content.

There is a need for South Africa to exploit the increasing convergence, sophistication, and reach of ICT (Technology & Science, 2018). The report cites the National Development Plan that recognises that ICT underpins a dynamic, inclusive and prosperous knowledge economy in which seamless information infrastructure and systems will meet the needs of citizens, businesses and the public sector. Such a situation where advances in ICT are used to strengthen economic competitiveness, generate youth employment and enable an enhanced quality of life can be described as a digital advantage. The attainment of a digital advantage is crucial if South Africa is to participate effectively in the Fourth Industrial Revolution (also known as 4-IR or Industry 4.0) to profoundly shape the country's effort to promote industrial development. The scale, scope, and complexity of this new technological revolution can bring experiences unknown to humankind in the form of cyber-physical systems where computers, networks, and physical processes are integrated. ICT is already playing an important role in transforming other sectors of the economy; however, in the educational system, there appears to be no systematic way of how ICT can be used for pedagogical purposes. More changes are expected in terms of new models for open-access, mobile, lifelong and ubiquitous learning beyond the traditional classroom. Integrating digital technologies into the provision of government services (e-government) and the management of cities (smart cities) has the potential to transform the scope and efficiency of public services.

The South African Cabinet approved the ICT Research Development and Innovation Roadmap, entitled "Our Digital Future" in 2013. The Roadmap identifies several strategic domains including ICT infrastructure for development. It is underpinned by the potential in the ICT sector and aims to enable South Africa to exploit ICT opportunities in areas such as sciences, m-health, e-services and education (Technology & Science, 2018). Klopfer, Osterweil, and Salen (2009) said that ICT can have a reciprocal relationship with teaching. The emergence of new technologies pushes mathematics education lecturers to understand and leverage these technologies for classroom use, and at the same time, the on-the-ground implementation of these technologies in the classroom will directly impact how these technologies continue to take shape. Undoubtedly, without these recent mathematics software applications (MATHEMATICA, GeoGebra, MathsExpert, Statistical software, etc.) in the classroom, strong lessons can still be achieved, however, there will be a sharp disconnect between the way pre-service teachers are taught in their teacher training programme and the way the outside world approaches socialisation, meaning-making, and accomplishment.

Despite significant spending by governments on equipping schools, vocational training colleges, and the universities with technical equipment and training, ICT adoption and implementation in schools for learning and teaching are often low. Government and organisations are motivated to support funding schools and crafting of policies relating to ICT integration by the potential for enhanced quality education and the transformation of pedagogy in classrooms. Basic reasons for integrating ICT integration in the classroom are to equip students with the knowledge and skills to participate in a thriving information society and create a highly skilled and readily available workforce (Gill & Dalgarno, 2008). The Net Generation students are expected to integrate the Web 2.0 technologies into their teaching programmes (Thompson, 2007).

This research advocates a ‘hands-on’ kind of teaching. The constructivist model is relevant in this study because it is more practical, and therefore, pedagogical strategies that can be employed in integrating ICT in teaching should be linked to the constructivist paradigm (Alimisis, 2007). Accordingly, in constructivism, knowledge is considered individually and socially constructed. Pre-service teachers may construct their own meaning through exploration and connecting interaction with their peers. ICT-based learning demands that teachers play a new role (Alimisis, 2007) and that they should expose and model crucial ICT-based examples and design ICT-based activities for their classes. Moreover, through ICT pre-service teachers can collaborate with their lecturers and peers and establish communities of practice (CoP) that allow them to construct their own knowledge base on different subject aspects. Zhou and Brown (2015) asserted that learning by seeing and doing is instrumental in teacher training institutions. Thus, cognitive apprenticeship training (Brown, Collins, & Duguid, 1989) that enculturates trainees (with zero experience of integrating ICT in teaching) into authentic practices through activity and social interaction in a real-world environment is considered ideal.

ICT pedagogical practices in teaching and learning have diverse functions that enable learning to be more interesting at teacher training institutions. Jung (2005) supported the innovative nature of ICT by affirming that "selecting appropriate ICT tools and supporting students in the use of these tools promotes learning activities and develops new methods of facilitating learning" (p. 95). Pre-service teachers can be trained through ICT-supported teaching strategies in their subject areas and mathematics lecturers can easily manage trainee-centred learning methods using ICT tools (Goktas, Yildirim, & Yildirim, 2008). The continued development of new ICT tools presents challenges to policymakers and pre-service teacher education on how to rethink the way they deliver a curriculum that meets the expectations of the pre-service teachers that are meaningful in the 21st century with regard to appropriating and integrating ICT into mathematics teaching practice. The South African government through the White Paper on e-Education (which acts as the official governing policy on e-education) "supports longer systematic, pedagogical, curricular and assessment reforms that facilitate improved education and improved use of educational resources such as ICT" (DoE, 2004, p. 14). The principal goal of the policy is that "every South African teacher and learner should be ICT capable" (p. 17). Education mathematics lecturers need to rethink on how they can use ICT not only for effective teaching and learning, but to think deeply on what ICT tools can be used to support mathematics curriculum delivery and build capacity through collaboration and cooperation (Blignaut, Hinostroza, Els, & Brun, 2010).

2.9 Learning Theories in ICT Environment

The three broad learning theories such as behaviourism, cognitivism, and constructivism are most often applied in the creation of instructional environments. According to Siemens (2014), these theories were in existence long ago before technology interrupted the way we lived, and thus, are not addressing the current issues that involve ICT. Connectivism is a learning theory that uses Internet technologies that have created new potentials and opportunities for students to learn and share information across the Internet and among themselves. In connectivism, learning occurs when knowledge is triggered through the process of connecting to and feeding information into a learning environment. The current learning is impacted by ICT. The advent of ICT has restructured how we live, how we communicate, and how we teach (Siemens, 2014). The behaviourism, cognitivism, and constructivism theories all have the limitation of failing to address the learning that is situated within ICT and organisations, and in addition, lack contribution to the value judgements that is needed in a knowledge-rich environment.

The assumption in behaviourism is that humans master small pieces of knowledge in phases, which over time will somehow merge to become whole. For instance, mathematics is considered as a complex subject and poses many challenges to South African learners, thus advocating a behaviourist approach of teaching. The approach assumes levels (or hierarchy) of knowledge acquired in a linear fashion. The conjecture is that knowledge is gained through passing stages pegged in a line, starting from simplest to complex. As learners pass these points, they assemble blocks of knowledge (Biddulph & Carr, 2017). The role of the educator is formulating specific learning outcomes (or objectives) on the knowledge to be acquired at a specific time. The overarching point is to get students to some predetermined concept of knowledge through transmission by the teacher or textbook. The knowledge transmitted is broken down into logical pieces, and a system of reward or punishment may accompany the teaching with the teacher at the top of the system. This teaching approach atomises knowledge and makes the teacher the source of knowledge and students dependent on the teacher not on themselves. With technology and Internet connectivity, there is no need for mathematics lecturers to play the role of the fountain of knowledge. Pre-service teachers can easily access the information through the Internet and get the information on their own that is probably more detailed and comprehensive than what their lecturer would have delivered.

Cognitivism advocates a view that knowledge resides entirely in the individual's mind. It adopts the notion of teacher knowledge and ignores 'tacit knowledge' (skills, ideas, and experience people have in their minds) that is stretched across people and their settings (Kelly, 2006). The assumption is that separating the acquisition of knowledge, skills, and experience from people, a process of transmitting knowledge is assumed. The advent of ICT has altered (rewired) our brains; the tools we use to define and shape our thinking. Many of the processes previously handled by learning theories (especially in cognitive information processing) can now be off-loaded to, or supported by, ICT. Furthermore, cognitivism overlooks the social context in which the teacher works and the knowledge they have.

The constructivist approach assumes that learning is a personal linking of ideas and skills. The idea of constructivism is as old as time. The concept of assimilation and accommodation was proposed by Piaget and some of Vygotsky's ideas about learning are constructivist in nature knowledge (Biddulph & Carr, 2017). Students invoke their already existing ideas and process them to produce new ideas. Learning often involves extending, reorganising or changing the present ideas through interaction with others. Constructivism's pitfall is that it assumes that learning is influenced by existing ideas, which act as input for the outcome of other ideas. It ignores the fact that human knowledge is rooted in tacit knowledge. With the influx of ICT, students can customise the way they want to learn mathematics.

ICT has brought up the issue of connectivism among players in any organisational setup. Kop and Hill (2008) viewed connectivism as a theoretical framework that enables individuals to understand the learning process. Learning occurs when knowledge is triggered, and then a learner connects to and feed information into a learning community. Siemens (2004, in Kop & Hill, 2008) stated that "a community is the clustering of similar areas of interest that allows for interaction, sharing, dialoguing, and thinking together" (p. 2). In a connectivism environment, cognitive tasks are shared between people and technology. People create a network as they solve complex problems. Network is defined as "connections between entities, which could be nodes" (Bell, 2011). Nodes in this set up can be individuals, groups, systems, or communities.

Mathematics lecturers make connections as they interact with their students and so do the students among themselves and with their learners. In this contemporary world, our competence is derived from forming connections. Meaning-making and forming connections occur between activities made by mathematics lecturers and their students (a process Siemens (2014) called specialised communities). In a learning environment, a concept of learning can be linked, depending on how well it was currently linked. Nodes, which can be ideas or communities, thus resulting in the cross-pollination of learning communities. Mathematics lecturers thus have to nurture and maintain connections to facilitate continual learning.

The connectivism theory presents a network model of learning that admits the paradigm shifts in society where learning is no longer an individualistic activity. However, learning occurs among networked nodes/entities where they share knowledge. How people work and function is altered when new tools are utilised. ICT has altered the way mathematics lecturers operate. Needless to say, the field of education has been slow to embrace the impact of new learning tools and environmental changes in teaching and learning. Connectivism creates the space for learning skills and tasks needed for the contemporary 21st century pre-service teachers to flourish in a digital era.

2.10 ICT Affordances and Teaching of Mathematics

To improve mathematics knowledge, there is a great need for material support to be available for both mathematics education lecturers and the pre-service teachers. The National Council of Teachers of Mathematics (NCTM) Principles and Standards for School Mathematics (PSSM) technology principle view technology as an essential teaching and learning tool for mathematics and have capabilities of enhancing students' learning, (NCTM, 2000). Recently, there have been a lot of improvements in the development of mathematical software such as GeoGebra, MATHEMATICA, Statistica, MathsExpert, SPSS Statistics and Fathom that mediates learning. For instance, these mathematics software may enable mathematics students to become effective independent learners, (Hall & Chamblee, 2013). Furthermore, Some research results indicate that these ‘software packages can encourage discovery and experimentation learning within the classrooms and their visualisation features can be effectively employed in teaching to generate suppositions’ (Hohenwarter, Hohenwarter, Kreis and Lavicza, 2008). Despite the fact that different packages support teaching at various levels, they can be used in teaching to enhance students’ understanding.

Even students with mathematics challenges can succeed herein because these software have possibilities in placing everyone on the same level. In addition, a lot of research in simulation and modelling through computer programming has been done for both lecturers and students to help understand everything from elementary mathematics to complex problems. These developments have raised the awareness of possible tools mathematics education lecturers and pre-service teachers can use to support teaching and learning. Mathematics software applications have the potential to facilitate an active approach to learning, allowing students to become involved in discovery learning and consolidating their own knowledge. The emergence of these mathematical tools and their ability to deal with most of the education mathematics cannot be ignored by mathematics education lecturers.

The 21st century has been characterised by the emergence of ICT and change in global communications induced by the digital environment: “Every country in the world places great importance on ICT development trends and they are actively proposing macro policies to provide a blueprint for information development. Because of its constant development, ICT has become an inseparable aspect of life” (Meng & Hsieh, 2013, p. 82). Currently, great efforts are being made to explore the influence ICT tools have in our society. By producing various new forms of social interaction and changing the ways that people engage with each other, people’s social capital has been transformed:

“ICT allows us to create, collect, store and use knowledge and information; it enables us to connect with people and resources all over the world, to collaborate in the creation of knowledge and to distribute and benefit from knowledge products”. (Tondeur, Sinnaeve, Van Houtte, & Van Braak, 2011, p. 152)

In teaching and learning mathematics, students can integrate technology using Excel computer software to create graphs, create frequency tables, histograms, and distribution polygons of favourites, pie charts, and income data analysis. In addition, Excel software can be used to determine the mean, median, mode, interquartile range and midrange of data sets. In applied statistics, Excel software and some statistical software can be used to solve the following problems:

- Standard Deviations and variance of data sets
- Linear, quadratic and cubic regression
- The correlation coefficient, r

Digital technologies have become a highly valuable resource in education and are deemed necessary tools in education (DiGiuseppe & Partosoedarso, 2014; Melton & Kendall, 2012). Without a doubt, pre-service teachers in their training institutions are exposed to a variety of digital devices and applications. Therefore, it is important to have a deeper understanding of technology affordances and how they contribute to teaching and learning. The term affordance was first coined by Gibson (1977, 2014) Greeno (1994) and then McGrenere and Ho (2000) expanded Gibson’s definition to cover both usability and usefulness. In our case, affordances are considered in relation to human-computer interfacing as applicable in education and in connection with the opportunities that technologies bring into teaching and learning (Hammond, 2014). While ICT tools are perceived as useful education tools that support learning activities, it is vital to unearth the features of technology that support pedagogical activities such as evolving mathematics application software, statistical software, Microsoft Excel and PowerPoint.

The affordances perspective was promoted in design and human-computer interaction research by Norman (1988), who defined affordances as the design aspect of an object. This definition states that the nature of an object informs how it should be used. However, subsequent scholars argued that affordances can emerge through direct interaction with technologies, which often leads to processes of experimentation and adaptation that shape the actions people take with technologies (Evans, Katty, Vitak, & Treem, 2017). Gibson's theory of affordances proposes that "the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Thapa & Hatakka, 2017). The potential value of technology affordances in education is most relevant in mathematics classrooms and contemporary teaching and learning environments. The study looks at the interaction between mathematics education lecturers and pre-service teachers in using the opportunities provided by ICT for pedagogical purposes. The provisioning of ICT infrastructure must not be construed as automatically affording pre-service teachers an opportunity to harness ICT in their teaching; the practice should begin at their teacher training programmes. Despite the availability and abundance of ICT infrastructure at pre-service teacher training institutions, it is disappointing to note that the rate at which ICT infrastructure is used for pedagogical purposes is very low even though high investments have been made to improve ICT access.

Some of the benefits of ICT are that it can capture, store, process, and provide information to learners and teachers in multimedia formats such as text, sound, video, etc. Information and data delivered via ICT in multimedia formats allows for a range of user preferences and study approaches. Another unique feature of contemporary ICT is its ability to support both synchronous and asynchronous communication. Despite these potential affordances of ICT, in the South African education system, it is mainly taught as a subject instead of being integrated as a pedagogical tool (Kafyulilo et al., 2015).

The lives of the current generation of learners are different from earlier generations because of the prevalence of ICT (Cameron, Bennett, & Agostinho, 2011). Today's learners are proficient in multitasking and active experiential learning and are dependent on communications technologies for accessing information and for interacting with others (Oblinger & Oblinger, 2005). Combes (2006, in Cameron et al., 2011) claimed that the skills possessed by today's generation are based on the premise that constant exposure to technology since birth means young people have an in-depth grasp and almost intuitive knowledge of how to use technology. The rejection of ICT is no longer an option as it derails the government's effort to implement the use of ICT in teaching and learning. ICT is fundamental to learning in the information age, and thus mathematics lecturers must be ICT competent to meet the demands of the 21st century classroom and to enhance the quality of education. Mathematics lecturers in the schools of education are expected to be facilitators, open-minded, analytical, active cooperators and collaborators, mediators of knowledge, and providers of knowledge to reinforce understanding.

2.11 Conclusion

The chapter reviewed literature on the influence of government policies on the use of ICT in South African and international education, including pre-service education. The chapter set out clearly how mathematics lecturers use ICT in their teaching practice, both internationally and within South Africa. The review of the literature discovered that mathematics lecturers' teaching is still dominated by textbooks and talking. However, the importance of pedagogical ICT integration in the teaching of mathematics was revealed. The use of ICT is that it supports pre-service teachers' skills and relationships across different contexts.

The notion that mathematics pre-service teachers' learning occurs through their participation with ICT tools as part of activities that include practicum, and mathematics teacher lecturers modelling and support for critical reflection was highlighted. The responsibilities and role of institutions of higher learning in preparing pre-service teachers to understand how they might use ICT in their teaching was explored, including some of the complexities involved in mathematics lecturers ensuring that their students understand how to appropriate and integrate ICT into their teaching practice.

Chapter three discusses ICT theoretical and conceptual frameworks. It further looked at the strength and weaknesses of these ICT theoretical and conceptual frameworks have with regards to ICT integration it teaching of mathematics.

CHAPTER 3: MODELS AND THEORIES

3.1 Introduction

The previous chapter focused on the importance of pedagogical ICT integration in the teaching of mathematics as revealed by several researchers. It also shed light on the government's stance on advocating teaching using ICT through policies and the kind of teachers that are expected to be relevant in the 21st century. So many models and theories have been proposed on how to integrate ICT in the teaching of mathematics. According to Maxwell (2008) posits that a 'conceptual framework' and 'theoretical framework' is the same thing within a study. However, he further defines 'conceptual framework' as the framework of 'concepts, assumptions, expectations, beliefs, and theories that supports and informs your research'. The use of a framework provides researchers with an understanding of what they are studying (Mertens, 2005). On the other hand, the theoretical framework is described as 'the "blueprint" for the entire dissertation inquiry' (Grant & Osanloo, 2016, p. 13). Simply put, it serves as the plan on which to build and support the study. A model guides how to facilitate effective change (Kirkman, 2000). This chapter focuses on the following three models and then adopts one theory as depicted in Figure 2. These models and theory were thoughtfully chosen because they can be adopted for teaching mathematics using ICT. The strength and weaknesses of each model are discussed and the reasons for choosing the theory underpinning the study are highlighted.

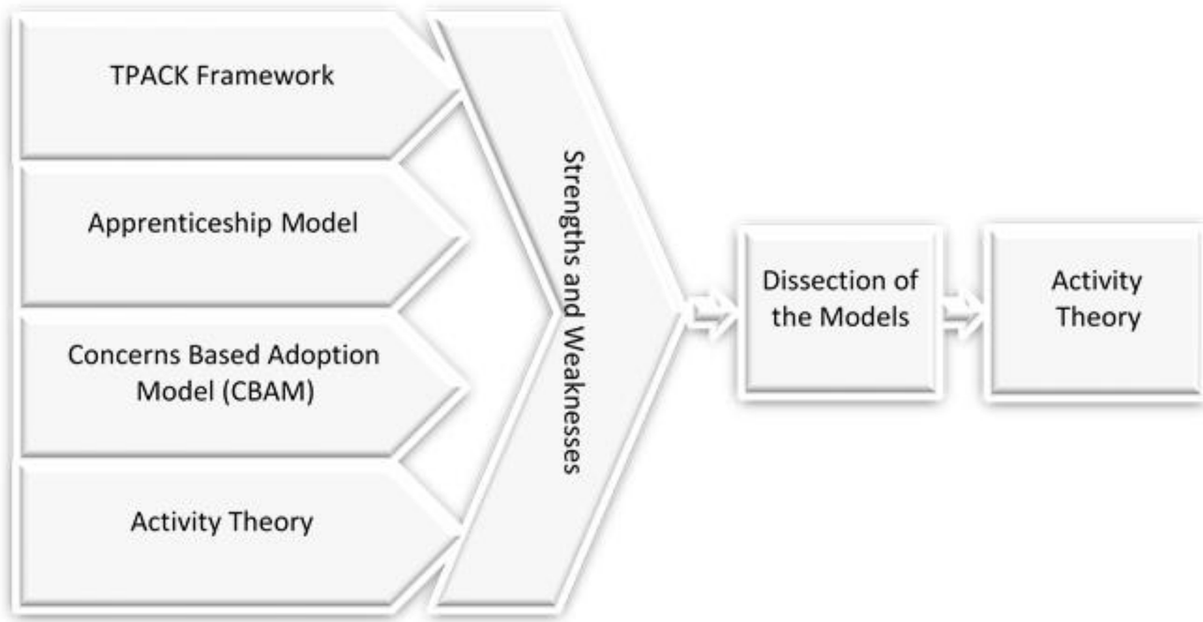


Figure 2: Models and theory considered

3.2 Teacher Educator Knowledge Types

Knowledge of technology has become an important part of mathematics teachers' overall knowledge (Koehler & Mishra, 2006). The type of knowledge that mathematics education lecturers must have in order to integrate ICT is how to use technology itself. Ertmer and Ottenbreit-Leftwich (2010) argued that teachers lack the knowledge about the technology itself to build on existing pedagogical content knowledge propounded by Shulman (1987, 1986). Pedagogical content knowledge, according to Shulman, is the blending of two bodies of knowledge, that is content and pedagogy, to enhance an understanding of how the subject matter is organised and represented for instruction. To achieve this Gür and Karamete (2015) suggested that mathematics lecturers require an understanding of an interrelated kind of knowledge instruction that includes technological knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009). Mathematics lecturers can help pre-service teachers develop TPACK in an educational technology course taking place in a lecture room.

3.3 Technological Pedagogical Content Knowledge Model (TPACK)

According to Mishra and Koehler (2006), teachers need knowledge of the following:

- The interplay between technology and content and what meaning that a teacher is aware of the use of content and appropriate technology to be used in the classroom.
- The interplay between technology and pedagogy knowledge and what comprises the teacher's ability to teach technology skills to learners and expose them to technology in the classroom.
- The intersection of technological content knowledge, technological pedagogical knowledge and pedagogical content knowledge contribute to the establishment of TPACK.
- The seven TPACK bodies of knowledge are described below:
  - Pedagogical knowledge—knowledge of teaching methods and how to use them.
  - Content knowledge— the ability to know the subject matter.
  - Technology knowledge—knowledge about standard technologies and how they work.
  - Technological content knowledge-knowledge of technological subject matter.
  - Technological pedagogical knowledge—knowledge of standard technologies and how to implement/use it in different teaching and learning settings.
  - Pedagogical content knowledge—knowledge of teaching methods for the various subject matter.
  - Technological pedagogical content knowledge—knowledge of using technology to implement various teaching methods for various types of subject matter content.
- The intra-relationship between the TPACK bodies of knowledge which indicates a teacher's ability to plan lessons and select appropriate technological resources and pedagogical strategies with technology to teach learners relevant content. When TPACK is demonstrated,

the technology used in the lesson complements and enhances the learners' understanding of the content.

The implication of the TPACK framework foresees properly prepared teachers taking advantage of the exclusive features of the technology to teach content in a way that promotes a quality learning experience for students (Garofalo, Harper, So, Schirack, & Stohl, 2001, in Apeanti, 2016). In addition, TPACK provides knowledge to solve difficult concepts and makes them easy to learn as well as helping to address some of the problems students may face. The TPACK framework explains how knowledge of technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones (Koehler & Mishra, 2006, 2009). Figure 3 and Table 2 depict the connections between and among content, pedagogy, and technology to provide interactions, affordances, and constraints. According to Mishra and Koehler (2006, p. 2025), knowledge about content, pedagogy, and technology is central to developing a good teacher.

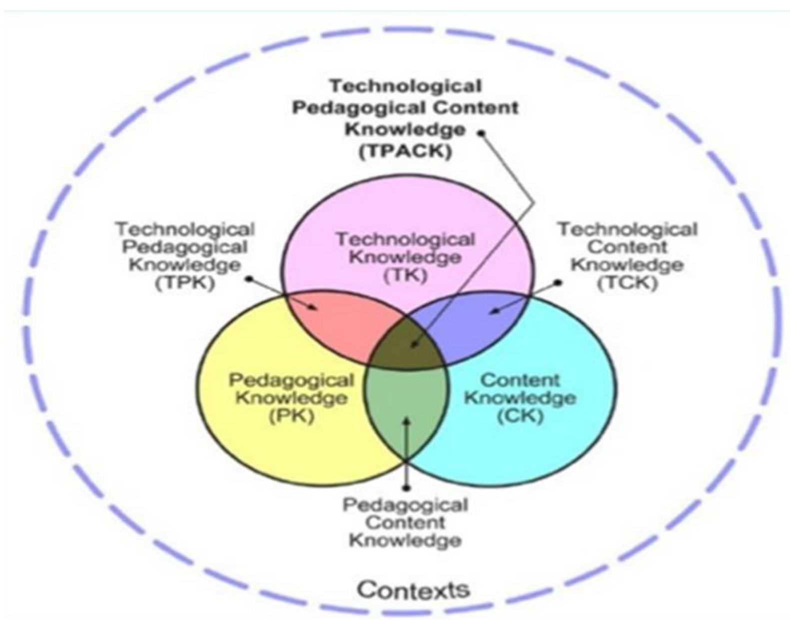


Figure 3: TPACK model: Adapted from Mishra and Koehler (2006)

Table 2 summarises the breakdown of TPACK model as per Mishra and Koehler (2006)

Table 2: Provide meaning to TPACK bodies of knowledge

Body of Knowledge	Meaning
Pedagogy	Application of learning theory in a classroom; differentiating technique; grading practices
Content	The ability to know the subject matter
Technology	Knowledge about standard technologies and how they work and used in the classroom teaching
Pedagogical Content Knowledge	Knowledge of teaching methods for various subject matter
Technological Pedagogical Knowledge	knowledge of standard technologies and how to implement/use it in different teaching and learning settings
Technological Content Knowledge	Knowledge of teaching methods for various subject matter
Technological Pedagogical Content Knowledge (TPACK)	knowledge of using technology to implement various teaching methods for various types of subject matter content

The TPACK model was criticised heavily by Angeli and Valanides (2009) who began to question its applicability in teacher education. They viewed TPACK as a transformative model. They argued that two component knowledge areas once blended to create an interpretational knowledge domain cannot be unwoven afterward. Colvin and Tomayko (2015) were of the opinion that there is "no consensus found in the literature about which approach to the interrelational knowledge areas of the TPACK framework has more validity" (p. 32). Thus, there is a lack of clarity on how TPACK can be used in the classroom scenario. They acknowledge the importance of TPACK to teachers; however, the model is not clear on how to integrate technology.

A myriad of mathematics software programs allows mathematics education lecturers to teach mathematics concepts in a variety of ways and to also capture pre-service teachers' thinking in a way that traditional blackboard and textbooks cannot. For example, graphing software can help visualising graphs and demonstrate mathematical ideas such as the movement of the slope along the y-intercept for linear functions and the intersection of functions at given points.

As ICT has become more accessible to people, mathematics education lecturers are challenged to think about how they can embrace technology in their pedagogy to enhance pre-service teachers' skills and knowledge needed in an increasingly technology-savvy society (Niess et al., 2009). ICT has become an essential tool in today's world (Hall & Chamblee, 2013), and it can be suggested that ICT is indispensable components of the modern society and are a basic requirement in the teaching and learning of mathematics because it lets students enjoy solving mathematical problems in various ways with the assistance of software.

3.4 Advantages and Disadvantages of TPACK Model in Pre-service Education

TPACK has become one of the popular models to assist teachers on how to integrate ICT in teaching across the curriculum. In addition, it also provides a basis for analysing the types of teacher knowledge required to ensure that they can integrate technology into their practice. According to Brantley-Dias and Ertmer (2013), at its launch, TPACK was seen as a tool teachers need to use technology effectively in the classroom and mathematics lecturers quickly embraced it. TPACK model clearly defines the types of knowledge bodies that a teacher should have and implement when teaching a concept.

However, TPACK does not clearly show how these bodies of knowledge should be implemented. In fact, the implementation of the model has brought more confusion than a relief (Brantley-Dias & Ertmer, 2013; Abbitt, 2011) and appears to lack practical application (Harris, Mishra, & Koehler, 2009). It is difficult to precisely measure the TPACK of pre-service teachers in a way that reflects the influence of teacher knowledge on their actual teaching. This raises concerns around the challenges of efficiency, reliability, and validity of the measurement interventions (Abbitt, 2011). Koh, Chai, and Tsai (2012) asserted that the survey tools developed for measurement have been for small sample sizes that are hard to generalise. They suggested that the complexity of TPACK as a theoretical model requires further development and research to validate its position in education. In conclusion, the unclear connections of these bodies of knowledge make it difficult to use TPACK as an effective model.

3.5 Cognitive Apprenticeship

A cognitive apprenticeship is viewed as a trade apprenticeship, and learning occurs as an experienced person and novices interact socially while focusing on completing a task (Dennen, 2012; Dennen & Burner, 2008). Lee, Dawson, and Cawthon (2016) believed that "in a cognitive apprenticeship, the master uses modelling, coaching, and fading to train the apprentice for expert problem solving within a specific context" (p. 348). In addition Collins et al. (1991, in Liu, 2005, p. 3) said cognitive apprenticeship learners observe how experts deal with problems in an authentic context and learn to solve the same or similar problems by "learning through guided-experience" in authentic activities. Cognitive apprenticeship is based on Vygotsky's research of scaffolding and is also related to other studies of conventional apprenticeship (Lave & Winger, 1991). The cognitive apprenticeship framework advocates that the master (in this scenario, the mathematics teacher educator) guides an apprentice (pre-service teacher) through each of the phases by modelling, coaching, and fading when integrating ICT in the teaching of mathematics. The general focus is to develop cognitive skills through participating in authentic learning experiences. Similarly, mathematics lecturers, just as in apprenticeships, may facilitate learning that is interactive and develop cognitive skills through participating in authentic learning experiences. In cognitive apprenticeship, students develop a declarative understanding of skills. The mistakes in mastering the concepts are detected and eliminated while associations between the critical elements involved in the skill are strengthened. Considering this, therefore, the researcher explored the current framework used by mathematics lecturers in South African universities to determine how they would fit in an apprenticeship-like framework that model and demonstrates ICT integration in teaching and learning in such a way that it would be easier for initial teachers to imitate. From the interviews conducted with mathematics lecturers, it was noted that there are no frameworks used as guides to integrating ICT in the teaching of mathematics. However, there are university-based policies that encourage mathematics lecturers to integrate ICT. Not many, if any, studies have been done in South Africa to unpack the use of an apprenticeship approach to integrate ICT in preparing future mathematics teachers.

ICT is essential in teaching and learning in the 21st century as it supports the instructional methods and understanding between content, pedagogy, and technology. Colvin and Tomayko (2015) asserted that in the 21st century, mastery of instructional technology is a key element of a successful teacher's skill set. Thus, mathematics lecturers have the responsibility to prepare their students for teaching ICT skills alongside their content areas. This is alluded by Smith and Lev-Ari (2005) who stated that there is "high agreement among educational theorists that the practical part is a strong and valued component in the education of teachers" (p. 292). Thus cognitive apprenticeship allows pre-service mathematics teachers to spend time in their lecture rooms to test and put into practice their developing pedagogical understandings and theories, learned under the supervision of a mentor (mathematics teacher educator). Such practicum experiences allow pre-service teachers to observe and learn from each other in the lecture room (Buitink, 2009). Mathematics lecturers may stimulate pre-service teachers' interests when teaching using ICT in developing their pedagogical teaching practice. Lambert and Gong (2010) stressed the point that practical experiences enable teachers to observe and participate in an activity and meaningful way; in other words, it provides them with an experience that influences their pedagogical development, including their pedagogical integration of ICT. During their practicum, pre-service teachers should experience the effective use of ICT and become hands-on practitioners in an authentic environment, reflecting the context that they are in.

Mathematics lecturers need to rethink how new teachers should be trained and make use of the new opportunities offered by ICT in an information and knowledge society. They should rise to the challenges brought by ICT to impart skills that are expected to be necessary and essential for the challenges of the 21st century. Delivery of mathematics lectures through cognitive apprenticeship makes tacit processes visible to pre-service teachers so that they can observe and then practice the learned skill. Table 3 shows the elements that can achieve cognitive apprenticeship.

Table 3: Components of the Cognitive Apprenticeship Framework for mathematics lecturers integrating ICT in teaching (Stefaniak, Maddrell, Earnshaw & Hale, 2016)

Cognitive Apprenticeship Framework			
Content • Presenting concepts, facts, procedures • Providing heuristics to assist learners	**Sequencing** • Increasing in difficulty • Elaborating on previously taught concepts	**Methods** • Modelling • Explanation • Coaching • Scaffolding • Articulation • Reflection • Exploration	**Sociology** • Promoting social learning • Exploration • Communities of practice

Collins, Hawkins, and Carver (1991) viewed cognitive apprenticeship as premised on situated learning theory that has the following four elements:

1. ***Content-type*** of knowledge required for expertise, that is, domain knowledge (concepts, facts, and procedures), heuristic strategies (tricks/building knowledge about the trade), control strategies (also referred to as metacognitive strategies) and learning strategies (knowledge in solving problems or carrying out complex tasks).
2. ***Pedagogy/method***—ways to promote development expertise. It includes modelling, explanation, coaching, scaffolding, articulation, reflection and exploration.
3. ***Sequencing of activities***—keys to ordering learning activities, that is, increasing complexity (refers to the construction of a sequence of tasks), diversity (wider variety of strategies) and global to local skills (requires some form of scaffolding to assist problem-solving).
4. ***Sociology***—social characteristics of the learning environment, that is, situated learning, CoP, intrinsic motivation, and cooperation (p. 33).

Cognitive apprenticeship experience allows students to view the real world and to experience what they are learning. Mathematics lecturers interact with pre-service teachers throughout the learning process of cognitive apprenticeship in situated learning using the following methods:

- ***Modelling***—demonstrating the temporal process of thinking.

- ***Explanation***—explaining why activities take place as they do.
- ***Coaching***—monitoring students' activities and assisting and supporting them where necessary.
- ***Scaffolding***—supporting students so that they can cope with the task situation. The strategy also entails the gradual withdrawal of the teacher from the process when the students can manage on their own.
- ***Reflection***—students assess and analyse their performance.
- ***Articulation***—the results of reflection are put into verbal form.
- ***Explorations***—the students are encouraged to form hypotheses, to test them, and to find new ideas and viewpoints.

The ability of teachers to practice pedagogical ICT is highly influenced by the knowledge, competences, and skills they received during university training years (Thomas, Herring, Redmond, & Smaldino, 2013). In South Africa, however, where existing policies support the use of ICT in education (DoE, 2004; 2007; The National Integrated ICT Policy Green Paper, 2014), there is a low intake of pedagogical ICT among mathematics lecturers in teacher training institutions.

The modelling of pedagogical integration of ICT by mathematics lecturers within the teacher education programme contributes to pre-service teachers' understanding of how to use ICT. Chen (2010) contends that teacher education lecturers have the responsibility to model ICT use in their lecture room. This role model plays a critical part in influencing pre-service teachers developing ICT efficacy. Chen also asserts that the skills students gained during the lecture can be taken to student teacher practicum experiences where they can demonstrate its application. In this way, Chen (2010) established that student teachers have a high probability to use ICT as pedagogical tools during teaching in their classroom. In addition, it has been shown that students' understanding of the affordances of ICT is developed through modelling by lecturers in campus-based programmes (Ertmer, 2005; Teo et al., 2008). Unfortunately, mathematics lecturers tend to use ICT the way they were taught. They were taught information technology literacy mainly in four areas: planning and designing lessons, lecture presentation, assessment, and professional practice.

3.5.1 Strengths and Weaknesses

The main advantages of the cognitive apprenticeship model (Brandt, Farmer and Buckmaster, 1993; Collins, 1991) in teaching mathematics using ICT can be summarised as follows:

- Differences might exist in the extent to which the rationales and practice knowledge of the master, particularly tacit knowledge, were taught alongside the practical skills;
- Novices focus on the skills inherent in the task rather than learning transferable skills or skills for unpredictable future tasks or problems;
- Experts can listen while novices express their thoughts and reasoning to pick up strengths and limitations in the novices' reasoning;
- Cognitive apprenticeship address the thinking and skills linked to practice;
- It makes efficient use of the time of experts, who can integrate teaching within their regular work routine;
- It provides students with clear models or goals to aspire to; and
- It acculturates learners to the values and norms of the trade or profession.

On the other hand, there are some serious limitations with the apprenticeship approach Brandt, Farmer and Buckmaster, 1993; Collins, 1991), particularly in preparing for university teaching:

- The teacher might be highly skilled but not a good lecturer;
- The apprentice might be seen as a worker instead of as a student;
- The apprentice's tasks would arise from and be limited to the tasks at hand;
- Much of a master's knowledge is tacit, partly because their expertise is built slowly through a very wide range of activities;

- Experts often have difficulty in expressing consciously or verbally the schema and 'deep' knowledge that they have built up and taken almost for granted, leaving the learner to have to guess or approximate what is required of them to become experts themselves;
- Experts often rely solely on modelling with the hope that learners will pick up the knowledge and skills from just watching the expert in action and do not follow through on the other stages that make an apprenticeship model more likely to succeed;
- There is clearly a limited number of learners that one expert can manage, given that the experts themselves are fully engaged in applying their expertise in often demanding work conditions, which may leave little time for paying attention to the needs of novice learners in the trade or profession;
- Traditional vocational apprenticeship programmes have a very high attrition rate, for instance, in British Columbia, more than 60% of those that enter a formal campus-based vocational apprenticeship programme withdraw before successful completion of the programme. As a result, there are large numbers of experienced tradespeople in the workforce without full accreditation, which limits their career development and slows down economic development where there are shortages of fully qualified skilled workers;
- The apprenticeship model can slow adaptation or change in teaching methods, because of the prevalence of traditional values and norms being passed down by the 'master' that may no longer be as relevant in the new conditions facing workers.

Nevertheless, the apprenticeship model, when applied thoroughly and systematically, is a very useful model for teaching in highly complex, real-world contexts.

3.6 Concerns-Based Adoption Model (CBAM)

This model is concerned with measuring, describing and explaining change processes experienced by teachers when attempting to implement new changes required by curriculum and instructional practices. It is believed to be a robust and empirically grounded theory for implementing educational innovations. To be clear, this model does not mention the integration of ICT in teaching anywhere; however, it focuses on how innovations can be implemented. Hall (1979) saw the “need for a mechanism to help educational personnel and their constituencies respond to change and to adapt effectively” (p. 202). CBAM tries to describe the processes of education mathematics lecturers, as change facilitators, experience during the adoption of innovation. CBAM allows facilitators to provide assistance during the process of adoption and appeal to innovation users to use key diagnostic tools (Bellah & Dyer, 2007). The model, in essence, tries to describe how people develop as they learn about innovation in teaching and when implementing it. The CBAM is a “widely applied theory and methodology for studying the process of implementing educational change by teachers and by persons acting in change-facilitating roles” (Roach, Kratochwill, & Frank, 2009). CBAM is built around assumptions of change. In this study, education mathematics lecturers are viewed as the focal point in training pre-service teachers to implement change that would provide them with a platform to integrate ICT in the teaching of mathematics. CBAM considers curriculum change and implementation as a process, not as an event as other models view it. CBAM has three parts: stages of concern (SoC), levels of use (LoU) an innovation configuration (IC). The SoC dwells on the feelings that individual teachers experience during the implementation of an innovation; LoU describes how individuals behave as they experience and implement curriculum change; and IC highlights what the new practices will look like when implemented (Hall & Hord, 2006).

3.6.1 Interventions in Educational Changes

CBAM views teachers moving at different SoC due to uncertainties they have while being involved in a particular innovation. The following are assumptions about classroom change that underpin CBAM (Anderson, 1997):

- Change is a process, not an event, and it takes time to institute change;
- Individuals must be the focus if change is to be facilitated and institutions will not change until their members change;
- The change process is an extremely personal experience and how it is perceived by the individual will strongly influence the outcome;
- Individuals progress through various stages regarding their emotions and capabilities relating to the innovation;
- The availability of a client-centred diagnostic/prescriptive model can enhance the individual's facilitation during staff development; and
- People responsible for the change process must work in an adaptive and systematic way where progress needs to be monitored constantly. (p. 333)

Generally, CBAM addresses three areas of assumptions:

1. The model focuses on individual concerns about innovation or change. In this study it refers to education mathematics lecturers' concerns around integrating ICT in the teaching of mathematics in preparing pre-service teachers.
2. It addresses the manner in which the innovation will be implemented by education mathematics lecturers.
3. It looks at the adaptation of the innovation by education mathematics lecturers.

Regarding this study, it has been noted that the response to pedagogically integrate ICT in the teaching of mathematics by education mathematics lecturers is very slow, and mathematics lecturers implement the integration of ICT at different paces, stages and levels. We are looking for education mathematics lecturers who will lead the way in adopting and adapting innovation in teaching using ICT.

3.6.2 The Three Diagnostic Dimensions

The successful implementation of a new programme is a personal developmental process. The diagnostic dimensions of CBAM were designed as a tool for analysing three diagnostic dimensions intended to help leaders and facilitators understand and support individuals to successfully implement change in educational programmes. These diagnostic dimensions are IC, SoC, and LoU. According to Straub (2009), the three components inform facilitators of how best they can facilitate the uptake of an innovation. CBAM help understand the concerns of a community (in this case, mathematics teacher educator) and how to facilitate innovation adoption.

3.6.2.1 Stages of Concern (SoC)

In this study, the SoC investigates the concerns education mathematics lecturers have as they improve through the adoption process. This stage has a collection “of feelings, perceptions, worries, preoccupations and moments of satisfaction for those engaged with implementing new approaches” (Hall & Hord, 2011). At the earlier stages, concerns are around personal issues and with time, those concerns are met. The other concern crops up around their students and the implementation of an innovation. In essence, SoC describes the attitudes and concerns of change facilitators.

3.6.2.2 Innovation Configuration (IC)

Teachers rarely implement the same innovation in the same way. IC attempts to describe variations on what innovation looks like in practice for different teachers. IC is measured using the innovation configuration component checklist, which specifies key behavioural components of change. It deals with patterns of practices across all innovation components and on how individual teachers are implementing a change. It serves as a yardstick to guide and directs staff efforts.

3.6.2.3 Levels of Use (LoU)

The LoU is premised on providing a framework for knowledge of understanding the behavioural implementation of an innovation. The actions of teachers are broken down into categories from “non-use at the lowest behavioural implementation to renewal, the highest, indicating a teacher transforming and extending the innovation” (Straub, 2009, p. 634). Concerns are broken down into the stages presented in Table 4.

Table 4: Stages and descriptions of the SoC (Anderson, 1997; Hall, 1979, p. 6; Hord, Rutherford, Adams, 2002, p. 288; Huling-Austin, & Hall, 1987)

Stage	Name	Description of Concern
0	Awareness	Teachers have little awareness of the innovation and are not likely to be concerned about it.
1	Informational	Teachers are seeking an understanding of the innovation itself
2	Personal	Teachers begin to express concerns about their ability to meet challenging expectations
3	Management	Teachers focus on innovation
4	Consequences	Teachers express concerns about the impact of the innovation on their students or families served.
5	Collaboration	Teachers begin to seek out relationships that will assist them in implementing the innovation.
6	Refocusing	Teachers express an interest in adapting the innovation or considering alternative innovations.

3.6.3 Change Facilitators and Intervention

CBAM theory is premised on the classroom change that can be facilitated. Change facilitators include, among others, principals, heads of departments, or consultants (Anderson, 1997). These people can measure teachers’ concerns about change, their level of use, and their configuration of use. The results can be used in planning and providing interventions to assist individuals/groups of teachers in implementing change.

3.6.4 Strengths and Limitations of CBAM

Strengths

CBAM highlights the concerns and feelings associated with the implementation of innovations and how to evoke change. The three diagnostic dimensions of CBAM with associated tools possibly provide tools and methods to do the assessment of SoC and the adoption of innovations to empower individuals with appropriate support to their concerns and their success in their endeavours (Straub, 2009). Management/facilitators of CBAM can adopt these three diagnostic dimensions to negotiate change and to provide concrete support to assist teachers in an innovation change (Hall & Hord, 2011).

Limitations

- Straub (2009) and Hall & Hord (2011) noted the following weaknesses with regards to CBAM:
- There is an inherent assumption that change is a process facilitated by managers/facilitators who are in a position to disseminate the adoption of change to students;
- The process used to predict and understand the experiences of teachers is ambiguous;
- The model sees teachers as very active facilitators of change and pays little attention to the students except for their role in the 'consequences' stage of teacher concerns;
- The focus is on the leader/facilitator or lecturer as the initiator of the change, which then filters down to the teachers/students;
- The model views students/teachers as adopters of change from facilitators rather than agents of change;
- The model is not a student-centred approach in teacher education as it leaves limited space for students' voices; and
- The model depicts a top-down approach to innovation adoption.

Brzycki and Dudt (2005) raised the issue of ICT integration in teaching as a stumbling block. The integration of ICT in the classroom remains limited and many mathematics lecturers in South African universities are still reluctant to adopt it. CBAM has been used widely in school settings to understand the process of implementing educational innovation. However, the use of pedagogic integration of ICT in teaching mathematics has been left to individuals. The main focus of the CBAM model is to gain insight into mathematics lecturers' concerns about new educational innovations of adopting ICT in lecturing.

3.7 Activity Theory

Activity Theory was developed by Engestrom (1987; 1996) and it is an object-oriented, tool-mediated activity, connecting the subject and the societal structure. Mathematics lecturers and their pre-service teachers are affected by the presence of ICT and how it transforms the world at large. Activity Theory can be used to understand the process of transformation within a system (such as a lecture room) as well as illustrate how different systems interact with and transform each other over time. Activity Theory is grounded in the work of Vygotsky and his student Leontiev, in the 1920s (Engestrom, 1987; 1996). It provides a lens through which to better understand human activity (Hasan & Kazlauskas, 2014). Vygotsky criticised the stimulus-response model of his contemporary Pavlov and supported the idea that people are not animals, but humankind's activity has a direction, is purposeful and is carried out by sets of actions through the use of 'tools', which can be physical or psychological (Engestrom (1987; 1996). Figure 4 below depicts the core of an activity.

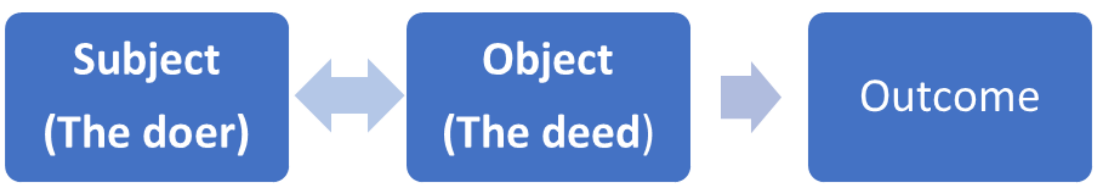


Figure 4: The core of an activity: Adapted from Hasan, and Kazlauskas (2014)

The relationship between the subject (human doer) and object (action being done or the deed) in Activity Theory forms the core of activity (Figure 5). The object of activity encompasses the activity's focus and purpose while the subject, a person or group engaged in the activity, incorporate the subjects' various motives. The outcomes of an activity can be successful or unsuccessful. According to Vygotsky (1978) for humans to change the world, tools are essential objects to use and humans themselves are transformed through the tools. In this context, mathematics lecturers in the education departments in higher institutions of learning can use ICT to meet the current educational demands of the 21st century.

In the Activity Theory, the place of interest is an activity system itself. The system here refers to a group of people working together for a common goal or a community that share a common object (or problem space) and who uses tools to act on that object, transforming it (Hardman, 2005). The connections in the system are governed by rules that have both enablers and disablers. The relations between the individual (subject) and community are mediated by the community's collection of mediating artifacts (tools), and rules. Rules are "the norms and sanctions that specify and regulate the expected correct procedures and acceptable interactions among the participants" (Lim, 2002). Division of labour is both horizontal, the labour is divided among community members, and vertical, the power is taken from the top and high-status people (Figure 5). The activity in the model is dynamic across time as there are continuous constructions and reconfigurations among its components. Rules are not static; they keep changing to suit the environmental change the subject would like to work in. The artifacts (tools) continue being reconstructed or new artifacts (tools) are developed by the subject to meet the object of the activity system (Lim, 2002).

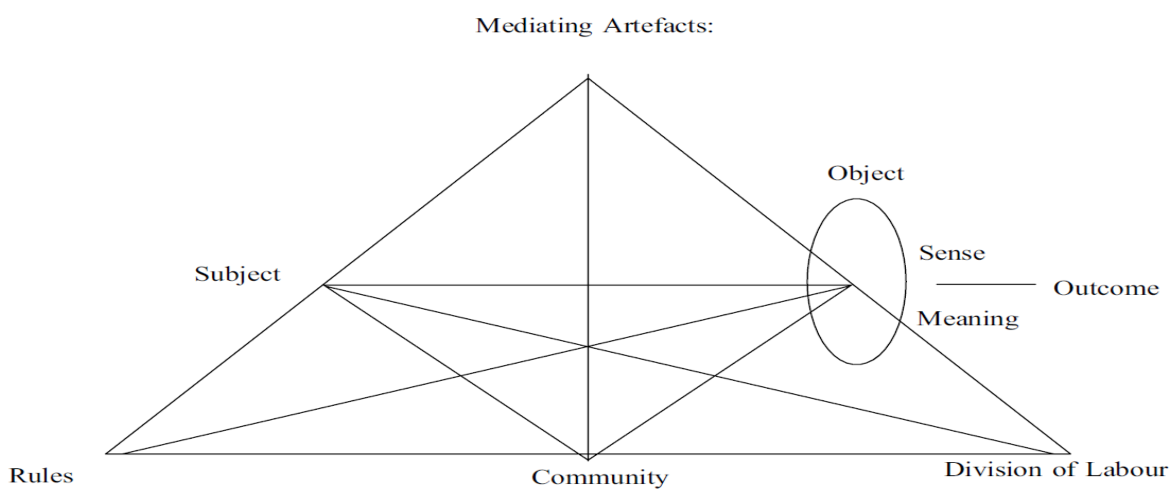


Figure 5: Activity theory (Hardman, 2005)

The proliferation of ICT in our contemporary society has disrupted the way we think and it defines and shapes our thinking. Thus the presence of ICT in higher education has brought means of mediating critical questioning skills that force a change in the activity systems of lecturing. Mathematics lecturers are therefore challenged to rethink the way they are acting on their students (objects). In the Activity Theory, the mathematics lecturers are seen as subjects, acting on the object to transform them to adequately use ICT (mediating artifact) to promote critical questioning skills (outcome) during the lectures. On the other hand, mathematics lecturers' pedagogic position is governed by the rules that define the use of ICT in the lecture room, which can be the general rules and regulations of the institution. The community in this instance are the students, mathematics lecturers, programme designers, and technicians, who are all working together on the primary object of imparting the appropriate skills to mathematics pre-service students. In the division of labour, pre-service teachers are expected to engage with their learning environment and the mathematics lecturers are expected to guide the interaction.

3.7.1 Strengths of Activity Theory

Activity Theory helps to understand teaching and learning through the use of object-oriented and tool-mediated interactions, as opposed to something opaque, only happening in one's mind. The theory advocates interactivity when teaching and making use of the tools that act in a mediational role. The construct such as community and rules depicts a scenario where learning takes place where there are people and people are controlled by the rules defined specifically for that particular community. Brantley-Dias and Ertmer (2013) stated, "When technological pedagogical content knowledge (TPACK) arrived on the scene as a new way to talk about the knowledge base teachers needed to use technology effectively in the classroom teacher educators were quick to embrace it" (p. 105). The strength TPACK appear to have is to isolate the types of knowledge teachers have, however it does not spell out on how ICT can be used in teaching specific topic in different subject discipline.

3.8 Dissection of the Models

The models TPACK, Apprenticeship, CBAM and Activity Theory are all of use in their own right. However, for this study, they do not all show how mathematics lecturers can integrate ICT in teaching. The models advocate for change of pedagogical knowledge/strategy from one level to the other. Mathematics lecturers are facing the challenge of connecting these models in teaching. The good part about these models is that they have vigorously triggered platforms on how practicing practitioners in education can appropriate and integrate ICT in the classroom. The Activity Theory model is adopted in this study with all its constructs. The Activity Theory is used to examine how mathematics education lecturers integrate ICT in teaching mathematics. The theory reflects the interactivity and connectivity among the users (subjects) and objects. In this study, mediating artifacts (tools or signs) are ICT software and mathematical application software; subjects are considered as mathematics lecturers; objects as pre-service teachers; community as schools of education; and rules as regulatory instruments in the initial teacher training (Figure 6). Both the subjects, objects, and communities partake in certain activities creating the construct division of labour. In this instance, players in the division of labour include mathematics head of departments, mathematics education lecturers, university authorities and the students.

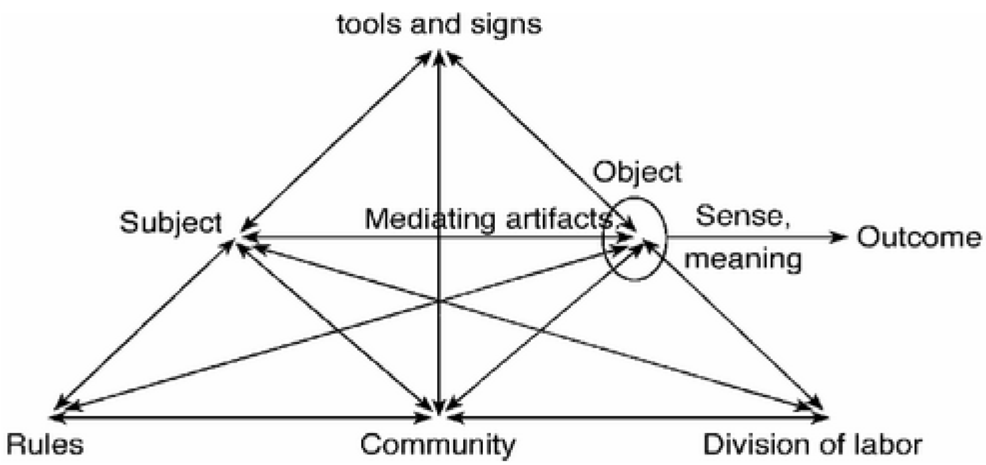


Figure 6: Activity system (Source: Engestrom, 1987, p. 78)

The Activity theoretical framework is used to determine the relationship among the constructs as shown Table 5

Table 5: Description of construct in the Activity Theory

Constructs	Roles or responsibilities
Community: *University stakeholders*	• Participating and creating a learning environment with resources–infrastructure,

Constructs	Roles or responsibilities
Mathematics ICT lecturers, students, leadership, Head of Division/ School/Faculty etc., administrators and ICT support providers	culture, training and guidance needed for ICTs to be used effectively.
Subject: *Lecturer* Mathematics Lecturer	• Modelling best practice in ICT pedagogical integration. • Exposing students in ICT learning environments. • Identification of tools that can be used to aid teaching. • Giving students guidance and skills in utilising ICTs for teaching and learning.
Object: *Student* Mathematics student	• Acquiring ICT experience for teaching and learning Mathematics in and outside the classroom.
Enablers	
Rules: *University policies* ICT Policies related to teaching and learning at national or university level. Policies related to Mathematics teaching with or without ICTs	• Providing guidance on how to deliver content with ICTs by lecturers. • Utilisation of ICT infrastructure by all stakeholders. • Acquisition of knowledge and skills required to meaningfully use ICTs for educational purposes. • Communication with and through ICTs. • Distribution of ICT resources within the university community.
Division of Labour: *Knowledge sharing spaces in Communities of Practice*	• University leadership- budgeting for ICT infrastructure and community development. Mathematics HoD and lecturers- create platforms for sharing on how best to prepare students for ICT use in the classroom. • Students—exposing themselves to mathematical digital tools and how to integrate them into teaching and learning. • ICT support—providing timeous support in respect to technical and integration activities.
Tools and signs: A*rtifacts*	• Mediation of mathematical concepts

Constructs	Roles or responsibilities
e.g. Mathematics Application Software and ICT multimedia	
Outcome: A*doption, adaptation and appropriation of ICTs for teaching*	• To produce an ICT competent student who can demonstrate proficiency in the use of digital technology for teaching Mathematics.

University stakeholders' role is to provide the sustainable infrastructure needed for ICTs to be used effectively in the lecture rooms. The main role of the first top three 'constructs' is to intentionally create a learning environment that facilitates the achievement of the outcome and the last two are regarded as enablers. Mathematics education lecturers transmit their content and pedagogical knowledge as they train pre-service teachers, who in turn, teach their future classes the way they were taught.

3.9 Government Position on ICT

The South African government supports ICT teacher development through EPDT SETA to enhance skill sets among teachers; however, the programme is failing to respond to the demands of the contemporary classroom. There are two notable gaps in the teaching sector: A policy gap and an ICT gap. The "Guidelines for Teacher Training and Professional Development" in ICT is fundamental to the implementation of e-education; however, it does not provide an implementation plan to support the integration of ICT into teaching and learning (Hindle, 2007). A digital framework must be developed to act as a guide on how ICT should be practiced in the context of teacher development and teaching.

3.10 Conclusion

The chapter examined the role of the TPACK framework, Apprenticeship model, CBAM and Activity Theory in integrating ICT for teaching mathematics to pre-service teachers. TPACK was studied to evaluate its relevance in the teaching of mathematics by mathematics lecturers. It was noted that it is silent on how technology could be used in the classroom; however, it is important for mathematics education lecturers to have technological knowledge in teaching.

The cognitive apprenticeship model is an old method of teaching and can slow adaptation or change in teaching methods that include the incorporation of ICT because of the prevalence of traditional values and norms being passed down by the 'top management' that may no longer be relevant in responding to the new demands of the 21^{st} century teaching. The CBAM was discussed but did not fit this study because of limitations such as that the model is not student-centred, leaves limited space for students' voices, and depicts a top-down approach to innovation adoption. Activity Theory was chosen as the theoretical framework and provides mathematics education lecturers opportunities to decide on their own on how they will integrate ICT in teaching and learning. The next chapter discusses the methodology for the study. Qualitative methods form the backbone of the study and are discussed in detail and the interpretive stance is taken. The participants are identified, the research methods are described and the data analysis is explained. Finally, the trustworthiness of the investigative procedures relevant to this research is discussed.

Chapter 4 discusses the study's research design and methodological approach. The qualitative research is discussed, and an interpretive stance is taken. The participants in the study are identified, the research approach is described and the data collection is explained. Last but not least, the trustworthiness and ethical considerations of the research procedures relevant to the research are discussed.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGICAL APPROACH

4.1 Research Design

This chapter describes the processes I used to investigate the focus of the study, and in addition, it describes the theoretical and epistemological underpinning of the research and how it may influence the design and implementation. The methodologies and methods used in this research are discussed with emphasis on the interpretive. Issues that affect the research output and the validity of the research techniques are also discussed. This research adopted a qualitative approach as it allows the enquirer to explore the phenomena in a naturalistic, interpretative way “from the interior” (Ritchie, Lewis, Mcnaughton, & Ormston, 2013) using the perspectives and accounts of the research participants as a starting point. Social constructivists seek to understand the world in which people live and work.

Research design is the plan organised to collect and analyse data to answer the research question (Fraenkel, Wallen, & Hyun, 1993; Cohen, Manion, & Morrison, 2013). The term ‘plan’ suggests that the research should be conducted in an orderly manner. There should exist a master plan of actions that have a start and an end. The search for the answers to the research questions needs a structure that needs to be followed. In this study, this structure is referred to as a ‘blueprint’ for the entire research inquiry. This blueprint allows me to determine the type of data that needs to be collected to answer the research question and how to interpret it meaningfully. Data gathering was done primarily through interviews and observations, while secondary data was used to validate the findings. Each interview session was audiotaped and supplementary notes were taken to record any non-verbal communication or other information that might have been pertinent to the content and process of the interviews.

This research focused on South African mathematics lecturers at the four universities in the Gauteng province (two conventional universities and two technological universities). Gauteng province was chosen because it is close to me, and therefore, travelling expenses were minimal. The research aim was to explore the current ICT pedagogical practices of mathematics lecturers at South African universities. The participants in the data collection were mathematics lecturers and fourth-year Bachelor of Education (B.Ed.) students at the Further Education and Training (FET) phase majoring in mathematics. Given the complexity of these settings, a well-crafted research design was necessary.

Figure 7 summarises the overall research process in this study. Each stage shows the activities carried out in chronological order.

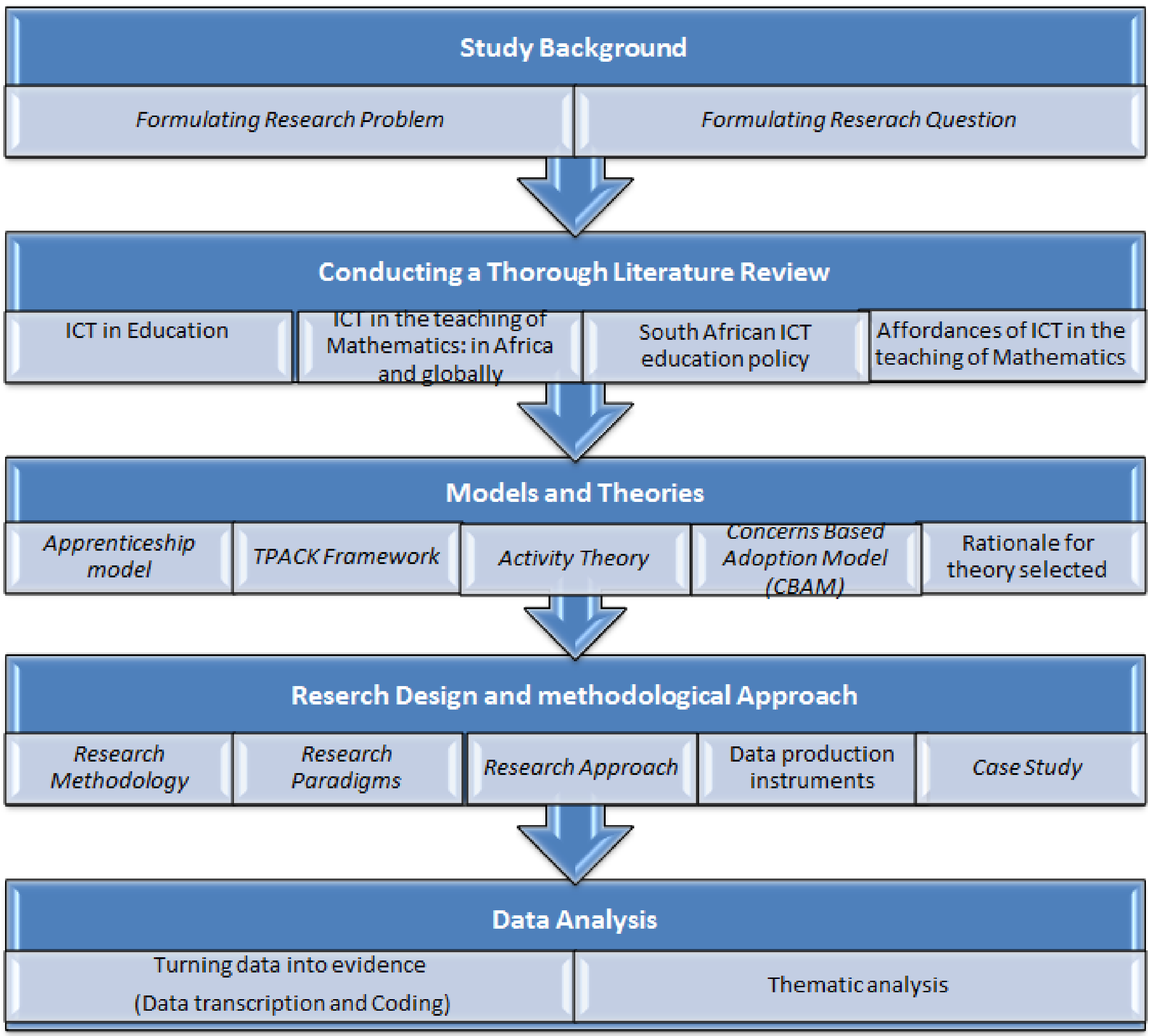


Figure 7: Research design blueprint

Before discussing the methodological approaches, it is important to first revisit the theoretical framework used in the research design.

4.2 Research Paradigms in Educational Research

A paradigm represents a worldview that defines for its holder the nature of the world, the individual’s place in it and the range of possible relationships to that world and its parts (Denzin, 2008; Denzin & Lincoln, 2005). Put it differently, “it is a way of looking at the world” (Mertens, 2014). It guides the researcher “in ontologically and epistemologically fundamental ways” (Guba & Lincoln, 1994). Different paradigms show different underlying ontologies, that is the philosophical assumptions that attempt to answer what is questioned. In addition, different paradigms have different epistemologies that is the philosophical assumption concerned with how knowledge can be acquired and try to answer the question asked (Scotland, 2012). Paradigms provide views about the rationale for research and oblige the researcher to be precise about the methods of data collection, observation, and interpretation. Thus research paradigms describe the views of how knowledge is constructed and what counts as truth (McKenna, 2010). A paradigm postulates consistent positions on ontology and epistemology, which is the researcher’s lens and is considered as truth (Cohen et al., 2013).

The research paradigm can be viewed as a network of connected ideas concerning the nature of the world as well as the objectives of the research (Antia, 2000). The researcher uses those connected networks to shape their thinking to direct their actions. Therefore the research paradigm focuses on what should be studied and how the results should be interpreted. The three commonly used research paradigms, which reflect different ontological and epistemological positions, are positivism (technical), interpretive (practical) and critical theory (emancipatory) paradigms (Cohen et al., 2013; Gray, 2014). These paradigms are associated with human interests and below are brief descriptions of their philosophical assumptions in relation to their view of the nature of knowledge. The two traditional research paradigms used in education are the positivist and constructivist paradigms (McMillan & Schumacher, 2010). The methodology paradigm follows when the ontology and epistemology have been established. In essence, the methodological paradigm is about how the knower goes about finding the ways of what can be known (Guba & Lincoln, 1994). Figure 8 gives an overview of research paradigms in a research study.

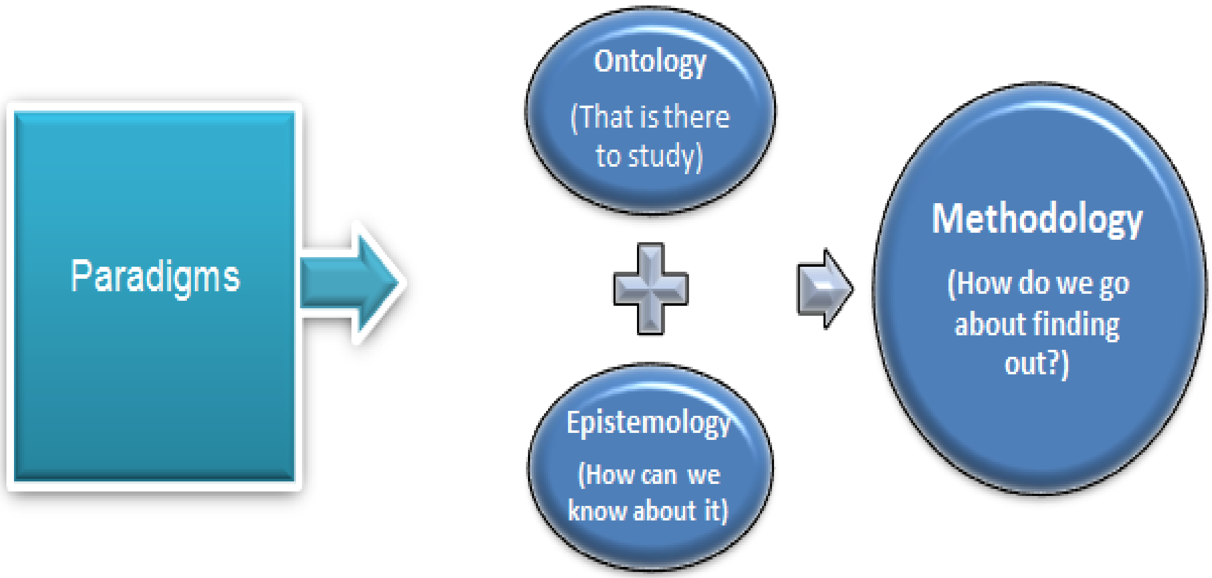


Figure 8: Research paradigms

4.2.1 Positivist Approach

Positivism is concerned with uncovering the truth and presenting it by empirical means (Henning, Van Rensburg, & Smit, 2004). According to Gray (2014), positivism "is the reality that exists external to the researcher and must be investigated through the rigorous process of scientific inquiry" (p. 20). This implies that knowledge can only be verified scientifically and the solution to the problem is solved using the deductive method. The deductive method starts with the general and moves towards the particular. Positivism's premises are that the social world exists externally to the researcher and that its nature can be studied through observation. Positivism argues that:

- Reality consists of what is available to the senses—that is, what can be seen, smelled, touched, etc.;
- The inquiry should be based upon scientific observation (as opposed to philosophical speculation), and therefore, on empirical inquiry; and

- The natural and human sciences share common logical and methodological principles dealing with facts and not with values (Gray, 2014).

According to March and Storey (2008), positivism tends to be objective, and it helps the researcher to predict and generalise courses of the phenomenon. Positivism is a philosophy of the theory of knowing. Collins (2010) explained that positivism as a philosophy dwells on the view that only accurate knowledge gained through observation (the senses) and measurement is trustworthy. In positivism studies, the role of the researcher is limited to data collection and interpretation through the objective approach and the research findings are usually observable and quantifiable. Of paramount importance in positivism is to determine measurability, patterning, predictability, rules, and laws of the behaviour and description of causality (Cohen, Manion, & Morrison, 2011). Critical outcomes are observed.

4.2.2 Constructivism

According to the constructivist paradigm, different aspects of the phenomenon attain meaning through their social environment. Constructivist theory premises are philosophy, anthropology, the natural sciences, semiotics, socio-linguistics and education (Zhou & Brown, 2015). Constructivism dates back to Socrates' dialogues with his followers in which he asked direct questions that led his class to think intensely about their strengths and weaknesses. ICT presents a plethora of affordances to students such as constructing deeper knowledge about the content they are learning through interactive learning that is "anchored around real-world authentic problems" (Chai, Ng, Li, Hong, & Koh, 2013, p. 41)

Zhou and Brown (2015) highlighted that Jean Piaget and John Dewey developed theories of childhood development and education, later known as progressive education, which led to the birth of constructivism. Piaget postulated that human beings actively construct their own knowledge, provided there is prior knowledge about that particular subject matter (known as schema), while Dewey advocated education that is grounded in real-life experience. Piaget believed that people are endowed with the innate knowledge of constructing a system of personal knowledge about the world given that there is an apparatus for that thought (Taber, 2011). According to Piaget, teaching involves igniting or activating relevant ideas already in learners' minds to help them construct new knowledge. For children to be able to construct their own knowledge, he suggested that children pass through a sequence of stages of cognitive development: The sensorimotor stage, the preoperational stage, the concrete operational stage, and the formal operational stage. According to him, children understand the subject matter at different levels of their development before they move to the next level of cognitive development. Piaget's view was partly supported by John Dewey who believed that children understand the world through interaction with their environment and, thus, that knowledge is constructed by the individual (Lutz & Huitt, 2004).

John Dewey's philosophy was premised on the 'theory of inquiry' and on how animal species survived in their environment. Dewey believed that in nature all living organisms interact with the environment and respond by developing an understanding of how to adapt to that situation and excel (Zhou & Brown, 2015). Other advocates who have added perspectives to constructivist learning theory and practice are Lev Vygotsky, Jerome Bruner, and Seymour Papert.

Lev Vygotsky added the social aspect of learning into constructivism and defined the 'zone of proximal development', which implies a learner's independent learning accomplishments, that is, accomplishments under the guidance of someone who is experienced. In addition, he proposed the scaffolding technique, a tool used to help learners do something they could not do on their own without assistance (Zhou & Brown, 2015). Jerome Bruner instigated curriculum change based on the perception that learning is an active social process in which learners construct new knowledge or ideas and concepts based upon their current and previous experiences (Zhou & Brown, 2015). Seymour Papert's pioneering work in using computers to teach learners has led to the widespread use of computers and information technology in the constructivist environment (Zhou & Brown, 2015).

In essence, the work of Dewey, Piaget, Vygotsky, and Bruner highlighted that human beings seek meaningful interactions with the environment and construct knowledge of themselves and the world around them through these interactions (Lutz & Huitt, 2004). They all provided the foundation of the learning approach called constructivism. The principle of constructivism is that meaningful learning requires an understanding of wholes as well as parts, which is supported by situated learning.

Albert Bandura advocated the social learning theory that focuses on the learning that occurs within a social context (Bandura, 1977). According to him, people learn from one another by observing, modelling and imitating. Bandura suggested that modelling is the basis for a variety of child behaviour (Bandura, 1986) because by merely observing the activities surrounding them, children acquire many favourable and unfavourable responses. For example, children can copy from their father how to ride a bicycle; thus, people can learn by observing and imitating what others are doing together with the behaviour displayed. The chief argument brought by Bandura is that the observer (learner in this case) is reinforced by the model. For example, a learner who is associated with a group of students who like solving mathematics problems has a high probability of liking solving mathematics tasks and is thus reinforced by that group. Modelling influences the frequency of previously learned behaviours. This gives teachers the challenge of exposing their students to a variety of models; the same can be said of mathematics lecturers in teacher training institutions.

4.2.3 Application of Constructivism in an ICT Integration Conceptual Framework

The research explored the pedagogical ICT integration practices by mathematics lecturers in preparing initial teachers for ICT use in teaching and learning, which highlighted the relationship between constructivism and ICT. Mathematics lecturers play an important role in a constructivist context (Nanjappa & Grant, 2003) because, in a constructivist classroom, mathematics lecturers create social and intellectual climates and facilitate collaborative and cooperative learning (Laurillard, 2013). Mathematics lecturers also contribute to understanding both the construction of and the relationship between curricula and events. In addition, they provide direction for the implementation of the ICT integration framework. The theory of constructive learning views teachers as playing a central role in academic curricula and suggests improvement according to the teachers' needs and interests (Woolfolk, 2010). Constructivist learning theory aids the individual's growth and leads the initial teachers to explore their learning potential to integrate ICT in teaching and learning. Using the modelling teaching method as an example, as advocated by cognitive apprenticeship, mathematics lecturers can act as coaches and mentors (Dennen, 2012). Collins et al. (1989) described a mentor as one who provides support that is continuous and a coach as somebody who typically focuses on assistance that meets a particular goal. Thus, mathematics lecturers would be involved in coaching initial teachers where more concrete, goal-oriented tasks such as demonstration of ICT integration concepts are needed.

Constructionist activists exhibit the following characteristics (Gould, 1996; Jonassen, Peck, & Wilson, 1999):

- Learning focuses on thoughts instead of facts;
- The learning process implies an interaction between mathematics lecturers and students;
- Focus on the construction of knowledge instead of repetition;
- Encouraging and supporting dialogue and discourse within a complicated world that involves various representations of knowledge;
- Students' interests define learning; and
- Learning experiences emphasise the prominence of realistic activities.

Integrating ICT in teaching and learning may develop high-order thinking skills such as applying, analysing, evaluating, and creating (Limbach & Waugh, 2010).

4.2.4 The Application of ICT in a Constructivist Approach

Constructivism argues that learning is interactive and that the student needs autonomy and active participation. Liu and Matthews (2005) were of the opinion that constructivists "of whatever ilk, hold that knowledge is not mechanically acquired, but actively constructed within the constraints and offerings of the learning environment" (p. 5) The initial teacher in this context is an information constructor and actively builds their own subjective representations of reality, because the teachers already have some knowledge of using ICT. New information is related to previous knowledge in terms of schema development. Constructivism is both a philosophical and psychological approach based on social cognitivism that assumes that persons, behaviours, and environments interact in a reciprocal fashion (Schunk, 2000).

Constructivists assert that learning is the active process of constructing rather than passively acquiring knowledge, and instruction is the process of supporting the knowledge constructed by the learners rather than the mere communication of knowledge (Nanjappa & Grant, 2003). In this instance, training pre-service teachers to integrate ICT in the classroom will be demonstrated by mathematics lecturers who, in turn, supervise and monitor them doing learned tasks. There are many other types of constructivism but there are certain ideas that all constructivists have in common. Nanjappa and Grant (2003) describe these ideas as follows:

- Knowledge is constructed by the learner—learners are not passive recipients of knowledge from the outside world but create it. The theory is vastly different from behaviourism, which defines learning as an externally modified behaviour. Learning according to constructivists is something a learner does, not something that the learner is compelled to do.
- Learners have prior knowledge so they come to the learning environment with ideas about the use of ICT. These ideas are called schemas, and teachers have to consider them and make teaching relevant to these conceptual structures by building from the known to the unknown.
- Learners have their own individual ideas about reality and generate their own meaning structures to cope with everyday living.
- Their ideas often contradict or clash with accepted scientific ideas or with school curricula and are culturally or socially conditioned.
- Knowledge is described by these theorists as conceptual structures in the brain and it is possible to describe and model them.

Most university classes use the lecture method or explanations to teach, which is problematic as students find concepts abstract and difficult to apply in concrete and real-world situations (Dennen, 2012). Training by abstraction is of little use in teaching ICT integration since teaching is a hands-on profession that needs demonstration and modelling. To mediate the lecture method, mathematics lecturers can model the concepts being taught to promote learning. In this regard, mathematics lecturers that model ICT integration in a lecture room provide pre-service teachers with information about what sequence of actions will lead to success (Schunk, 2003). A properly learned concept will equip the pre-service teachers with the skills they will use when going to their future schools. As mathematics lecturers model ICT integration in teaching and learning, pre-service teachers code the information for retention and produce the demonstrated pattern, and consequently are motivated to perform the learned concept in their own way. In constructivism, learning practice is viewed as important for active learning. Pre-service teachers need exposure to ICT integration in teaching in various practical activities to master the concepts; they need to be seen doing a lot of practice. By integrating ICT with constructivist methods such as problem-based learning, learners will be more active in the learning process.

4.2.5 Situated Learning/Contextual Learning

Constructivists are of the opinion that cognition is situation-bound and distributed rather than a product of minds (Lave, 1988). In situated learning, learning occurs naturally in real-life situations and there are collaboration and participation during the activity. The activity in which knowledge is developed is an integral part of what is learned. Lave (1988) claimed that learning as it normally occurs is a “function of the activity, context and culture in which it occurs” (p. 33). This implies that in situated learning there is an element of social interaction. The situated learning theory suggests that all learning takes place within a specific context and the quality of the learning is a result of interactions among the people, places, objects, processes, and culture within and relative to that context. Thus, integrating ICT in the teaching of mathematics requires interaction between mathematics teacher educators and their students. As they explain and demonstrate the concept using ICT, the students start moving from the periphery of their ‘novice status’ towards the CoP where skills, beliefs, and behaviours are acquired. They become more engaged within the community, and with time they assume the role of expert.

A number of researchers believe that knowledge is situated and should not be treated separately from the situation in which it is constructed (Brown et al., 1989; Greeno, Smith, & Moore, 1992). Situated learning, or situated cognition, is a theory of how knowledge is acquired (Kincheloe & Horn, 2007) when students work on authentic tasks that take place in real-world settings (Winn, 1993; UNESCO, 2002). Thus, situated learning is viewed as an activity where the context and culture in which it is happening, differ from abstract classroom learning and out of context (UNESCO, 2002). Learning is shaped by location, and the learning environment is a key component of any theory of instructional design. Learners observe practices of experts as they learn to perform tasks on their own. Lave (1988, 1996), who advocated the idea of situated knowledge, suggested that “learning cannot be separated from context, activity, and culture” and added that “social interaction is a critical component of learning”. In other words, learning occurs in a participation framework (or social practice) and is not a one person act (Lave & Wenger, 1991). It is facilitated by students’ prior knowledge which is connected to current activities. Thus, it can be said that learning takes place through interaction among people. In other words, learned concepts are linked to the situation in which they are learned. Here are some examples of situated learning:

- Field trips—enable learners to familiarise themselves with an unfamiliar environment.
- Corporative education and internship programmes—help learners by participating actively in real-life situations thereby gaining the appropriate experience.
- Laboratories and child-care centres—learners are involved in activities that extend to or simulate actual work settings.
- Collaboration, practice, and assignment (Laurillard, 2012).

Similarly, when integrating ICT in mathematics lectures, both mathematics lecturers and students are physically present and interact with each other during the learning process.

4.2.6 Interpretivism as a Paradigm Approach

Interpretivism believes reality and the individual who observes it, cannot be separated. It acknowledges that different social realities exist because of various human experiences and that human behaviour is influenced by the environment they are socialising in. The interpretive paradigm focuses on how people construct meaning in their own local context without manipulating their setting. In the interpretive paradigm, the researcher seeks to understand the participants' experiences by interacting with them through processes that allow participants to express their views, knowledge, and motivations. This study focused on the interpretivist paradigm.

Myers (2013) said interpretivism compels researchers to interpret elements of the study, in other words, there should be a human presence in the study. In addition, interpretivism focuses on the meaning and may employ multiple methods to reflect different aspects of the issue. The world is interpreted through "the classification schemas of the mind" (Williams & May, 1996, in Gray, 2014, p. 23). In terms of epistemology, interpretivism is closely linked to constructivism. Interpretivism asserts that natural reality (and the laws of science) and social reality are different and therefore require different methods. While the natural sciences look for consistencies in the data in order to deduce laws (nomothetic), the social sciences often deal with the actions of the individual (ideographic) (Gray, 2014).

An interpretive paradigm is based on the idea that people interact socially to construct their own realities to make sense of their world (Cohen, Manion, & Morrison, 2007). It is premised on the fact that human experiences and behaviour is influenced by context and the variables within it. The interpretive paradigm centres on the construction of meanings in an individual's own local context.

4.2.7 Post-positivism

Post-positivism was created because of the limitations posed by positivism as a research paradigm. Panhwar, Ansari, and Shah (2017) highlighted that the positivism paradigm had some flaws and could not fulfil all the requirements of social sciences as it is based on scientific (observable) and empirical evidence. Post-positivism takes the good characteristics of "both positivist and interpretivist approaches" (Panhwar et al., 2017, p. 253) and focuses on the experience of the majority. The results depend on what the majority says. Furthermore, it provides the direction and perspective of the research study from multi-dimensions and multi-methods according to the nature of the research question (Guba & Lincoln, 1994). It tends to lessen biases and prejudices because of its multiplistic approach that uses different instruments to explore the phenomenon. In other words, the principal aim of post-positivism is to come up with "theories that explain rather than just describe social reality" (Gamlen & McIntyre, 2018, p. 4). This study seeks to understand the low ICT uptake by mathematics lecturers in the schools of education and explain the situation as it is found in the context of the respondents' setting. This philosophical paradigm was not used in this study as it is more applicable in a mixed methods approach.

4.2.8 Critical Theory

Critical theory can provide significant insight into how social knowledge is produced by linking research to social structural contexts. Willis and Jost (2007) described the critical theory as a paradigm that focuses on "how the sociocultural world of human beings operates—that is, in a context where there is typically oppression and use of power to privilege one group over another". Critical theory needs both researchers and participants to agree and disagree on what they term 'false consciousness' to develop new ways that will act as a guide to effective action. The critical theory assumes that ideas are mediated by power relations in society and that certain groups in society are privileged over others and exerts an oppressive force on subordinate groups (Gray, 2014). The purpose of critical theory is not to understand the situation around the phenomena but to change it. Teaching and learning in the South African context are still dominated by traditional methods (use of chalkboard and textbooks), yet the world is moving towards using ICT. The purpose of this study is to see a change in the teaching and learning of mathematics, particularly at initial teacher education. Mathematics lecturers are a group of people in a society that have been disempowered and need to be emancipated: they are expected to use new technology, yet they are not ready or emancipated to embrace that technology. Thus, the critical theory attempts to uncover the truth of the phenomenon in a particular context and investigate the legitimacy of it.

4.2.9 The Rationale for Adopting Interpretive Research

Critical theory can provide significant insight into how social knowledge The interpretive researcher seeks to understand the manifold realities of individuals in different contexts. In this research, participants are mathematics lecturers and fourth year B.Ed pre-service teachers that are mathematics majors at the FET phase and are regarded as helping to construct 'reality' with the researcher. This collaboration assisted in the construction of meanings and actions to be taken. When carrying out research, there is a need to understand different situations and contexts through which researcher and participant work, and an interpretive approach involve a process of conducting an inquiry in natural real-world settings. The interpretive paradigm attempts to "understand and interpret the world in terms of its actors" (Cohen et al., 2011, p. 31). Interpretation and meanings of the phenomena is of paramount importance in interpretivism. Interpretivism employs multiple data-collection methods to allow a range of perspectives. Researchers working within an interpretive framework tend to favour interviews and participant observation as data-collection method (Denzin & Lincoln, 2009).

This study is concerned with how mathematics lecturers are integrating ICT in their lectures. To find out how they are doing this in practice, I adopted the interpretive approach as it is practical. The practical interests refer to the craving within a person to take the right action in a specific environment. The paradigm is context-driven and allows the researcher to generate practical knowledge. The interpretivist methodology enabled me to collect qualitative data and use methods such as interviews and participant observation (popular primary data-collection methods) to collect the required information. Interpretivism assisted me in interpreting the real situation of mathematics lecturers integrating ICT in teaching and learning. In addition, it allowed me to interact more with the targeted population. The data obtained helped me to generate data, present the findings as rich descriptions, and consequently to analyse data inductively.

The interpretive paradigm provides a theoretical and practical lens through which to understand the change that is brought by integrating ICT into the teaching of mathematics. Knowledge is acquired through interaction and so is the construction of knowledge. Integrating ICT in teaching mathematics needs exquisite knowledge of technologies combined with content knowledge. Lecturers are challenged to interact with ICT gadgets in order to make their teaching more relevant in the 21st century. The global economy and workforce require people that can use ICT to propel the economy forward. Mathematics pre-service teachers require the same ICT readiness as they leave their university training to enter the teaching profession.

4.3 The Setting for This Case Study Within Interpretive Research

A case study is a deeper study of a particular situation that has been narrowed down from a very broad field to a researchable topic. Cohen et al. (2013) defined a case study as "specific instance, an instance in action, particular" (p. 289) that provides clear ideas when conceptualising or theorising them. Case studies penetrate areas or instances that cannot be analysed numerically. It is useful for testing scientific theories and models to determine whether they work in the real world. A case study focuses on a system or a unit. In this study, the case is mathematics lecturers and their B.Ed. fourth year students. They were studied in their settings, which were the schools of education in universities. The universities were the proper setting for the study because it is where these pre-service teachers are being prepared and there are ICT facilities and resources (such as computers, Internet, interactive white boards, Wi-Fi) that mathematics lecturers can use during the lecture. The case study was the preferred approach to find answers for what, how, where and why questions (Punch & Oancea, 2014).

For a case study to provide valid research data, it is of paramount importance that the collection of information is planned and structured. All relevant variables need to be investigated and verified. Collecting data at the participants' natural settings is advantageous and helps to maximise the validity of the information. One of the strengths of a case study is that it draws information from a smaller field that could have been missed in a bigger setting.

The purpose of the study was to assess ICT integration to support the teaching of mathematics in teacher initial education level. ICT has been envisaged as a panacea to help students understand abstract mathematical ideas by allowing them to explore challenging mathematical problems in different ways. I used the case study because it is suitable for the bound context of this exploration. The study required an in-depth understanding of the reasons for the low use of ICT in the teaching of mathematics and other factors (beliefs and attitudes) that might emerge. The case study is ideal because it sets parameters for the context in which the study is carried out, which affords the researcher deep insight into the studied phenomenon. As alluded earlier, a case study aims at understanding a phenomenon as fully as possible from the players in their perspective setups (McMillan & Schumacher, 2010). The emerging findings from the case study can be presented and interpreted by the researcher, who must apply their pre-existing, relevant knowledge and experience to make some judgement about the findings from the case study (Cohen et al., 2013).

4.4 Methodology Approach

This research is a case study that investigated the contemporary phenomenon of ICT integration by mathematics lecturers in preparing pre-service teachers. In this case, the researchers wanted to find specific challenges mathematics lecturers are experiencing or that are hindering them from integrating ICT in preparing future teachers. The case study seeks a holistic description and explanation of the phenomenon (Merriam, 1988). A methodology can either be quantitative, qualitative or both, also known as mixed methods. In quantitative methods, all the data collected are counted or quantified. Trochim and Land (1982) defined the quantitative research design as the paste that makes the research project a single item. A quantitative method is used to deduce information, in the sense that inferences from tests of statistical hypotheses lead to general inferences about the characteristics of a population. On the other hand, Creswell (2012) defined a qualitative approach as one in which the inquirer often makes knowledge claims based primarily on constructivist perspectives. In addition, Creswell and Poth (2017) described qualitative research as “a situated activity that locates the observer in the world” (p. 7). It consists of a set of interpretive, material practices that make the world visible (Lewis, 2015). These practices transform the world ….” Qualitative researchers study things in their natural settings and try to make sense of them, interpreting the phenomena in terms of the meanings people bring to them (Denzin & Lincoln, 2005). The qualitative research method allowed me to hypothesise, explain, and conceptualise from details provided by mathematics lecturers, which makes qualitative methods appropriate for the interpretive paradigm. In summary, qualitative research displays the following characteristics (Creswell, 2009; Bogdan & Biklen, 2007; Leedy & Ormrod, 2010):

- It is conducted in natural settings (such as schools, sports field, etc.);
- It uses extensive data to describe a phenomenon in words, rather than with numbers;
- The emphasis is on process rather than on product;
- It is often based on inductive logic: Going from the specific to the general;
- Data are generated mainly through interactions like conversations and interviews; and
- The search for meaning is often evident and focuses on how people try to make sense of their lives.

4.5 Research Approach

Figure 9 provides the blueprint for the research approach.

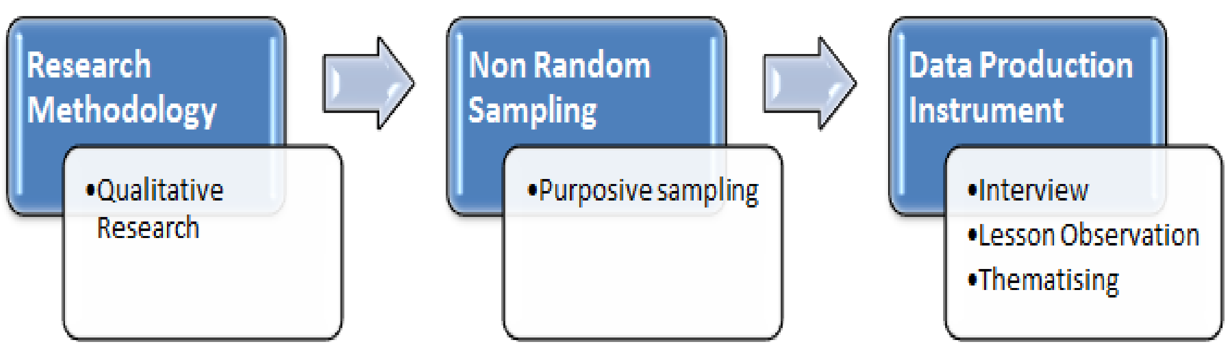


Figure 9: Research blueprint

A research design is a plan or proposal to conduct research (Mouton, 2001): it is a blueprint for conducting the study. Bogdan and Biklen (2007) said a research design is a plan for how to proceed. It involves the intersection of philosophy, strategies of inquiry, and specific methods. I used a qualitative method approach for this study because it unpacked the mathematics lecturers' ICT experiences in classrooms, thereby providing a rich, interpretive exploration of (Patton, 2015) their opinions about integrating ICT in teaching practices by applying the cognitive apprenticeship method.

This section outlines the in-depth processes and strategies used in data gathering and analysis of data. Qualitative research is naturalistic by nature and allows the research to be carried out with people in the context of their current situation. It is concerned with the activities of people in their daily lives. Therefore, qualitative research worked well for this study as it looked at the everyday interactions of mathematics lecturers with their students. An interpretive research approach was chosen as it positions itself squarely in the sociocultural framework of learning. The interpretivist paradigm gives researchers the opportunity to express their view of their world through participation, perceptions, and experiences. Thus in seeking the answers to the research question, I used "those experiences to construct and interpret his understanding from gathered data" (Thanh & Thanh, 2015, p. 24). In order to determine how mathematics is taught at institutions of learning in South Africa, I needed to closely observe and deeply interrogate the participants to learn about their lived experiences in their environment.

4.6 Interviews as Method for Research Questions 1 and 2

An interview is a face-to-face dialogue between the interviewer and interviewee with a particular purpose in mind (Cohen et al., 2013). An interview gives space for the participants to express their thoughts and narrate their situations from their perspectives. It is through interviews that the researcher comes to know about people, their experiences, attitudes, and feelings in the world they live in. In-depth information can be gathered directly from the participants using their native language. In an interview, the researcher can explore the stimulus and elucidations for participants' behaviour, which is often hard to observe directly (Punch & Oancea, 2014). Furthermore, knowledge is constructed in the interview as the conversation unfolds (Kvale & Brinkmann, 2009; Cohen et al., 2011). Qualitative research interviews seek to understand themes of the lived experiences from the people's own perspectives.

The purpose of the interviews in this research was to try and answer questions regarding how mathematics lecturers are preparing pre-service teachers for ICT pedagogical integration. Some of the questions that were asked were: Is there an existing framework used for the preparation of pre-service mathematics teachers for ICT integration in South African universities?; and How does it fit into the teaching of mathematics?. These questions helped to generate data that contributed to my understanding of how ICT is used by mathematics educators without imposing any prior categorisations that might limit the breadth of inquiry (Punch & Oancea, 2014).

I was not able to take notes of everything that was being said as I conducted the interviews, and therefore, audiotaped all the interview sessions. The audio recordings of the interviews meant that everything said during the interviews was saved and I could rewind and listen to it repeatedly to get clarity on the interviews.

This study used semi-structured interview questions (see Appendix I, II, and III). The semi-structured questions allowed both me and the respondents to explain the question or give feedback. Appropriate questions were added and inappropriate ones were excluded. All the respondents were asked the same questions, and the questions were explained further when the respondents wanted clarity. Denzin and Lincoln (2009) explained semi-structured interviews as sets of predetermined questions created by the researcher. It tries to understand the themes of daily lived experiences from the rightful people in the area where they live. This form of interview is usually scheduled and the appointment time and location are agreed upon. The researcher crafts the questions based on their research interests but is flexible and allows room for the respondents' descriptions and narratives (Brinkmann, 2014). The questions permit some flexibility to re-word or paraphrase the questions as participants are being interviewed. Data generated from such an approach can give insight into the phenomenon studied and can be comprehensive, however, it can pose some challenges when analysing.

4.7 Thematic Content Analysis Method for Research Questions 1, 2 and 3

At the policy level, Roach, Niebling, and Kurz (2008) highlighted three ways of establishing alignment within the policy elements of the curriculum. The elements include content, instruction, and assessment. The approach has three stages, which are:

a) Sequential development—is whereby one policy element is created and accepted, which subsequently serves as a plan or blueprint for additional policy elements.

b) The process of expert review—involves a panel of content experts who convene a meeting to review the policy elements and determine the need for alignment.

c) Content/document analysis—includes the coding and analysis of documents that represent the different policy elements. Cohen et al. (2013) defined content analysis as "the process of summarising and reporting written data" (p. 563). Their definition of content analysis indicates that there are rigorous or deep examination and verification of the contents of data.

From these three approaches, document/content analysis was adopted; the other two approaches are useful at the curriculum and developmental design level. The term 'content analysis' will be used throughout the study. The content analysis helps when working with an already existing document while the other two help to create new documents.

Content analysis was employed in this study because it is a way of finding patterns in the data required to answer research questions that were conceptualised at the theoretical level. Content analysis refers to analysing meaning and facts or themes in already existing written data. The information gathered can be used to arrive at the conclusion. I chose this method because it could be used to contribute new information about how ICT can be appropriated and adopted by schools of education. The raw data was collected and organised, re-organised and interpreted to search for patterns in the data. Figure 10 shows the general process followed to analyse the data.

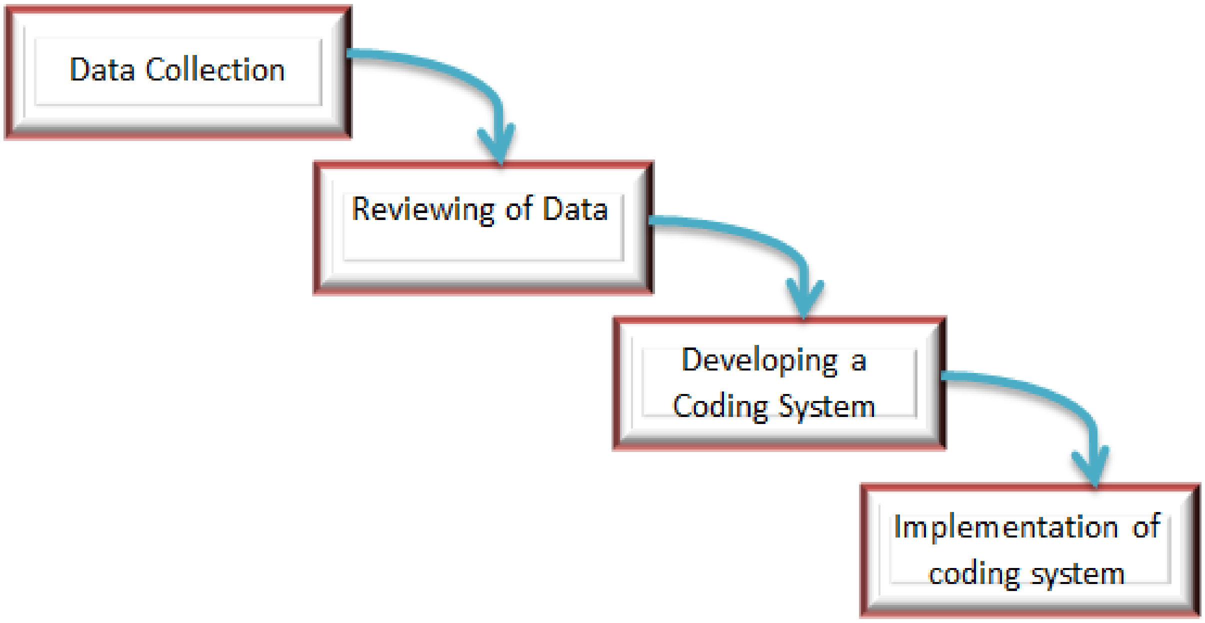


Figure 10: Process of analysing data

4.8 Empirical Setting and Participants

Empirical setting is a way of gaining knowledge by means of direct and indirect observation or experience. Taylor and Bogdan (984) defined participation in research as social interaction between the researcher and informants in the environment during which data are systematically and unobtrusively collected. I actively participated in capturing first-hand information that other researchers might otherwise not have seen. Data was collected from two mathematics lecturers and the subject Head of Department (HoD) in each of the four Gauteng universities; in addition, one mathematics lesson was observed per lecturer. The purposive sampling method was used to select the participants. The aim of purposive sampling in this research was to focus on mathematics lecturers in the mathematics departments who could assist in answering the research questions outlined in Chapter 1. The sample is not representative of the population; therefore, the findings of the study cannot be generalised beyond the participants. I focused on the following research questions:

1. How do mathematics lecturers prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

2. What ICT tools does mathematics lecturers need to adequately prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

3. To what extent are the pre-service teachers being prepared to meet the demands of the 21st century classroom?

4. What ICT pedagogical model/structure is suitable for preparing pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

4.9 Data Analysis Approach

Data analysis is the technique used to make sense out of data and determine behavioural patterns. Mertens (2014) mentioned that data analysis throughout the collection process enables researchers to continue discovering something about the data. This discovery opens up ways of either modifying the data-collection process or extending data collection up to a point where the final data is ready for analysis. Data analysis also refers to a process of applying some statistics with the intent of identifying a phenomenon and coming up with a hypothesis derived from the data. Bogdan and Biklen (2007) defined qualitative data analysis as manipulating, arranging and organising, chopping data into manageable pieces, and searching for patterns. The principal aim of analysis of qualitative data is to take note of patterns, concepts, and meanings obtained from the data. In this research, I considered the data as a whole and then attempted to cut it into manageable pieces and reconstructed it to make it more meaningful. Classification and categorisation helped me to make comparisons and contrasts between data patterns and finally arrive at a better-informed decision or conclusion. Themes and notions from the supporting literature was also used in the process of data analysis (Cohen et al., 2007). The responses from the participants were analysed, compared, classified and categorised with the results of the recorded focus group interview, and subsequently triangulation was applied to draw conclusions (Merriam, 1988). The data interpretation was intended to capture the authentic meanings behind the patterns and themes and provide information that would be grouped to fit within an analytic framework (Patton, 2002).

There are different kinds of analysis that include content analysis, narrative analysis, discourse analysis and thematic analysis (Cohen et al., 2007; Punch, 2009). I adopted thematic analysis in this research because it tries to locate the themes and patterns that are related to qualitative analytic methods in relation to epistemological and ontological positions and it is also flexible, useful and compatible (Braun & Clarke, 2006). It provides rich data that is detailed, though complex (Braun & Clarke, 2006). Generally, thematic analysis is a method "for identifying, analysing and reporting patterns within the data" (Braun & Clarke, 2006, p. 79). This method posits itself as an interactive process between the researcher's views and notions about the topic and tries to match the ideas to the data in an analytical framework. The analysis of themes can be both an inductive and deductive process in qualitative data. An inductive approach moves from "fragmentary details to a connected view of a situation" (Gray, 2014, p. 16) and a deductive approach begins with "a universal view of a situation and works back to the particu-lars" (Gray, 2014, p. 16). Although deductive theory is often used in quantitative research, it can also have place in qualitative research to test verified themes against a hypothesis. An inductive approach is the most common method used in thematic analysis and was used in this study. The inductive approach starts with a data-collection exercise, after which the data is analysed to determine any emerging patterns that suggest relationships between variables. Generalisations, relationships, and theories can be constructed from these relationship variables. The induction process helps the researcher to move towards discovering a binding principle or make some inferences. Figure 11 shows the steps taken in the inductive approach.

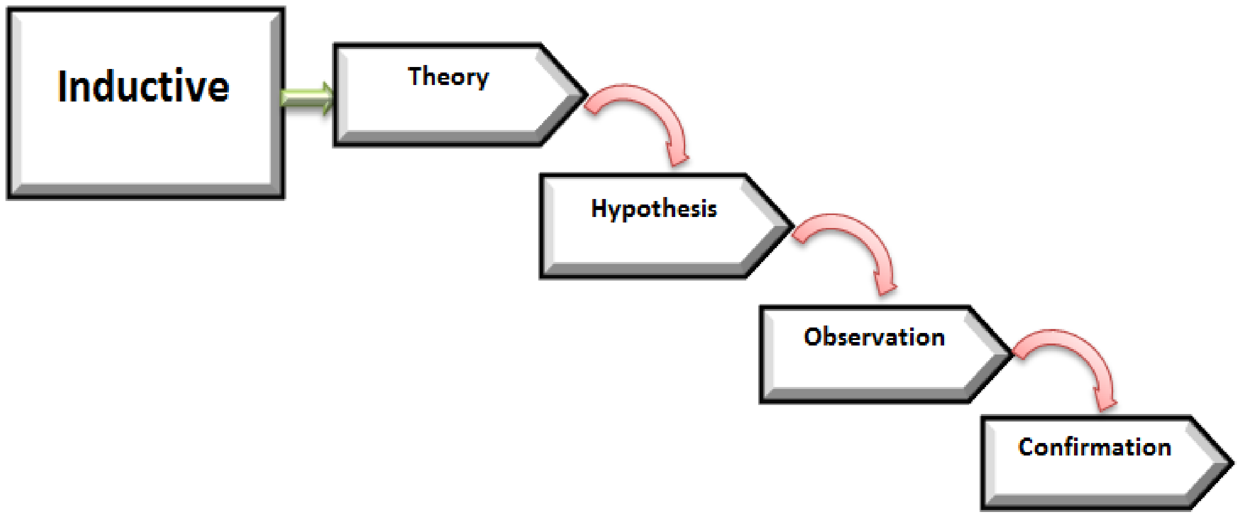


Figure 11: Inductive process approach

I began analysing my data as it was transcribed. This made me aware of the emerging themes that indicated the reasons for the low uptake of ICT by mathematics lecturers at the universities. This awareness allowed me to evaluate the data to determine emerging themes informing the reasons ICT was not used as required by MRTEQ (2015). To validate my themes, I used NVivo software, a qualitative data analysis software programme used by qualitative researchers around the world for thematic coding and visualising data. NVivo improves the quality of research significantly. The software reduces the manual tasks the researcher has to do to find themes and provides more time to discover data pattern tendencies, recognising themes and deriving conclusions. NVivo also has the advantage of returning control of data and supporting the widest range of different data sources. To analyse data, one can choose from manual or autocoding and refine a large data set. It has the provision of continuously exploring and questioning data with the widest range of visualisations on the market. Another advantage that NVivo offers is that boarding tools help the software solve particular problems quicker, thereby reducing the time that has to spend with the data. It can handle many data types and import Portable Document Formats (PDFs) and libraries, including attached PDFs from the reference management software. Once there is a source file, NVivo can be used to identify key themes within the text to show how many times they have appeared in the text.

4.9.1 Trustworthiness

Trustworthiness in qualitative research is closely related to the "paradigmatic underpinnings of the particular discipline in which a particular investigation is conducted" (Morrow, 2005). Trustworthiness refers to the quality of the research and includes credibility, dependability, and transferability throughout the research procedure (Griesheim & Landman, 2004). According to Morrow (2005), credibility refers to the idea of internal consistency, transferability refers to the level at which the reader is able to generalise the findings of a study to their own context, and dependability deals with the way in which the study is conducted and should be consistent and reliable across time. The research findings should be shaped by the response of the participants and not influenced by a researcher's bias, interest or motivation.

To establish the credibility of data, a method called triangulation is used. Jick (1979) cited Denzin (1978: 291) and defined triangulation as "the combination of methodologies in the study of the same phenomenon" (p. 602). To improve accuracy in judging a phenomenon, researchers should collect different kinds of data about the same phenomenon. The method allows the data to be cross-checked from different sources and assesses the credibility of an account, resulting in a convergence consensus of the interpretation of the events being investigated. The higher the degree of correlation between data gathered from the different methods, the more confidence is given to the researcher's data to give a credible picture of the situation. Using different sources of data helps the researcher "to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint" (Cohen et al., 2007, p. 112). This study focused on mathematics education lecturers, however, to have a complete picture of how mathematics is taught to pre-service teachers, fourth year B.Ed. students at the FET phase was part of the study in order to gain their insight about current methods used in teaching and learning mathematics. The interpretation of the findings may converge and thereby strengthen the knowledge claims of the study, or it may diverge and force an explanation of the lack of convergence of the results.

4.9.2 Ethical Considerations

Ethics was observed as I interacted with the university officials who served as participants (respondents) in the research while conducting this research. To begin with, I received written permission from the universities in which the research was undertaken or the departments in which the data was collected (see Appendix IV); in addition, the participants received independent declarations and non-disclosure/confidentiality consent forms that had an official university letterhead and stamp to sign. These forms were signed before any data and information were collected to give legal protection should there be any harmful information leaks. In other words, before collecting data, I received the ethics clearance. I fully explained the purpose of gathering the data to the respondents and assured them that I will keep all the responses confidential and/or anonymous. The university letterhead and stamp on the independent declarations and non-disclosure/confidentiality forms informed the respondents that this is an authentic university activity. In addition, the participants were made aware of the research data gathering process in advance to enable them to carefully consider whether they wanted to participate.

4.9.3 Generalisation of the Study

Guba and Lincoln (1994) asserted that generalisability is a measure in which the findings emerging from the study can be inferred and used by other researchers in different educational institutions. Since this study is a case study, I focused on the trends that are happening in selected universities in the Gauteng province of South Africa with a limited number of participants. Thus, it was a challenge for me to generalise the data so that it could be transferred and used by other institutions (Cohen et al., 2013). Limited transferability can be dealt with by putting the burden of transferring the findings of a case study to the reader who in turn will compare and contrast the similarities between the case study and their situation. It is the reader’s obligation to determine whether the study’s findings fit into the situation. I, as a researcher, have richly described the setup and interactions in the study to provide the reader with a detailed picture of the case study setting that will lead to an informed decision-making comparison.

4.9.4 Conclusion: Research Methodology and Design

The methodology adopted in this study was qualitative. An interpretivist paradigm was chosen as appropriate because it looks for "culturally derived and historically situated interpretations of the social life-world" (Gray, 2014, p. 23). The interpretive approach emphasises developing an understanding of the experiences of people's practices in order to gain a clear understanding of the phenomenon being studied.

Trustworthiness and ethical issues are of paramount importance in qualitative research methodology. Participants in the study needed a clear understanding of the research before they engaged as respondents and would want to know possible ethical issues that might arise during the study. The next section outlines the methods used.

4.9.5 Research Organisation

The research was a case study of two conventional universities and two Universities of Technology in South Africa. The study involved 8 mathematics lecturers, 4 mathematics Head of Department and 20 fourth year B.Ed. students at FET senior phase. Lecturers together with the students were interviewed and one lecture was observed.

In this study, detailed and rich information was obtained during the interviews. Each participant in the study was identified using a unique code. This was done to keep the names of the participants confidential. The coding system was arranged in a logical order to produce data required to answer the research questions.

Mathematics education lecturers

Mathematics education lecturers that I requested to interview in all four universities agreed to participate in my research. I used the ethics clearance letter obtained from the university where I am studying as an authentic tool to seek permission to conduct the interview. I wrote an email to the participants who in turn requested me to schedule a meeting with them with dates convenient to them. All the interviews were conducted in participants' offices. The 12 lecturers whom I had scheduled for the interview mentioned various opinions on how they use ICT for pedagogical purposes.

Table 6 below gives the composition of mathematics lecturers I interviewed and their context. The names of the participants were coded as AL#1 to represent the university name followed by the first mathematics lecturer interviewed (e.g. A is the university name, L#1 is the name of the lecturer interviewed first).

Table 6: Composition of mathematics lecturers participated

University Participants	Gender	Position	Conventional/Technology University
AL#1	Male	HoD	Conventional
AL#2	Male	Senior Lecturer	Conventional
AL#3	Male	Senior Lecturer	Conventional
BL#1	Female	HoD	Conventional
BL#2	Female	Lecturer	Conventional
BL#3	Male	Lecturer	Conventional
CL#1	Male	HoD	Technology
CL#2	Male	Senior Lecturer	Technology
CL#3	Male	Lecturer	Technology
DL#1	Male	Lecturer	Technology
DL#2	Female	Junior Lecturer	Technology
DL#3	Male	HoD	Technology

Mathematics pre-service teacher participants

To collect data from pre-service teachers, I took the opportunity I had with the HoDs to ask for permission to speak with the pre-service teachers in one of the tutorial sessions. The HoDs provided me with a list of names of the students from which I randomly selected five students. I also requested their contacts in the form of email and/or mobile. I was provided with both contacts. I contacted the pre-service teachers and outlined my research process and requested them if I could meet them at their convenient time to discuss my research data gathering. All 20 students I approached for data gathering, agreed to participate. Table 7 outlines the pre-service teachers' composition. The names of the respondents were coded as AS#1 to indicate the university name where the student teacher studies followed by the first pre-service teacher interviewed (e.g. A is the university name, S#1 is the name of the first pre-service teacher interviewed).

Table 7: Composition of mathematics pre-service teachers

Pre-service Teacher University	Gender	Study Phase	Year of Study
AS#1	F	FET	4th Year
AS#1	M	FET	4th Year
AS#1	F	FET	4th Year
AS#1	M	FET	4th Year
AS#1	M	FET	4th Year
BS#1	M	FET	4th Year
BS#2	F	FET	4th Year
BS#3	F	FET	4th Year
BS#4	F	FET	4th Year
BS#5	M	FET	4th Year
CS#1	F	FET	4th Year
CS#2	M	FET	4th Year
CS#3	M	FET	4th Year
CS#4	F	FET	4th Year
CS#5	M	FET	4th Year
DS#1	M	FET	4th Year
DS#2	M	FET	4th Year
DS#3	M	FET	4th Year

DS#4	M	FET	4th Year
DS#5	M	FET	4th Year

4.10 Data Collection

Data was collected in three phases. The first phase involved interviewing mathematics lecturers teaching fourth year mathematics FET pre-service teachers.

4.10.1 Mathematics Lecturers Data Collection

Data collection was done through interviews. I first explained the reasons why I chose this approach to the interviewees: Interviews are one-on-one interactions between an interviewer (the researcher) and an individual (respondent) used to gather information on a specific area of interest. The purpose of an interview is to gather descriptions of real life in the "world of the interviewee with respect to interpretation of the meaning of the described phenomena" (Opdenakker, 2006, p. 1). All mathematics education lecturers in education departments were interviewed at times convenient to them in their offices. The interview questions are in Appendix I.

4.10.2 Pre-service Teachers Data Collection

The second data source was interviews with mathematics pre-service teachers. As I mentioned in Section 4.9.5, the HoDs provided me with a list of names of the students from which I randomly selected five students at each university. I managed to conduct five interviews with students from the same university as a focus group. Focus group interviews are interviews conducted within a group of between 4 and 10 participants, aiming to collect a variety of information. There were some topics in mathematics that I thought would be taught better with the use of ICT, as listed in the questions for the pre-service teachers' interview in Appendix II. The purpose of the interview was to gain insight into how they are taught mathematics. The interviews were conducted at times and places convenient to them. All the students interviewed agreed to be audio recorded to ensure accurate capturing of the data.

The two main questions asked were:

1. This is your final year as a B.Ed Mathematics student at this university. Do you think your university and your mathematics lecturers have prepared you enough to pedagogically integrate ICT in the teaching of mathematics? How do you see ICT as a relevant tool in the teaching of mathematics?

2. Today's learners are natives of technology. They interact with technology almost every day of their lives. Some of you even spend most of your time using technology. Drawing from your past experience as a student at university, do you think universities should include a programme that pedagogically integrates ICT in teaching and enable you to teach using ICT? Please provide reasons for your answer.

4.11 Thematic Data Analysis

The thematic analysis focuses on distinguishable patterns and themes that come out of the processed data (Aronson, 1995). Braun and Clarke (2006) defined thematic analysis as "a method for identifying, analysing and reporting patterns (themes) within data. It minimally organises and describes data set in (rich) detail" (p. 79). This process is vital as it brings out themes and patterns inherent in the data. The identified patterns were grouped and regrouped to allow me to gain an understating of the participants' experience in their local context. Issues that emerged as critically important were taken into consideration. A thematic framework was set up to sift and sort data. I drew up the priori issues, those informed by original research aims and emergent issues raised by respondents were also taken into consideration (Huberman & Miles, 2002). Constructing a thematic framework involves a lot of logical thinking coupled with intuitive thinking. The researcher needs to make a meaningful judgement around the data gathered and "make implicit connections between the ideas" (p. 314). In addition, the research questions should be fully addressed.

4.12 Thematic Analysis: Mathematics Lecturers Interviewed

Thematic analysis was used to determine the use of ICT in the lecture room by mathematics lecturers, how they understand the pedagogical integration of ICT, their skill level, and their perspective on ICT. Inductive thematic analysis was used to analyse the interviews. Thematic analysis is a flexible approach to analysing qualitative data and provides the fundamental skills required for analysing data and "conducting other forms of qualitative analysis" (Braun & Clarke, 2006, p. 78). Braun and Clarke (2006) also claimed that thematic analysis gives the researcher the ability to identify themes /patterns from data and is a flexible tool to use. Punch (2009) asserted that the themes are determined by the researcher and will continue being reshaped to meet the researcher's expectations.

I used the interviews that I recorded to assess mathematics lecturers in education departments to determine whether they are harnessing ICT in their lectures. I read the transcribed data over and over to determine their responses to the questions. I gathered all the responses question by question to determine their practices. The patterns and ideas coming out of the questions were coded. Coding is a procedure that allows the researcher to organise the text of the transcript and identify some patterns or themes within that organisational structure (Auerbach & Silverstein, 2003). It is these patterns/themes that inform the theory to be adopted. I used a table to capture the responses of the interviewees and further regrouped the responses that had similarities. I counted the number of mathematics lectures' responses per theme identified. This enabled me to note the similarities and differences within a question.

4.13 Thematic Analysis: Mathematics Pre-service Teachers Interviewed

To analyse the pre-service teachers' interviews, I used the same technique as highlighted in the mathematics lecturers' data. Each question posed was distributed to the interviewees and I extracted the common themes/patterns and subthemes. I grouped and counted the number of responses to the question. The questions for the pre-service teachers were not necessarily the same as for the mathematics lecturers. The purpose of the interview was to confirm their perceptions regarding the use of ICT in the teaching of mathematics.

The text recorded from the interviews was broken up into manageable portions (Auerbach & Silverstein, 2003) to reduce the overcrowding of data. This was done by reading the text with the research questions in mind. The text that related and was relevant to the research question were grouped together. The text that did not relate to the research questions was saved somewhere else to be looked at later. On several occasions, I noticed that different research participants used similar phrases or words to express an idea; these ideas were grouped together as they were important for the study. It is at this point that I noticed mathematics lecturers' perception towards pedagogical integration of ICT in the classroom. Common ideas were grouped to determine the theme. The categories of data that were identified were analysed for the purposes of noting the relationships. The relationship between data and analysis are presented in Chapter 5.

4.14 My Role in Data Collection

To begin with, I clearly stated the purpose of the research, the methods used, and the possible outcomes of the research. I informed the participants that they were invited to take part in my research because it involved collecting information on their experience of using ICT in classroom instruction. I distributed emails to the mathematics HoD of the identified universities together with the ethics clearance letter. An information sheet providing details and explaining the purpose of the study and the role of respondents were developed (Appendices II and III). The consent letter also indicated that participation was voluntary and the participant could withdraw at any time. I mentioned that the data would be collected from the mathematics HoD, two mathematics lecturers and five students and that research participant would be selected using an extreme case sampling strategy that singles out the participants who display distinguished characteristics. In this case, I selected participants who were more knowledgeable about ICT. The HoDs assisted in this regard. Face-to-face interviews were conducted at the participants' workplaces. I used group interviews for the pre-service teachers. They felt more comfortable and confident to respond in a group environment than in face-to-face interviews.

While conducting the interviews, I took notes and audiotaped the interviews with the consent of the interviewees. The audiotaped information has the advantage that it can be backed up for safety. The audio recordings enabled me to make a thorough analysis as I could rewind and listen to it repeatedly to get clarity.

4.15 Confidentiality and Privacy

I promised all the respondents that the information collected from them would be confidential and would not be shared with anyone. The raw data would be kept in a safe place and destroyed 5 years after completing the study. Furthermore, I promised them that their anonymity would be ensured by using pseudonyms in the research write-up instead of their actual names. No information would be disclosed or shared with other interviewees. The data collected would be used for this study, and to a lesser extent, for writing articles. Raw data was encrypted and then saved on a CD or removable disks as backup. In addition, the information stored on the devices was password-protected to make it difficult for other users to access the stored data.

4.16 Conclusion

The chapter described the methodologies and methods used in the research. The research adopted a qualitative method approach and interpretivism as a paradigm lens. The interpretivist approach emphasises the lived experiences of people and their practices in order to gain a clear understanding of the phenomenon being studied. Issues to how data was gathered were clearly highlighted together with the issues of ethical and privacy considerations.

The following chapter looks at the relationship between the findings obtained from the interviews with the lecturers and the students. The findings reflect participants' voice in verbatim that communicate their perception about the use of ICT into teaching and learning.

CHAPTER 5: MATHEMATICS EDUCATION LECTURERS' USE OF ICT IN TEACHING

5.1 Introduction

This chapter responds to two sub-questions of the main research question, which are:

a. How do mathematics lecturers prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

b. What ICT tools does mathematics lecturers need to adequately prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

As reported in the previous chapter, 12 mathematics lecturers and 20 pre-service teachers participated in this study. This chapter reports on the findings and themes that emerged from the interviews. The common themes identified were 'type of ICT tools used as part of pedagogy', 'skill level, perceptions', 'lack of professional development' and 'absence of framework'. The interviews were quoted verbatim to respect the authenticity of the respondents. The participants were coded following the name of the university they belong to and the name of the first lecturer interviewed, for example, Lecturer AL#1, Lecturer CL#3 and so on. The thematic approach was used to analyse the data.

5.2 Pedagogic ICT Tools

The pedagogic ICT tools that mathematics lecturers reported on using in their lecture rooms are:

- YouTube—used to supplement/reinforce taught concepts;
- Internet—used for further research on the topic taught;
- Sakai/Blackboard—used as a repository for learning materials. Lecture notes, assessments and communication between the lecturer and students is done via the Sakai/Blackboard learning management systems;
- PowerPoint—used for lesson preparation and delivery; and

- Projectors—used to project PowerPoint slides.

These tools, according to mathematics lecturers' beliefs, are used by lecturers to meet the demands of the 21st century classroom, which include collaboration and sharing, critical thinking, problem-solving and creativity. However, mathematics lecturers mentioned that they use these tools to aid their teaching, not to teach mathematics.

5.2.1 Mathematics Lecturers' Beliefs and Attitudes of What ICT Pedagogical Integration Is

Human factors such as attitudes and beliefs have a major influence on lecturers' behaviours, and consequently, on their readiness to use ICT in the lecture room. To understand mathematics lecturers' perspectives on their preparedness to use ICT in the lecture room, their attitudes towards, experience with and confidence in the use of ICT were investigated. The 12 mathematics lecturers' comments indicated a belief in ICT and the value it holds as a teaching tool to solve mathematical problems in various ways. The following comments encapsulate their attitudes and beliefs.

L#1W felt that ICT was a positive tool and commented that, "It depends on lecturers, some view pedagogical integration of ICT as the right step in solving challenging mathematical problems. Some feel comfortable with their old methods of teaching". His comments tally with the demands of the 21st century classroom that require, among other things, the promotion of collaboration, knowledge sharing by mathematics lecturers, problem-solving skills and critical thinking.

AL#2 said that he has some fear of technology that leads to his resistance to using it in teaching. He remarked:

> *… technology is for young people, some of us who are old, beyond 60, do not think technology is necessary, because they have managed without technology for many years. There is that resistance to change. Another barrier is that technology is ever-changing. Very few can use the smart board, including me. Learning using technology is another load to already overloaded work. Some people would say let me go ahead with*

what I have. The issue of the use of technology is slow because of a lack of training. However, the opportunities are very great.

One of the strongest themes was fear and most of the mathematics lectures did not believe that the outcomes of ICT integration will be positive. AL#3 remarked:

I think sometimes it is fear, and sometimes the fear that my students [sic] will not able to access the technology/ICT. I think a large part of it is people's habits. Many think that the technological advantages of ICT are going to be difficult to integrate. I think habits are the people that keep people away. If somebody was told you are going to attend a course on integrating ICT in your subject in the classroom and that kind of training was provided and the likelihood is that lecturers will start integrating it more and over time, but I think it takes an effort on management to take it. Habit and issues of the time. Lecturers do not have enough time, in addition to the curricular load requirement to do more work.

The other hindrance to the adoption of ICT as a mediation tool is the time needed to prepare lectures that embrace technology. Lecturers claim that they already have an overloaded schedule and using ICT will take away what little time they have. BL#1 reiterated that the lecturers' mindset makes them resist any change that might mean they have to change their teaching style. She commented:

As I mentioned earlier, I think it's about the mindset. I have taught for many years, why should I change, that is one reason. Lecturers do not have enough time to accommodate new programmes. Many people believe mathematics is an abstract subject; it's not a human subject. Technology is seen as associated with human being doing something. It's a practical subject yet mathematics is seen as abstract. That is a reason why it cannot be taught using technology.

According to B#1, habits, time and mindset keep mathematics lecturers from embracing ICT. They see teaching using technology as an added load on their already fully packed curriculum. She thinks that 'hand-on' ITC cannot work with abstract mathematics, which shows a lack of knowledge about integrating ICT and how useful it can be to illustrate abstract concepts.

DL#1 indicated that ignorance makes mathematics lecturers shun embracing technology because they do not know the reasons behind integrating ICT in their teaching. He suggested that integrating technology in their teaching should be explained and demonstrated to give the lecturers insight into the value of technology in the classroom. He explained:

> *Lack of knowledge and ignorance is the main thing. Wherever possible the benefits of technology should be demonstrated to indicate what they currently do. The benefits should be stated upfront and am sure once that is done they may accept technology in the class. Let me tell you something about lecturers, most of our people are suffering from superiority complex: They are still stuck in that mode of saying I am an expert, I am expected to be knowing everything. Where in actually if you can be in a situation where you learn from your students; and there is nothing that excites the students when they teach their lecturers something. They enjoy it. By doing that you are empowering them to take ownership of their own learning.*

A view that lecturers suffer from superiority complex emerges: A number of them feel challenged by the already information technology knowledgeable students and thus decide not to use technology in the class. In our information technology-driven society, the use of ICT is a must, and mathematics lecturers will have to change their attitudes and beliefs towards the use of ICT in the classroom and think of the students they are preparing who are expected to meet the demands of the 21st century.

All 12 lecturers interviewed agreed that ICT is important in teaching and learning. However, their understanding of pedagogical ICT integration in teaching and learning differs and I noted the main theme from each individual regarding their understanding of ICT integration. Table 8 displays the different themes that came out and the number of respondents per the theme.

Table 8: Mathematics lecturers' understanding of pedagogical ICT integration in teaching and learning

Understanding of pedagogical ICT integration in teaching and learning		Number
5.2.1.1	Tools used in the class by mathematics lecturers to teach with and to	2

	create understanding	
5.2.1.2	Tools used as a repository to upload lecture notes, communicate with students and do assessments	6
5.2.1.3	Data projectors, computers, use of Internet and websites	3
5.2.1.4	TPACK—This is actually the merge of three bodies of knowledge	1

5.2.1.1 Tools used in the class by mathematics lecturers to teach with and to create understanding

Two mathematics lecturers associated pedagogical ICT integration with using ICT to further regulative discourse, and two of the lecturers understood ICT integration as using it to enhance students' understanding of mathematical concepts taught using traditional pedagogies. In other words, they thought that ICT should be used after the material is taught to enhance and/or consolidate learning. Table 9 lists lecturers' views on how ICT is used to enhance understanding.

Table 9: Lecturers' use of ICT as a tool to enhance understanding

ICT as a tool to enhance understanding		Number
5.2.1.1.1	Lecturers use the traditional method in combination with ICT	11
5.2.1.1.2	Traditional method and the challenges of teaching mathematics using ICT	10
5.2.1.1.3	Refer pre-service teachers to YouTube websites	8
5.2.1.1.4	ICT is used to prepare lessons using Microsoft PowerPoint	12

5.2.1.1.1 Lecturers use ICT as a mediation tool

Eleven of mathematics lecturers interviewed mentioned that ICT is a tool that can be used to enhance learning, and according to them, ICT facilitates higher-order thinking skills through the knowledge gathered during interactions with the technology. Thus, ICT creates an environment where students can share ideas, collaborate and work together in solving complex mathematical problems. As lecturers use ICT in teaching, the students learn more about the concept, thereby mastering the concept and gaining confidence. BL#U described pedagogical ICT integration as a tool that cannot be avoided in contemporary education. This is what she commented regarding the use of ICT in teaching:

I am a mathematics specialist. I do not teach students to use ICT but I use ICT to teach students. For example, I use videos of the lectures. If students do not understand the concepts I refer them to a website and go over the lecture and rewind it. Technically that is how I use ICT. However, I am of the opinion that ICT acts as a mediating tool that enables student teachers to think critically and understand the subject matter. It exposes them to many ideas and the world they live in thereby creating an environment where all participate together to solve some problems.

BL#2 acknowledges that ICT can be a mediating tool if used correctly. She says she does not teach students how to use ICT; however, she refers them to websites for further research to extend skills in problem-solving or to cultivate the spirit of critical thinking to solve problems. In addition, she sees teaching mathematics using ICT as creating an environment where students can work together to solve some problems, thus owning the skills to solve complex tasks.
BL#1 concurs with the above statement by saying she uses ICT to mediate the concepts already taught. She commented:

ICT is used as a resource, for example, in geometry I will show them with the software how to do graphing; again in trigonometry, teaching the movement of the graph; and I will show them with software if you change the amplitude or if I look at minimum and maximum values and how to change the degrees at the end using the software. It is a tool that mediates learning and consolidates learning particularly if the concept has been taught using the usual method of teaching.

Notably, ICT in teaching is used as a resource to enhance students' understanding of the mathematical concepts. The visual images last longer in students' minds than the text, and it consolidates what has been taught using the traditional method. AL#2 saw ICT in teaching as a mediation tool to increase students' understanding, especially for those who face challenges in mathematics. He is of the opinion that ICT can be used together with traditional teaching methods to reinforce students' understanding. He commented:

In the South African situation, where learners are not doing well in mathematics, that is why we bring in ICT mediation, it's another tool that can add on to other approaches.

> *That is why I said I use ICT to consolidate concepts that have been learned to enhance/cement their understanding.*

5.2.1.1.1 Using a combination of ICT and Traditional Teaching Methods

AL#2 uses ICT in teaching mathematics to supplement students' understanding of mathematics after a concept has been taught using other approaches. According to my understanding, lecturers used the expression 'tool that can add on to other approaches' to mean that it can be combined with the usual way (traditional) of their daily teaching practice.

The lecturers strongly believed that mathematics is taught well with the traditional teaching methods. They did not trust ICT as it hides a lot of the processes/steps in solving mathematical problems. They lamented that ICT needs the input of the required variable and it provides the final solution, hiding all the processes. They suggested that ICT can be used after the concept has been taught and understood by the learners. ICT technical glitches can also disturb the flow of the lecture, while also taking a lot more time to prepare lessons. Traditional teaching methods have none of these challenges.AL#2 commented:

> *I teach using traditional methods, that is, the use of chalkboards and textbooks. In my case, I have discovered that if you introduce new concepts using ICTs, learners would not have faith in you. They think that you are joking. My experience is that you teach normal mathematics using normal traditional methods. But then, when you are now consolidating/revising the concept of what they have already learned, you can use ICT as a mediating tool. In the traditional method, the teacher defines the content, give examples, and show representations.*

His comments show that he had some misconceptions and limited knowledge about using ICT in teaching mathematics. He sees presenting the content, giving examples and showing representation as being afforded by the traditional method. However, there are possibilities that one can use to define the content and give some examples using ICT. For example, the lecturer can present his entire lesson using Microsoft PowerPoint and other ICT tools. The lecture rooms that are equipped with interactive whiteboards can be used for demonstrating and working out mathematical problems. However, he is advocating for ICT use only after the concept has been taught using the traditional method.

AL#1 mentioned that ICT integration is still at its infant stages in South Africa and a number of lecturers have not mastered the use of ICT but see it as moving in the right direction, thus he commented:

> *It depends on lecturers, some view pedagogical integration of ICT as the right step. Some feel comfortable with their old methods of teaching*

Although he did not specify which methods he uses during his teaching practice, he views the pedagogical integration of ICT as the way forward. However, most lecturers are still teaching using traditional methods.

AL#2 described the way he favours traditional methods in developing the concepts. It allows him to model the concepts clearly, making sure his students receive all the required material to teach the topic.

> *I have not been teaching using GeoGebra because I do not teach [sic] a lot of geometry work. I am aware of it and the software is installed in our computer labs. My modelling, teaching of functions without technology is a necessary component of my work. The reason being that when teachers go into classrooms and only have ICT skills [sic] without the pedagogy content will impoverish or impair student's understanding. I like to demonstrate pedagogically the origin of the concept and when it's done, I can use the software applications.*

The lecturer reiterated that it is of paramount importance to have ICT pedagogical skills before engaging with ICT integration, otherwise, students may be confused about what skill is being developed. It is after the teaching of the concept that he may use the software as a mediating approach to enhance the understanding of the already taught concept.

BL#1 opined that both ICT integration and traditional approaches are important in teaching mathematics. However, she went further by highlighting that the traditional method sometimes helps a lot in explaining some mathematical concepts. Her comments suggested a scenario where students are facing some challenges in solving a mathematical problem. She said:

> *I believe in a blended approach when it comes to pedagogy. For me it's a blending, sometimes you have to do traditional, face-to-face; sometimes it helps a lot to do offline approach. I encourage my students to go to find information via the Internet. They may also search for the information on YouTube to reinforce what they would have learned.*

She uses ICT only as a method to reinforce her teachings. She uses the Internet to get YouTube videos that she later shares with students to further their understanding of the concepts.

CL#2 mentioned that he still teaches using the traditional method because he had never received training in the use of ICT. He highlighted that he was taught using the traditional method; and that, the use of ICT is a more recent methodology that most of his contemporaries were never trained to use.

> *I do not use GeoGebra to teach mathematics because I do not know how to use it. I know the software and it is installed in our computer labs, but I do not know how to use it. Thus I am still stuck to the old method of teaching. However, the current teaching is towards the use of ICT. ICT usage is recent in South Africa. Most teachers were trained in their subject area using the traditional method. ICT has just after our training. If you have not got any training in the use of ICT you would not able to integrate it, you tend to focus on the traditional way of teaching.*

Like CL#2, DL1# thought that they are still stuck in the traditional way of doing things. They used the term 'stuck' to refer to the continuous use of the traditional teaching method. Despite the effort by the university to make mathematical software available, most of the lecturers are finding it difficult to use the software because they know very little or nothing about it. This comment indicates that universities spend a lot of money to equip the education system with the new digital software, but the effort is not benefitting students or lecturers.

> *Most of us are still stuck in the traditional way of doing things. However, the university has put in place the infrastructure to upload our material online instead of relying on the distribution of hardcopies.*

I am using a lot of material from the websites. In terms of using the software, we are using none. We find it difficult to use software because we do not know how to use the application.

CL#2V believed integrating ICT cannot work in South Africa where students struggle to understand mathematics and he thinks the only way to make them understand is with the chalkboard and duster. He challenged the use of ICT as an approach that hides a lot of steps that students need to know, thus he commented:

General in mathematics and the use of ICTs, the way I see it as I said, a lot of these students and their nature in South Africa, you cannot use ICT alone. It cannot be effective. You need to clean the board and teach and go the traditional way. We have the challenge of the type of students we have. These students need to see a solution to a problem step by step. The processes will come out clearly when taught using traditional way.

The concluding message from all these comments is that mathematics is still taught using the traditional method. The software that can help lecturers teach mathematics was not fully explained, and this means they are not using it to support students' learning.

5.2.1.1.3 Refer pre-service teachers to YouTube website

Eight mathematics lecturers indicated that they use YouTube videos to enhance students' understanding of concepts. L#3U explained how he used videos in his lectures:

I do not teach students to use ICT but I use ICT to teach students. For example, I use videos of the lectures. If students do not understand the concepts I refer them to a website and go over the lecture and rewind it again and again.

BL#3 indicated that videos afforded students the ability to engage with the teaching material repeatedly to try to understand the concept. The main advantage the YouTube videos have is that they are permanent and can be replayed.

Their comments implied that videos can help students to understand taught concepts. They can be used to supplement their previous knowledge, exploring other methods to solve the same mathematical problem, and to develop expertise. The following six commentaries from AL#2, BL#1, CL#1, CL#3 and DL#2 respectively are illustrative of this:

> *I do use ICT, and sometimes I suggest to them links where they can get further materials, links like YouTube material online. I do encourage them to say that we are now in a new world, you can learn 24/7 nonstop. I always encourage them to use ICTs to research the concepts they do not understand instead of depending on me. Go online and google and you may be surprised that you will find some explanation that is clearer to you than what we had in class. Or another point of view that supplement what we had in the class. What I do not want is to divorce my responsibilities as a teacher just to say go and research online.*
>
> *Having access to these, one can also use the website and introduce them to various academy sites to consolidate what they would have learned.*
>
> *I encourage my students to go to find information via the Internet. They may also search for the information on YouTube to reinforce what they would have learned.*
>
> *Today's students are good at using ICT. They have smartphones that have access to the Internet. I usually refer them to sites where they may watch videos on YouTube to enhance their understanding of the learned concepts.*
>
> *Teaching mathematics using ICT is not ideal in the South African context because many students struggle to understand mathematics. ICT provides solutions. It does not show the entire work of the mathematical solution. However, I sometimes refer my students to some sites on the Internet where they can watch some YouTube videos to supplement their reading.*
>
> *These students need to see step by step. The processes will come out clearly when taught using the traditional way. We sometimes use ICT but not in a full way. We use YouTube videos when there is a need to demonstrate some concepts.*

Notably, all respondents shared that they ask students to use the multimedia content available on YouTube to supplement their study because they can use their smartphones to access these videos. However, the last two comments reveal that lecturers see the integration of ICT tools as an interruption, which does not even explain the steps required when solving some mathematical problems.

5.2.1.1.4 Microsoft PowerPoint as an ICT tool for lesson preparation

All 12 mathematics lecturers mentioned that they use Microsoft PowerPoint to prepare their lectures. They view PowerPoint as a tool that is easy to use when going through their lectures. This is what AL#1 said about it:

> *Some of us use PowerPoint to prepare lectures. As far as going deeper than that, we do not have a special skill.*

L#1W described PowerPoint as a tool he used to prepare and present his lectures and was quick to point out that he does not have any further skills. AL#2 acknowledged the support provided by the information technology department; however, challenges like power failures and the malfunctioning of some ICT gadgets are hard to avoid when teaching with technology. Hence, he always has a backup plan that does not use technology. He commented:

> *But I can tell you that even with his support, this year I did prepare some lecture slides [sic] in PowerPoint for use in my lecture, but you go to the lecture room and note that the system cannot log or can't play a video or can't play a data projector. Those hitches occur often. Whenever I go to the lecture, I ensure that I have notes in case there are technical [sic] hitches I fall back to the traditional method. If you do not do that you will appear like a fool.*

BL#1, like AL#2, always has a backup of the lecture in the form of printouts because sometimes ICT gadgets fail to work. She prepares the lesson on PowerPoint slides and uploads them on the Blackboard platform for students to access before each lecture. This enables students to prepare for the lecture and to understand it when it is taught. She commented:

> *I prepare my lectures on PowerPoint slides and upload them on Blackboard for students to access them before the lecture. But as a lecturer you must always have a plan B, sometimes power failure can disturb lessons to be delivered using ICT.*

AL#3 prepares his lectures in PowerPoint and uploads them on Sakai to be accessed by his students. Most students can access the Sakai platform, an educational software tool that supports both lecturers and students to teach, research and collaborate. This is what he said:

> *They have computers, Sakai platform, they can search on any engine for math computer software. However, they rely more on lecture notes prepared in PowerPoint.*

Though Sakai was built to provide higher education with a range of innovative tools for use in online teaching, it is underutilised by most mathematics lecturers. Most often, it is used to upload teaching materials and communication, yet it also has a built-in collaboration tool, forum-based discussions, flipped classrooms and project collaboration. Most lecturers seem unaware of these tools.

> *That is why in every department there is an ICT department. For instance, I prepare my lecture on Microsoft PowerPoint. It is a powerful tool because it contains text, images, and videos. It captures students' attention again.*

The above comment by BL#3 suggested that lecturing using PowerPoint is powerful as it combines different media into one platform. PowerPoint presentation comes with pictures, flow charts, animations, even video clips, and may make the lecture vivid and appealing to the students. Thus, each department needs to have an ICT department to provide support whenever there is a need. The support from the ICT department may boost the confidence of the lecturers who fear using ICT. In case technical hitches develop, these lecturers are assured of immediate support and that their lectures would not be interrupted too much.

5.2.1.2 Sakai/Blackboard used as repository to upload lecture notes, communicate with students and do assessments

The concept of associating pedagogical ICT integration with the repository tool was common among six mathematics lecturers interviewed. All the universities in this study have a repository management system where lecturers can upload teaching, research and communicate the information to the students. The repository systems have different names: In one university it is called Blackboard (Vutela) and in another university, it is called Sakai. These platforms provide facilities for courses, collaborative projects, and research and communication aspects. The platforms can be reconfigured (redesigned to look the way desired) to meet the environmental needs of a university by using open-source software. In addition, the repository functionality and tools can be customised to meet the lecturers' and students' requirements.

The perceptions of mathematics lecturers on how ICT should be integrated into mathematics teaching were linked to (or nested in) the teaching environment they worked from. Table 10 shows what the mathematics lecturers use the repository tools for according to the data analysis.

Table 10: ICT used as a repository tool

ICT as a repository to upload lecture notes, communicate and assess the students		Number
5.2.1.2.1	To upload teaching material	12
5.2.1.2.2	To communicate with students	12
5.2.1.2.3	To assess and provide feedback to students	12
5.2.1.2.4	To enable students to submit assignments	6

5.2.1.2.1 To upload teaching material

All 12 mathematics lecturers commented that they use ICT to upload teaching materials. The materials include lecture notes, reading the material in the form of books or journals. Each responder used the term 'I' for practical use of the repository tool in everyday teaching practice, which is evidence that they feel confident in its use. Uploading materials on a repository platform is considered as integrating ICT in teaching even though it is an administrative task.

AL#3 implied that ICT has been a big help to make communication with students much easier. His remarks were:

> *From an administrative perspective, we use Sakai. All my resources are uploaded to Sakai. It can be used as a communication tool.*
>
> *Sakai is a website that has the facility of electronic means of accessing students quickly, it is a repository for lectures, resources, course material, communication, assessment*

and fabulous tool for data and data becomes research. My course is uploaded on Sakai; students can print out my lecture slides. In short, it's a time-saving device.

AL#3's comment shows that he understands the concept of a repository tool. He said 'from the administrative perspective' to show that ICT can be used as a management tool. It handles a lot of information and it has come as a relief as it saves time.

BL#1 acknowledged that the use of a repository tool makes teaching much easier because students are given the lecture slides in advance to prepare for the next lecture and it makes her work much easier as she now comes to the lecture to teach not to provide notes. She commented: "I prepare my lectures on PowerPoint slides and upload them on Blackboard for students to access them before the lecture". These comments indicate that using the repository platforms available at universities is the norm and part of the everyday teaching practices, of the participants.

5.2.1.2.2 To communicate with students

These repository systems have built-in functionalities that allow both lecturers and students to communicate with each other using email. Lecturers can make an announcement through the platform and it will reach all the intended students. Students Pages within the platform enable students to share rich content with their peers and even with their lecturers. AL#3 views Sakai as a tool that allows him quick access to the students. He remarked: *"... it is a repository for lectures, resources, course material, communication, assessment and fabulous tool for data and data becomes research …".*

CL#2 communicates with his students via the Blackboard platform and it enables his students to prepare for the lesson in advance. He commented:

> *As a lecturer you need to plan for a lesson, you need to know the tool that you are going to use. Thus it's important to bring your student on the same page of your lesson. You need to communicate to the student through the Blackboard platform about what the next lesson is all about. Sometimes we communicate their results through the Blackboard and encourage them to work together as groups (collaboration).*

He seldom uses the Blackboard to publish the students' results. He noted that he encourages the students to work together through the Blackboard platform, but he did not explain how students could work together through the Blackboard platform and neither did he elaborate on his involvement in the collaboration. His statement implies that he knows what the Blackboard platform offers, for example, a forum, wikis and group chat functionalities. He knows that the current crop of students is 'digital natives' and assumes that they can easily use these functionalities provided by the Blackboard platform without challenges.

CL#1 indicated that at his university they have software they use to communicate with students. However, he highlighted that they have challenges with timely communication because many students do not have iPads or powerful handsets to access their emails. His remarked:

> *The university has the software like Blackboard and Sakai (though we have moved away from Sakai). These tools are available. They are for administration purposes. We can use them to communicate with students through their iPads, laptops. However, not all students have iPads and smartphones and also have a challenge of access to Wi-Fi.*

The communication is also sometimes hampered by poor Wi-Fi connectivity as there is a limited number of users that can access the Wi-Fi at a given time. These challenges implied that lecturers in this university are hesitant to use technology. They may send email communications to their students, however, not all students will able to see the communication. Thus, they revert to the old way of communicating by putting a notice on the notice board.

Overall the lecturers' coded comments indicated that repository systems are in place at South African universities and can be used to communicate with students. Students receive the emails, and as long as they are registered for the course, they can communicate with lecturers using Backboard or Sakai. Lecturers can share valuable information with students as and when required through the repository system.

5.2.1.1.1 To assess and provide feedback to students

Students always want to see their scores after they have submitted their assignments, projects, or tests. Of the 12 mathematics lecturers interviewed, only six mentioned that the repository system enabled them to give feedback to their students. Lecturers used the Gradebook functionality (calculates, stores and distributes marks to students) to enter students' marks on Sakai. AL#1 indicated that students use the repository system to submit their examination answer scripts. The scripts are downloaded by the lecturer, marked and sent back to the students for feedback. He remarked that "The students can submit the exams electronically and their work can be downloaded and marked. The marks can be sent to the students using Gradebook functionality". There is no need to display the marks on the notice board. Students just log into the system and view their marks.

AL#3 uses the repository system to assess students, among other things. He commented: "It is a repository for lectures … assessment and fabulous tool for data and data becomes research …" This is evident that he has experience in using the repository to assess the students and gives the impression that he uses the same system to give assessment feedback.

BL#1 discussed how she uses the Blackboard at her university in assessing students. She sets a multiple-choice test in Blackboard and assesses students using the Blackboard platform. Students log into the system using their credentials and write the test or do the exercise. Immediately after clicking the submit button, the students receive their score for the assessment. She commented: "I also use the Blackboard as a platform to do the assessment, mark multiple choices using the technology, and give the students feedback. I expose my students to do peer assessment via Blackboard". Another notable way that she uses the system is to engage the students by letting them assess one another, creating collaboration and using a learner centred approach.

CL#1 mentioned that he uses Blackboard to assess his students. He likes the multiple-choice type of questions because it allows Blackboard to mark the answers quickly and provide instant feedback. He remarked:

> *If I put tutorial questions for mathematics question on Blackboard in the form of multiple-choice or true/false, Blackboard can mark for you. This is the easiest method to*

assess the students. But if the questions are not objective, that is, question and answer or multiple-choice kinds of questions, Blackboard cannot mark for you.

Accordingly, Blackboard has some limitations as it can only mark multiple-choice type questions, which are of limited help in teaching mathematics. However, it can mark this type of work instantly and the student does not need to wait for the lecturer to provide feedback later; the feedback is available at the click of the button.

The feedback tool is often used by the mathematics lecturers. However, there everyone uses the system differently: Some use multiple-choice questions whose answers are already in the system, and others allow students to submit the tasks in the system, the lecturer downloads it, marks it, and sends the students feedback. The trend is for the lecturers to work in isolation, within teaching teams or divisions, instead of sharing their expertise and building on each other's experiences. There is a need to form CoPs to support and expand each other's work and to make teaching more effective and enjoyable.

5.2.1.3 Data projectors, computers, use of Internet and websites

During the data analysis, the notion emerged that the integration of ICT in teaching mathematics refers to the use of computers, projectors and Internet websites. It is the combination of computers, data projectors, and websites that make lecturers employ ICT integration in the classroom. Three mathematics lecturers responded on the aspects of digital gadgets and websites as part of their understanding of ICT integration in the classroom. However, during the interview, all 11 mathematics lecturers mentioned the aspects of data projectors and websites as tools that can be harnessed in teaching. Table 9 shows these themes that emerged during the data analysis.

Table 11: Data projectors, computers and websites as ICT integration in teaching

Data projectors, computers, use of Internet and websites themes		Number
5.2.1.3.1	Using YouTube for research to support students' learning	10
5.2.1.3.2	Using data projectors for lecturing	12
5.2.1.3.3	Using Internet for further research	8

5.2.1.1.1 Using YouTube for research to support students' learning

YouTube is a video website where users share, upload and view video clips. YouTube is part of the Web 2.0 new media (Duffy, 2008). YouTube videos appeared to be a favourite method of mathematics lecturers to support learning. This is how AL#2 described the way he uses YouTube: "I do use ICT, and sometimes I suggest to them links where they can get further materials, links like YouTube, material online". Students are referred to websites where they can watch videos on the same material that were taught by their lecturer. The sole purpose of using YouTube is to gain further understanding of the concept. YouTube videos expose students to how the concept is explained differently by different people. BL#1 described how in her lecture students use ICT: "I encourage my students to go to the Internet to find information. They may also search for the information on YouTube to reinforce what they would have learned". Students use ICT in various ways, including searching for information on the Internet and using YouTube videos where similar information is taught. All this is done to reinforce what students have learned.

DL#3 and DL1# mentioned that they refer their students to the Internet where they can watch YouTube videos to cement their understanding of the learned material. The benefits of watching the video podcast are that they improve learning and study habits. DL#3 commented: "However, I sometimes refer my students to some sites on the Internet where they can watch some YouTube videos to supplement their reading". DL1# added that "I usually refer them to sites where they may watch videos on YouTube to enhance their understanding of the learned concepts".

Consequently, this implies that videos are used to support the learned concept and to provide interesting resources to introduce new concepts. Kay and Kletskin (2012) noted that the step-by-step explanations displayed by YouTube videos help to make mathematics concepts meaningful to the students while supporting clear connections between the steps pronounced.

5.2.1.3.2 Using data projectors for lecturing

All mathematics lecturers interviewed indicated that they use data projectors during their lectures. Contemporary students are so immersed in ICT that it is sometimes difficult for them to concentrate on listening while taking notes. Showing presentation slides with data projectors enable lecturers to share the slides with students after the lecture. In some instances, the slides are loaded on the data repository (see Section 5.2.1.2) well ahead of the lecture to enable students to concentrate on the materials taught and they only have to take notes on additional information. The mathematics lecturers noted that data projectors assist students to remain focused on the material being taught. AL#3 mentioned that he used a computer and data projector to presents the slides. He commented:

> *Fundamental things that I have are data projectors, computers, basically, these are the only ICT resources that I have …. My lecture slides are uploaded on Sakai; students can print out my lecture slides. In short, it's a time-saving device. During my lecture, I use the data projector to present the slides I would have given them.*

The above comment implies that ICT plays a useful role in supporting teaching. The lecturer does not need to dictate notes to the students because they have received them well ahead of the lecture. The lecturer and students can focus on material taught. L#3V summed up her view on the use of ICT, data projectors in particular with the following remark:

> *As a lecturer, you can use a data projector the same way you would use a chalkboard, but its advantage is that you tend to maintain eye contact all times with your students unlike teaching using the chalkboard where you need to turn around and write on the chalkboard ….*

Her comment implied that eye contact with the students is important when lecturing. This gives the lecturer positive or negative feedback on their session. In addition to allowing everyone to focus on the lecture and keeping the attention of the students, data projectors also allow lecturers to look directly at the students most of the time.

However, there are some drawbacks associated with the use of projectors in the classroom: It needs a constant supply of power and maintenance and hardware problems may occur. Thus L#2W commented: "... I did prepare some lecture slides in PowerPoint for use in my lecture, but you go to the lecture room, and note that the system cannot log or can't play a video or can't play a data projector …". Technical problems are common when using ICT gadgets. Besides hardware glitches, lecturers should always have a buffer for continuity sake. They should either have the 'know-how' to fix simple problems or they have to be able to fall back on the traditional method. Another challenge lecturers face is that they need the skill to produce videos. Producing videos is very expensive and time-consuming. Mathematics lecturers can record a video to clarify a point missed during the lecture and share it with students at a later stage.

5.2.1.3.3 Using Internet for further research

Eight of the 12 mathematics lecturers' responses mentioned that using the Internet to research broadens students' understanding of the learned concept. They indicated that they refer their students to get supplementary information on the Internet by using a 'google' search engine. L#3U described the Internet as a tool that provides students with information they understand better than when it is provided by the lecturer and enable them to extend their understanding. He commented:

> *There is a lot of information on the Internet that can be accessed at any given time. I have told my students that you were born in the best time ever than most of us who used to get all the information from the textbook. The information is at their disposal, in their cell phones and laptops, etc. The Internet can give you a definition that you understand better than me.*

The above comment indicated that the Internet provided easily accessible information to the student that they can access using their smart cell phones, laptops, and iPads. Searching for information using the Internet is faster than accessing it with the textbooks. BL#1 suggested that the Internet provided additional information outside the lecture; she commented: "I encourage my students to go to the Internet themselves to find information". In other words, the Internet adds value to the students' learning processes. Mathematics lecturers use the Internet for their professional growth and share the websites that they deem suitable for their students. This is what AL#3 said: "… one can also use an Internet website and introduce them to various academy sites to consolidate what they would have learned". The Internet provides students the opportunity to research their own additional information that can enhance their understanding.

5.2.1.4 TPACK

Only one of the 12 mathematics lecturers remarked that pedagogical ICT integration in teaching mathematics as TPACK merges three bodies of knowledge into one. BL#1 remarked her belief: "I think of TPACK immediately as technology, as pedagogy, and as content. This is actually the merge of three bodies of knowledge, which is not always possible". Her response implied that to integrate ICT in teaching all the bodies of knowledge should be merged, however, she quickly pointed out that it is not always the case. There are situations where technology can be applied in teaching and there are times when it is not needed.

5.3 ICT Skill of Mathematics Lecturers

The term ICT in this study refers to both hardware and software application technologies. For mathematics lecturers to pedagogically integrate ICT in their lectures, they must have a rudimentary knowledge of how to operate the technology. All 12 mathematics lecturers rated their various ICT skill levels and said what they needed professionally. Table 12 shows the subthemes derived from individual comments and the number of respondents per the theme.

Table 12: ICT skills set of mathematics lecturers

ICT skill set of mathematics lecturers		Number
5.3.1	Limited skill set to use Sakai/Blackboard	4
5.3.2	No knowledge of how to use mathematical software	4
5.3.3	Need for professional development	2
5.3.4	Absence of knowledge sharing space	2

5.3.1 Limited Skill Set to Use Sakai/Blackboard

According to the mathematics four lecturers, they do not have extensive knowledge on how to use Sakai/Blackboard in teaching. They were very clear that they only use Sakai/Blackboard to upload lecture notes and to relay some communications. Anything more than that was beyond their skill level. Table 13 shows the themes that stood out in the data and the number of mathematics lecturers who lack the skill.

Table 13: Challenges faced by mathematics lectures in using Sakai/Blackboard

Challenges in the use of Sakai/Blackboard		Number
5.3.1.1	Inability to do assessments on Sakai/Blackboard	8
5.3.1.2	Inability to mark and display students' work on Sakai/Blackboard	6
5.3.1.3	Inability to use Forum functionality on Sakai/Blackboard	8

5.3.1.1 Inability to do assessments on Sakai/Blackboard

Eight mathematics lecturers' comments identified their lack of knowledge to use Sakai/Blackboard as a drawback in ICT integration. AL#1 indicated that he was concerned because he cannot use Sakai to assess his students. He commented:

> I will say they have a limited skill set, which includes me because I cannot do the assessment on Sakai. I did an assessment on Sakai in 2010 when I was teaching my statistics course, my tutor did it for me. There was one ICT teacher (he set the whole exam session on Sakai) and had knowledge of Sakai. The student can submit the exams electronically and their work can be downloaded and marked. The marks could be sent to the student using Gradebook functionality. Only one lecturer now has the knowledge of using Sakai.

AL#1 suggested that Sakai provides a good platform to assess students but he cannot use this platform without help because he does not have the necessary knowledge. The assessment functionality in Sakai allows practicing question-based online tests, exercises and other forms of assessments. The user can customise the existing settings to suit their needs. Accessibility to the assessment tests or exercises can be restricted to site participants only and site members can open the assessment once they receive the URL. Questions can be in the form of essays, multiple-choice, true/false, and matching sentences. The assessment can be set in such a way that all participants receive the same questions or that questions are pulled randomly from a database of questions.

CL#1 indicated that his university uses the Blackboard platform that can be used to assess the students, but he also does not know how to use it. He remarked: “We have the Blackboard platform in this university, but we struggle to use it to the fullest because we do not have the required skill to use it in assessing our students”. His comments indicated that the Blackboard platform is not fully utilised for the benefit of the students because the lecturers lack the skills to use it.

5.3.1.2 Inability to mark and display students’ work on Sakai/Blackboard

Sakai/Blackboard provides students with a function to submit online written assignments. The function is web-based. Submitted assignments are stored internally on the automatic marker that initiates the marking process. The automatic marker uses different scripts/graders for different types of assignments. Each exercise/task is linked to an XML configuration, storing information on how to mark a task. Each question is associated with programming commands that compile and run the program, and files are compared for correctness. Unfortunately, this function is not used by many mathematics lecturers. AL#1 remarked: “I cannot mark on Sakai neither can I put marks on it”. AL#1 is aware that Sakai has functions such as marking assignments and displaying marks but lacks the knowledge to use it. These facilities offer the advantage of reducing lecturers’ making load, especially for large classes. The other advantages is that it provides consistency in marking as it uses the same criteria and students receive instantaneous feedback, improving interactive learning.

CL#1 reiterated that he uses very little of what the Blackboard platform offers, though he is aware of what it offers. He remarked, “… personally I have not really done anything serious on the backboard. I do not know how to set the exam on Blackboard neither on how to make it mark correct answers”. Preparing a task on Sakai/Blackboard needs thorough preparation and extra time has to be put aside to complete a task. It is important that the information captured on the system should be accurate, otherwise the output will be incorrect.

Through the analysis of mathematics lecturers' responses, it was noted that lecturers are aware of the benefits of using Sakai/Blackboard platforms, but they are limited by their lack of skill and knowledge on how to use it for the benefit of themselves and their students. ICT is considered as valuable tool in teaching, but the drawback is that it needs special skills to use it.

5.3.1.3 Inability to use forum functionality on Sakai/blackboard

Sakai/Blackboard offers a discussion functionality called Forum. It allows lecturers or site members to initiate a group discussion on a topic. Topics created in the Forum allow participants to post their opinions. Common features found in the forum are, among others, availability dates (Forums can be released per specific dates), moderation (lecturer may moderate topics posted), counts (unread posts), email notification (site members can choose to receive/not to receive email notification) and statistics (to determine the frequency of participation by a participant). Asynchronous forums provide site participants with an opportunity to engage with each other and allow for both convergent and divergent ideas. Unfortunately, most mathematics lecturers are unable to use it and are struggling to understand the basic functionalities that are used most often. L#2W remarked: "Yes, I have heard of the forum function on Sakai, I do not know how to use it. We can know the use of such a thing if we receive training …" L#2W's response implies that training would help him to use the forum functionality.

5.3.2 Need for Professional Development

Professional development programmes are organised to accelerate individuals' learning in an organisation to a level required by current environmental needs. In education, professional development brings about change in lecture room practices, attitudes and beliefs of the lecturers and consequently improves the learning outcomes of students. All 12 lecturers interviewed talked about the importance of professional development to effectively integrate ICT in teaching and learning. Table 14 lists the professional development themes that came from the data.

Table 14: Professional Development

Need for professional development		Number
5.3.2.1	Lack of support by the school of education	12
5.3.2.2	Absence of knowledge sharing platforms	8
5.3.2.2	Time constraints	5

5.3.2.1 Lack of support by the school of education

The biggest concern that was raised was the notion of not being supported by the school of education. All 12 mathematics lecturers acknowledged the importance of integrating ICT in teaching mathematics and the way it may change the learning landscape; however, they all felt that their school of education was not offering enough training opportunities for them to learn how to use the new tools. AL#1 commented: "The main barrier is the limited ICT skill set and lack of support by the school of education". There have been rapid developments in mathematical software in recent years and these products are marketed to the university and adopted as powerful tools that can be used to enhance students' understanding. However, the school of education is not doing enough to ensure that the lecturers are trained on how to use this software. This makes the software redundant because no one can use it and the university has wasted money buying it. L#2V reiterated that the university is not doing enough to prepare them for operational readiness for any new software on the market. He remarked:

> *I have never used GeoGebra, but I know about it. Even if you ask me, 'Do I use the GeoGebra to teach?'. I would say, no, because I have never used it practically. Our university has never organised a training workshop for such software. At the same time we are encouraged to use such software when teaching topics such as geometry, trigonometry and so on.*

CL#2's comments indicated that he cannot use the GeoGebra software because he has never been trained, though he is encouraged to use it in teaching concepts related to trigonometry.

AL#2 indicated that university support in providing professional development is lacking, commenting: "Well to be clear, the support is minimal. If you want support you have to go on your own. Some mathematics packages/software could not be provided by the university". His comment implied that the university is leaving ICT integration up to the individual. It does not matter whether the lecturer uses the traditional or contemporary methods that are supported by ICT; the important thing is to reach the outcome. He further noted that some mathematics packages that they are supposed to use are not available in the school of education; this makes it impossible to pedagogically integrate ICT in the teaching of mathematics.

BL#1 viewed professional developments organised by the school of education as limited and sometimes not useful at all. She remarked:

> *Yes we do have professional development, but very limited. It is usually a day or two day training and we attend the training and come back you forgot almost everything. I have learned more on YouTube than on professional development courses. Playing YouTube videos provide better training than professional development.*

BL#1 indicated that the duration of the workshops is too short and after these workshops they forget what they learned as they do not apply it in their everyday teaching practice. Workshop attendees may sit through the one-hour long lecture just listening to the facilitator; though helpful, it is not sufficient. YouTube videos can be replayed several times until understanding is reached. Mathematics lecturers will be engaging with the material as they go along. Another advantage YouTube videos provide is that it gives instant feedback.

AL#3 suggested in his comment that lecturers need to be workshopped to effectively integrate ICT in their teaching: "... we need to try to make management decide to adopt some form of professional development programme. As lecturers we need to be workshopped on how to use the software so that we can teach using it with confidence". His comments showed that having adequate skills and knowledge of using ICT is important as it instils confidence; otherwise, lecturers may not use the software in their teaching practice. Mathematics lecturers often do not feel sufficiently prepared to successfully integrate ICT into their lectures.

Mathematics lecturers in schools of education acts as role models to scaffold pre-service teachers to the level they want to be at regarding integrating ICT in teaching. They should be able to provide their students with the right skills they will use in a particular educational context. Professional development gives an impression that the participants will develop and increase their knowledge and skillset, which will contribute to their individual growth and enhance their teaching effectiveness (Guskey, 2002). The workshops must be specific and practical towards day-to-day desirability of instructional innovation in the classroom environment. The acquisition of scanty skills is not adequate to transmit purposeful teaching. Mathematic lecturers need repeated training with the ICT in order to connect their teaching well.

5.3.2.2 Absence of knowledge sharing platforms

The mathematics lecturers acknowledged the importance of forums where the sharing of knowledge is encouraged. For them, forums are an effective model for professional development that encourages reflection on their own working environment. The end product of knowledge sharing platforms like forums is the sharing of ideas, solutions to a problem and the building of a repository skill set of new knowledge. Eight mathematics lecturers mentioned that they do not have such platforms in their departments. AL#1's response is representative of how the CoPs function at his school of education. He remarked:

> *We do not have such communities here. We definitely need the platforms/forums to share ideas. In fact we have asked one of the lecturers to do that for the department. The identified lecturer has volunteered to train all mathematics teacher educators. Unfortunately the training kept on being postponed and up-to-date we have not been trained.*

In the above comment, AL#1 indicated that they are in need of communities to foster collaboration among mathematics lecturers to consider ways they can solve a particular mathematical problem or methods that can help them to achieve a required goal. Time also seemed to be a problem because the workshop had to be repeatedly postponed and finally cancelled. AL#3 reiterated that lecturers do not attend workshops because of commitments: "We do not have platforms to share ideas here. It will be useful to have knowledge of sharing platforms. I offered to do a lecture in school on the use of Sakai as a teaching aid and administrative tool so that it would be possible to develop knowledge sharing platforms. But none attended”. The invitation for this lecture was an initiative to establish a knowledge sharing platform within the mathematics department; however, none attended the meeting. Nonetheless, he sees the importance of having knowledge sharing platforms.

Overall, mathematics lecturers can as a group establish goals for their classes and discuss various methods that can help them to reach their goals. A working example can be used as a model to be used in a lecture room environment. Subsequently, the lecturers in the department may convene a debrief session to target a new lesson, observe its proceedings, or come up with a new approach based on what they see.

5.3.2.2 Time constraints

A total of 5 mathematics lecturers’ responses referred to time as a factor limiting their use of ICT in teaching, even though they acknowledged the importance of ICT in teaching and its potential benefits.

The mathematics lecturers felt that teaching using ICT is another load on their already overloaded curriculum; this is evident in AL#1’s comment. He commented, “Lecturers do not have enough time, in addition to the current curricula load requirement to do more work”. His statement seems to suggest that if they had enough time, they could integrate ICT in teaching, but they are being limited by an overcrowded curriculum.

AL#2 described how time affected him when he tried to prepare a lecture that embraced ICT. He remarked:

> *Any good lecture requires a lot of time for preparation. So the fact that there are so many things you can do with ICT, you really need a lot of time to prepare ICT mediated lesson. Should I devout my time to learn other new things and with a lot of hitches?*

DL#2 highlighted that teaching mathematics using ICT is time-consuming. He remarked: “ICT is time-consuming and that is why it is not used”. Though he did not elaborate on how it is time-consuming, it is clear that effective teaching using ICT requires a lot of time.

His comments indicated that ICT is a good tool and there is a lot of information to prepare a good lecture, however, it requires a lot of time. The time needed to search for information on the Internet ends up affecting the time allocated to teach the subject. He noted that there are hitches that come with the use of ICT during the lecture that disturb the rhythm of the lecture, and these hitches bottleneck the time slot for the subject.

BL#1 mentioned that learning new software is a mammoth task. She commented, "It takes time to start understanding a new software or new programme". Overall, 'learning new software' featured strongly in her comments. She viewed the mathematics mediated software as a new burden that needs to be learned in very little time. DL#3 echoed the same thought by mentioning that, "Lecturers do not have enough time to accommodate new programmes". This comment suggests that ICT plays an important part in the teaching of mathematics, but it is not implemented because of a lack of time.

The above comment linked well with BL#2's comments; he mentioned that "It is part of our plan to workshop each other; however, we are being limited by the time". Although he recognised that there is a need to educate one another on how to pedagogically integrate ICT, he admitted that the time factor is a big obstacle. Learning ICT concepts need a lot of time, which the lecturers do not have. The other issue is that there is constantly new mathematical software being introduced. BL#3 remarked: "We do not have enough time to apply this ever coming mathematics software to our student teachers". The comment suggested lecturers' habit of doing things in a unidirectional way. They saw introducing new pedagogics in teaching as a challenge that requires investing a large amount of time.

5.4 Absence of Policies

In this study, a policy is a document that guides mathematics lecturers on how they should integrate ICT in their teaching. The comments made by the 12 lecturers interviewed indicated that there is no framework to guide them on how they should integrate ICT in their teaching.
AL#1W shared his perspective that the provision of an ICT-rich environment provided opportunities for pre-service teachers to understand some abstract concepts with ease as they

may explore challenging mathematical problems with ICT tools. He commented: “Each lecturer teaches the way he sees it fit”. Because of the absence of a policy or framework that spells out the use of ICT in teaching, most of the mathematics lecturers in the schools of education feel they are not obliged to use ICT and hence they teach the way they see fit.

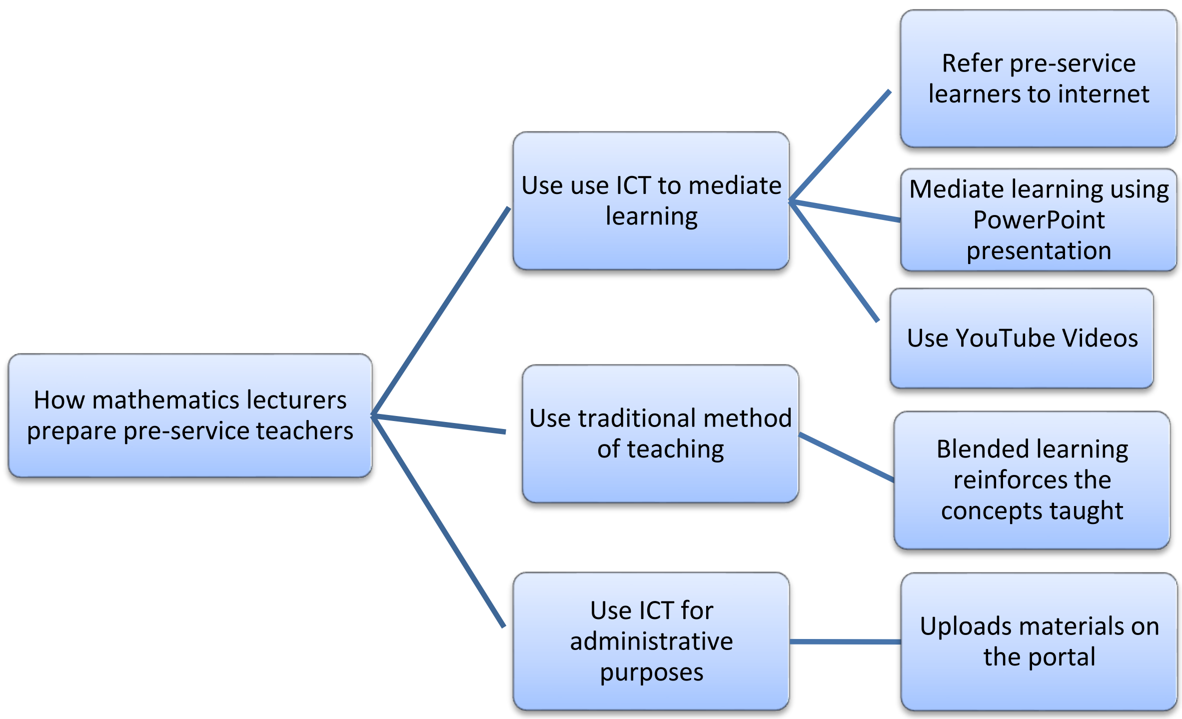
BL#1 mentioned that there is a framework in her university; however, it is silent on the use of ICT in the teaching of mathematics. She commented, “We do not have any ICT policy; we have our own mission of the university, but not necessarily an ICT specific policy. It is just a framework that does not mention the use of ICT in teaching”. This comment suggests that there is a need for schools of education in South African universities to create policies that instruct and guide the lecturers to integrate ICT in teaching. L#2W’s remarks concurred with the above comment when he mentioned that,

> *The truth is that we do not have any ICT policy from the university or the government. It is being spoken on meetings and educational conferences. The NCTM says the use of technology enhances the teaching of mathematics. In general, I can say that there is no policy from the government/from the university. It is an individual thing.*

It can be concluded that harnessing ICT in the teaching of mathematics is left to the individual as no policy dictates the mandatory use of ICT during the teaching process. Lecturers in the schools of education can pedagogically harness ICT in teaching only if there is a document that requires them to do so. The document, however, is non-existent.

5.5 Chapter Summary

In summary, there seemed to be a technological skill imbalance among mathematics lecturers in the four schools of education investigated. Furthermore, mathematics lecturers seemed to have missed out on opportunities for professional development to catch up with ICT knowledge acquisition, given that they are not provided with the necessary support by the university authorities. There is a need for an integrated reconfiguration of professional development initiatives to address the speedy adoption of ICT by lecturers. If these challenges are left unattended they have the potential to amplify the number of teachers who cannot embrace ICT in the classroom, thereby leaving the universities to continually produce graduates that cannot meet the demands of the 21st century teaching standards. Continuous professional development in ICT areas can assist in the upskilling of mathematics lecturers, which in turn will be transmitted to their pre-service teachers. Consequently, they will have the appropriate technological knowledge, and the confidence to use ICT in their lectures without fear. The presence of free mathematical software augmented with virtual reality technology brings a genre of learning technologies that lecturers should adopt and acclimatise to. Figure 12 summarises the way the mathematics lecturers prepare pre-service teachers using ICT and the perceptions they have on ICT use in teaching and learning. The challenges identified pose as pediments in the integration of ICT in the lecture rooms.



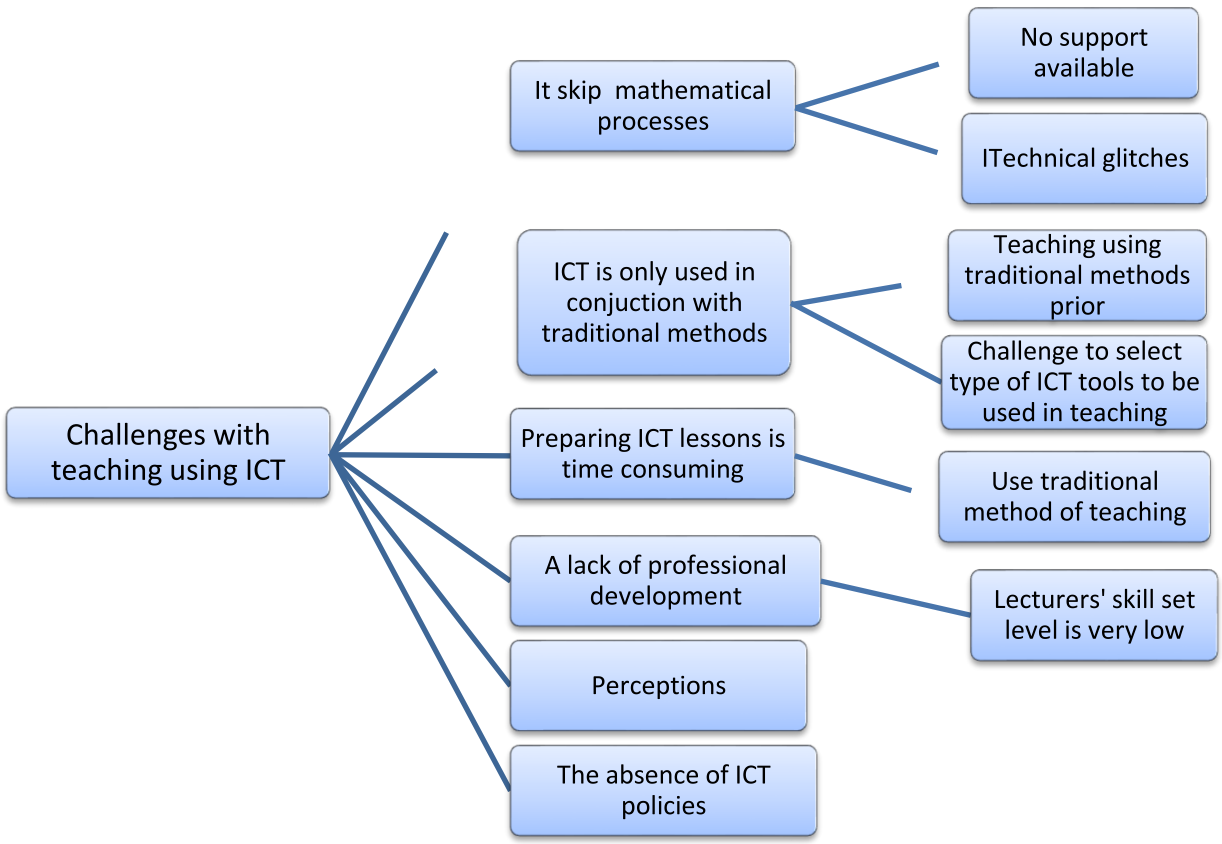


Figure 12: Mathematics lecturers' usage of ICT and their perceptions

5.6 Conclusion

This chapter reported on the findings of the interviews held with four HoD mathematics lecturers and eight mathematics lecturers in the schools of education in relation to how they pedagogically integrate ICT to prepare their pre-service teachers in their lectures. They expressed a range of pedagogical purposes for their use of ICT. Aspects such as the type of ICT tools used as part of pedagogy, lecturers' skill level, perceptions of a lack of professional development and the absence of policies that act as a framework for ICT integration.

Mathematics lecturers did affirm that ICT makes their administrative work much easier as they upload all the teaching materials in advance on the portal. They acknowledged that ICT creates an environment where students can share ideas, collaborate and work together in solving complex mathematical problems. Although the use of ICT for administrative purposes appeared as the strongest aspect of pedagogical use of ICT, mathematics lecturers raised a lot of concern pertaining to the reasons for the low use of ICT in their lectures. These included time constraints, attitudes and beliefs and lack of support from the schools. There was a strong indication that it was normal practice for mathematics lecturers to teach the way they see fit, as there is no synchronised way to teach integrating ICT. Many mathematics lecturers appeared to have developed a positive view of the role ICT could play in the teaching of mathematics, however, they lack training. There is plenty of free mathematical software that can be used in teaching, but they lack the knowledge to use it. On the other hand, some mathematics lecturers indicated that they were disturbed with the issues associated with the use of ICT in the classroom; these include technical hitches, lack of support by technicians and power failures. Others expressed concerns that ICT hides a lot of required steps that students need to be aware of and thus leaving them with no choice but to revert to traditional ways of teaching.

To understand what teaching method is employed in the lecture room, pre-service teacher participants were incorporated into the study. As the world is immersed in digital technologies, it is imperative that new ICT skills have to be learned to prepare the future teachers to implement new developments in ICT. Mathematics education's role is to model and explain the use of ICT materials in teaching and learning. Pre-service teachers, as future prospective teachers, need to tell the story on their competencies, experiences, and readiness to integrate ICT in the teaching and learning of mathematics. As future teachers, they need help to understand how ICT can be used to elaborate on mathematical concepts that seemed difficult when teaching using the traditional method, in rich and meaningful ways. The next chapter reports on pre-service teachers' lecture room experiences and how they understand pedagogical uses of ICT in teaching. I chose to present the findings of pre-service teachers' pedagogy ICT integration separately because I am interested in finding out whether the findings converge or diverge from those obtained from the mathematics education lecturers. If they converge, the mathematics education lecturer's claims will be corroborated; otherwise, more investigation will be needed to explain the divergence.

CHAPTER 6: MATHEMATICS PRE-SERVICE TEACHERS' USE OF ICT IN LEARNING

6.1 Introduction

The chapter responds to sub-question three which reads: To what extent are the pre-service teachers being prepared to meet the demands of the 21st century classroom? Furthermore, the chapter reports the findings gathered from the focus group interviews with 20 fourth year B.Ed students. The students were drawn from four universities in the Gauteng province as discussed in Chapter 4. These students were in their final year and left the university at the end of 2018 to work at their respective schools. The main reason to involve them in the study was to justify the variables needed by the Activity Theory, which was adopted as a theoretical framework for the study. In the Activity Theory, there are constructs such as 'subject' and 'object', where 'subject' represents mathematics lecturers and 'object' represents pre-service teachers. The other reason to interview them was to determine whether there is ICT integration during the lectures that prepare them for their future profession.

I used the exact quotations as transcribed to respect the authenticity of the pre-service teachers' voices. To protect their identities, the pre-service teachers' names were coded, using the name of the university pre-service teachers were studying followed by pre-service teachers' names, for example, Pre-service Teacher 1 (AS#1)), Pre-service Teacher 2 (AS#2) and so on, as shown in Table 6. Pre-service teachers were asked to respond to the following questions (refer to Appendix III):

1. To what extent do your university and your lecturers prepare you to pedagogically integrate ICT in the teaching of mathematics?
2. How do you see ICT as a relevant tool in the teaching of mathematics?
3. Drawing from your past experience as a student at university, do you think universities should include programmes that pedagogically integrate ICT in teaching and enable you to be confident in preparing learners whose future is already technologically driven?

4. As a mathematics student, have you ever considered teaching yourself to solve mathematical problems using any mathematical software such as GeoGebra or Microsoft Excel? Give the reasons why?

From four three questions, common themes were extracted from the pre-service teachers' commentaries. These themes are listed in Table 15.

Table 15: Pre-service teachers' experiences regarding pedagogical ICT integration

Pre-service teachers' experiences regarding pedagogical ICT integration		Number
6.2	Teaching is largely chalkboard and textbook based	20
6.3	Skill set level to teach using technology is limited	18
6.4	ICT affords students enhanced learning	17
6.5	Embracing ICT should start at teacher training institutions	20
6.6	Hope for using ICT in the classroom	13

Pre-services teachers' experience in the lecture room is that mathematics lecturers conduct their lessons largely using the traditional method that is characterised by the use of chalkboards and textbooks. They sometimes use a learning management system such as Sakai and Blackboard as a repository to upload learning materials. Pre-service teachers appeared to be positive about the potential of ICT to enhance teaching and learning. Among the participants, some have explored and pedagogically used ICT in teaching during teaching practices and have noted the affordances it has in supporting teaching practices. However, the use of ICT in the classroom is an individual effort and does not come from formal training at their respective institutions.

6.2 Teaching Is Largely Chalkboard and Textbook Based

There were 20 pre-service teachers who contributed to this discussion and they all said that the teaching at their universities is still chalkboard and textbook based. They indicated that though the demands of the 21st century require the use of ICT across all disciplines in society, mathematics lecturers are rooted in traditional teaching methods. Table 16 contains the contributions to this theme.

Table 16: Teaching in the lecture room does not embrace ICT

Teaching is largely chalkboard and textbook based		Number
6.2.1	Teaching is dominated by the traditional way	20
6.2.2	Both Lecturers and pre-service teachers use PowerPoint and data projectors	14
6.2.3	Pre-service teachers are not ready to use smart boards in schools	17
6.2.4	Sakai/Blackboard is used to assess pre-service teachers	13

6.2.1 Teaching Is Dominated By the Traditional Way

Twenty pre-service teachers mentioned that their mathematics lectures are dominated by the traditional method. In response to Questions 1 and 2, which asked: To what extent universities and lecturers prepare them to pedagogically integrate ICT in the teaching of mathematics and its relevance? There was a resounding "no". The following four examples indicate that lectures are still conducted in the traditional way.

1. To what extent do your university and your lecturers prepare you to pedagogically integrate ICT in the teaching of mathematics?
2. How do you see ICT as a relevant tool in the teaching of mathematics?

We have never had a lesson on how to teach Mathematics using slides or how to teach Mathematics using technology or anything like that. (BS#1)

No. We are still being taught how to teach using a chalkboard instead of using a smartboard. Everything is still old-fashioned even though there are developments and innovations in schools, especially in Gauteng. But the way we are taught how to teach does not involve ICT. (AS#1)

Yes, I agree with them (student AS#1 and AS#2). We are still being taught with chalkboards and how to teach with chalkboards as well. (AS#3)

I also think that the universities are not equipping us enough because the same way my mother was taught is the same way I was taught and it will probably be the same way I will be teaching as well when I get to schools. So, as much as they give us access to some resources here on campus, for the fact that the learners are already being taught using ICT when we qualify, we will be expected to be at a higher level compared to the learners so that we can teach effectively. So with us leaning on ourselves here, I don't think it will be enough for us to be able to adjust to the system of technology because they are already immersed in it. (DS#4)

The comments from BS#1, AS#1, AS#3 and DS#4 confirm that teaching is still characterised by the use of a chalkboard. AS#1W noted that there are some developments and innovations in Gauteng schools, like interactive whiteboards, however, the teaching has not moved with the times. DS#4 was afraid that he will use the same method of teaching in his future career because he has not been exposed to teaching that embraces ICT. In addition, he sees himself irrelevant to digitally immersed 21^{st} century learners. In summary, this information provides evidence that the pedagogical use of ICT at teacher training institutions is still at the beginning stage and that many lecturers still conduct their lectures using the traditional method. Yet, the use of ICT in education has revolutionised learning and there is no longer only one way of teaching.

6.2.2 Both Lecturers and Pre-service Teachers Use PowerPoint and Data Projectors

Apart from chalkboards and textbooks, mathematics lecturers are also using PowerPoint slide shows and data projectors in their teaching. The following comments confirm this.

The only thing that we see lecturers using is the use of data projectors to present PowerPoint slides. Other than that, there is nothing. (CS#3)

They use sometimes PowerPoint presentation to explain some mathematical concepts. Because the nature of mathematics is that the solution to a problem should be worked out, probably this explains why most of these lecturers teach using the chalkboard. (BS#2)

> *In some instances, they lecture through the use of data projectors. (DS#1)*

CS#3 said that data projectors are used to present lecture slides and not necessarily to teach mathematics. His comments imply that data projectors are not used in everyday teaching but are used sporadically when there is a need. CS#1 concurred with the above statement. This gives a clear picture that there is a minimum usage of ICT in the lecture room. BS#2 suggested that the reason why ICT is not used during the teaching of mathematics is that the steps to solve the problem must be shown. The chalkboard method is ideal to work out mathematical problems as it provides the space the students need to see all the steps involved in solving the problem.

Pre-service teachers highlighted that mathematics lecturers often used PowerPoint presentations to introduce lessons. They described how their lecturers set up a PowerPoint slideshow to demonstrate the aspects of some mathematical concepts. S#4W's contribution encapsulates their lecturers' practice. He remarked:

> *Most of these lecturers use PowerPoint slides to introduce their lessons. Lessons presented on PowerPoint slides capture students' interest and make class management easier. However, when it comes to working out mathematical problems, our lecturers use the whiteboards.*

In the above contribution, AS#4 indicated that lecturers in his university use PowerPoint often to introduce a lecture and to explain what will be discussed during the lecture. He also noted that PowerPoint tends to capture students' attention, making class management much easier. It allows both lecturers and students to present their lectures/lessons in a dynamic way compared to simply lecturing and writing on the blackboard, which seemed to be a common trend. The remarks also indicated that lecturers face some challenges to work out some mathematical solutions using PowerPoint slides and feel more comfortable writing the solution on the blackboard.

W#2T mentioned that he uses PowerPoint when presenting group work discussions. PowerPoint improves the students' learning motivation and encourages interaction between the teacher and the students. He commented:

> *We use PowerPoint slides to present our group work discussion. It makes the presentation operational and live as it includes graphics that increase visual impact and audience focus. Animation that comes with PowerPoint make some explanation of concepts clear compared to when using chalkboard. However, we lack the skill on how to solve some mathematical problems using PowerPoint. We are pinning our hope to our lecturers that one day they will teach us such a skill so that we can go out with it to teach to our future schools.*

This contribution highlighted that the use of the PowerPoint assists in making some concepts clearer than when using the traditional method. However, he noted that they lack the skill to use it to solve mathematical problems and that they will really need this skill when teaching in their future schools. PowerPoint use in the classroom yields more learning gains, it is motivating, provides animated pedagogical agents that support learning, accommodates different learning styles, and facilitates learner-managed constructivist and discovery approaches that are beneficial to learning.

6.2.3 Pre-Service Teachers Are Not Ready To Use Smart Boards in Schools

Pre-service teachers acknowledged that in some lecture rooms there are either interactive boards or whiteboards and the lecturer can switch between the two. However, most of the lectures are conducted on the whiteboard. The reason is that most of the lecturers do not know how to use interactive whiteboards. The same scenario cascades to schools in the province. In some schools, you find both chalkboards and interactive whiteboards, but teachers prefer teaching using the chalkboard. AS#3 remarked:

> *We have interactive whiteboards in most lecture rooms, they are not being utilised during lectures. We are expected to use these interactive whiteboards when we finish training. But we do not have the knowledge.*

Her comments suggested that interactive whiteboards in the university lecture rooms are white elephants, yet they are expected to use them after completing their training. The issue is that they will fail to use this technology in their future classrooms. At the school level, DS#3 witnessed a scenario where the teacher was failing to use the smartboard. He commented:

> *After my Matric last year, I went back to high school where I was in to do my teaching experience. In the classroom, there was an option that teachers can choose either to use smartboards or chalkboards.... And I believe that if you know ICT and how it works, then you can be able to change and be diverse about your teaching methods in the class. So if there is a learner that does not understand a certain concept, then you can incorporate ICT into the lesson to make the concepts you are teaching clearer.*

The above comment implied that teachers do not have the knowledge and skills to operate smart boards at school. Furthermore, he gained no knowledge pertaining to the use of smartboards, as his mentor could not operate it. He also noted that the skills and knowledge to use the technology is vital and if the teacher had the skill to use it, he would have.

6.2.4 Sakai/Blackboard Is Used to Assess Pre-service Teachers

AS#1 mentioned that the only tool mathematics lecturers use is Sakai. Lecturers post their teaching materials on this platform and students receive the notification message. This notification acts as a reminder for students to go and check the materials loaded on Sakai. He commented:

> *As students, we access Sakai to view the teaching materials uploaded for the preparation of the lecture or for further reading. Our lecturers also use this platform to communicate and give feedback for the exercises we would have written. One lecturer used to set multiple-choice questions on Sakai and instructed us to write it on Sakai. The advantage it had was that it could mark the exercise and provide the feedback instantly.*

The above contribution indicated that lecturers use the Sakai platform to upload student learning materials and also to assess them. The system has the advantage of providing a communication module via Internet protocol. Students can submit their assignments to their lecturers using the same platform.

6.3 Skill Set Level to Teach Using Technology Is Limited

Question 4 reads "As a mathematics student, have you ever considered teaching yourself to solve mathematical problems using any mathematical software such GeoGebra or Microsoft Excel? Give the reasons why? Give the reasons why?" The question required students to explain whether or not they had taught themselves to solve mathematical problems using any mathematical software. They were required to substantiate the answers they give. This question was aimed at finding out about students' exploration with regard to the use of ICT in solving mathematical problems. Twelve students mentioned that they have tried to solve mathematical problems using GeoGebra, Photomath, and MATHEMATICA; however, they do not feel they have adequate skills to teach using the software.

AS#3 mentioned that he has taught himself how to use GeoGebra to transform graphs. He commented: *"Though I have limited knowledge with GeoGebra, I use it to view graph transformation. Sir, do you have GeoGebra in your machine to demonstrate the transformation of shapes"*. The researcher allowed the student to demonstrate the transformation of graphs using the available desktop computer in the office, and the screenshots taken are shown as Figures 13-19. In each case, he explained the nature of the transformation and the narration of each graph is summarised in Table 17.

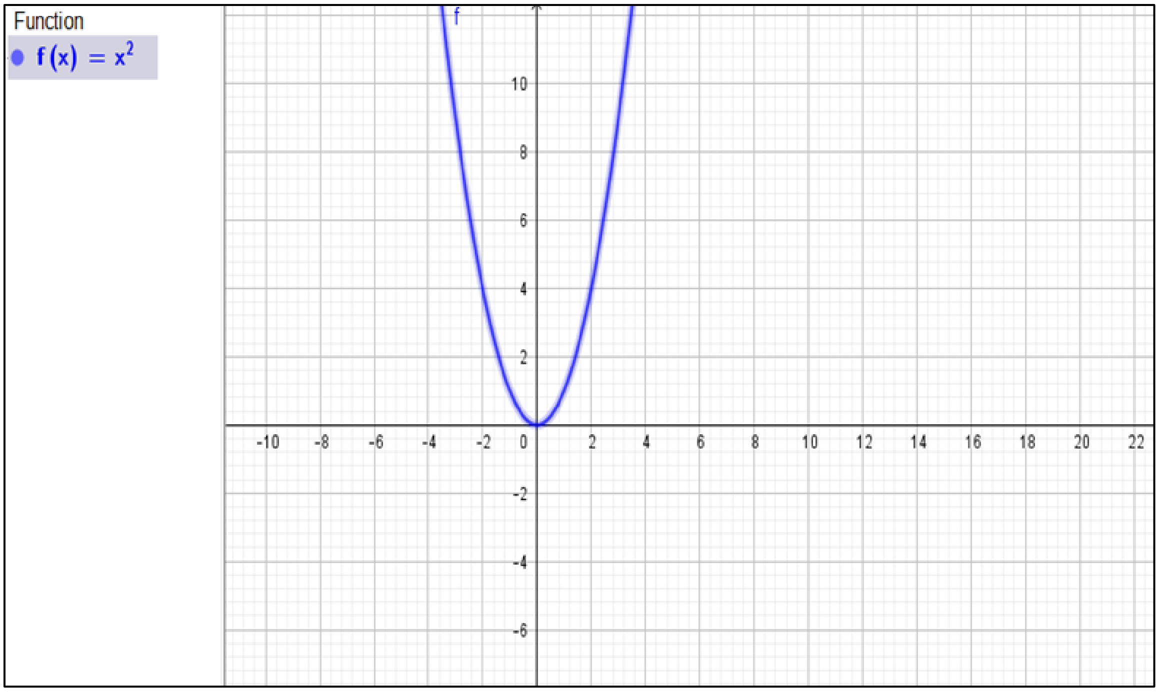


Figure 13: f(x)=x^2

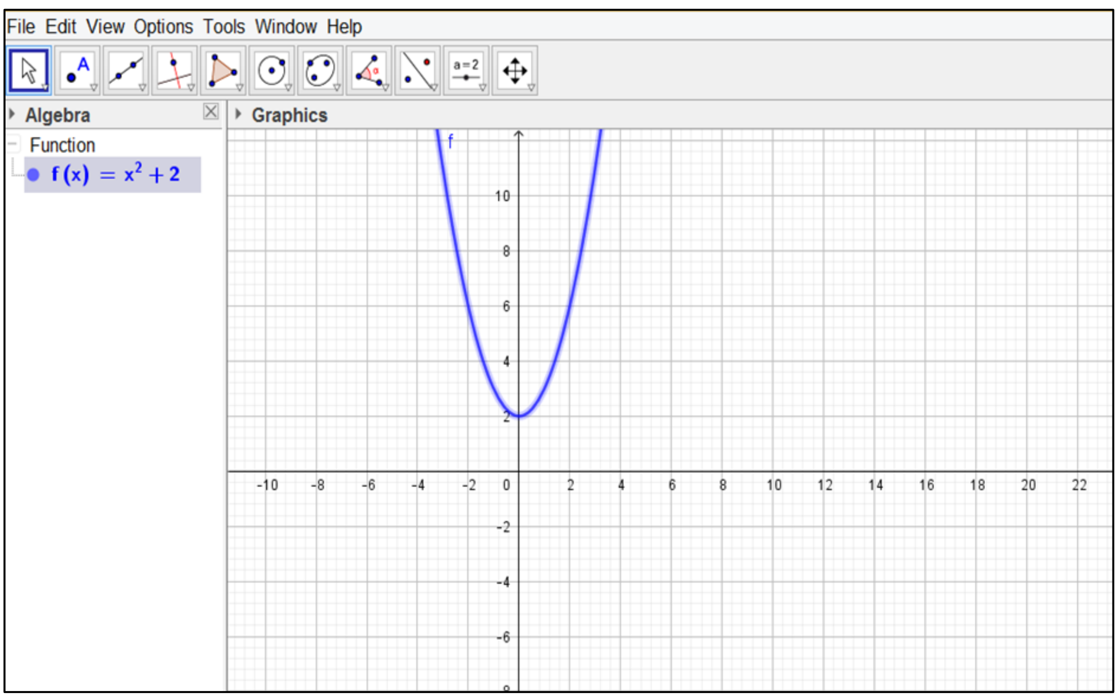


Figure 14: f(x)=x^2+2

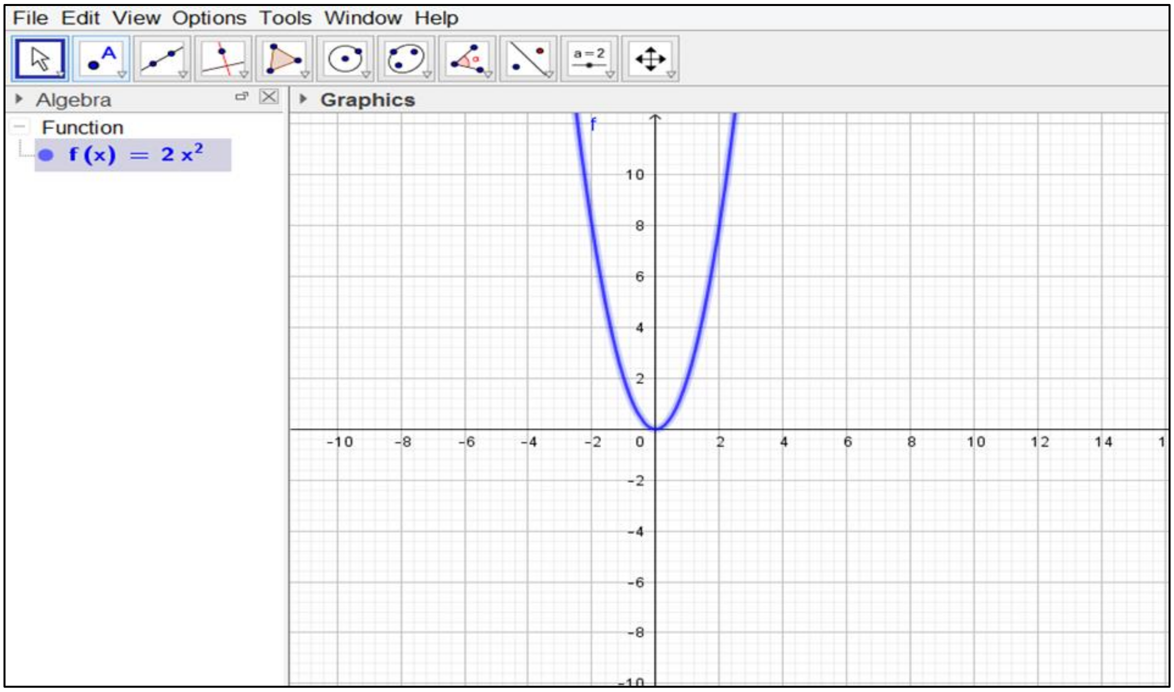


Figure 15: f(x)=2x^2

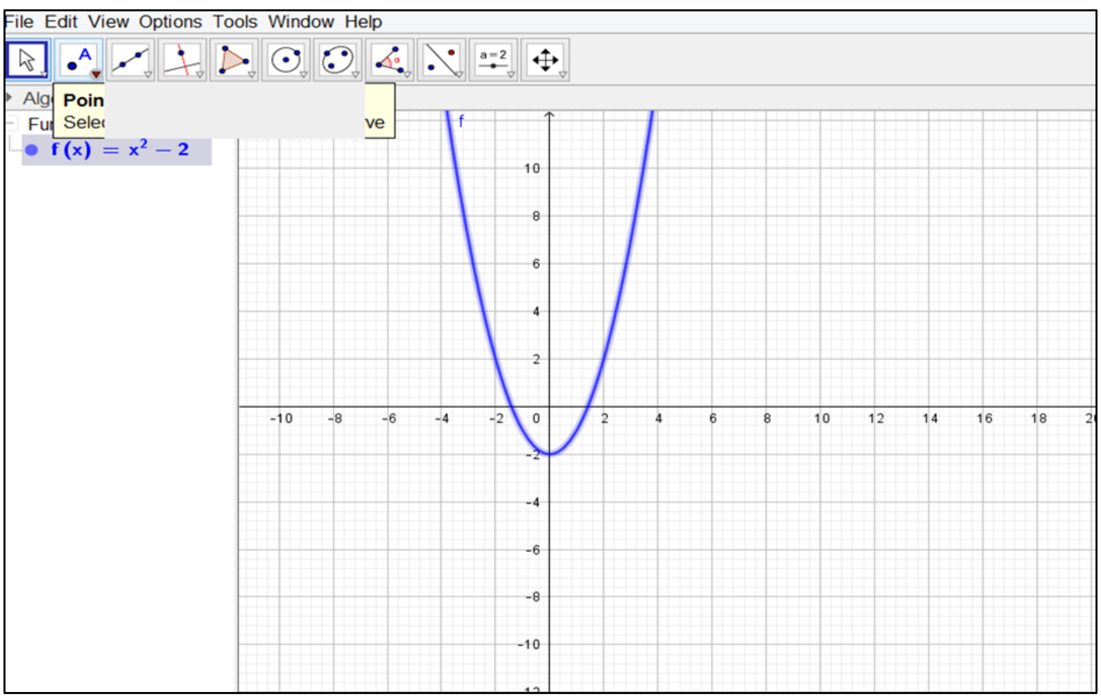


Figure 16: f(x)=x^2-2

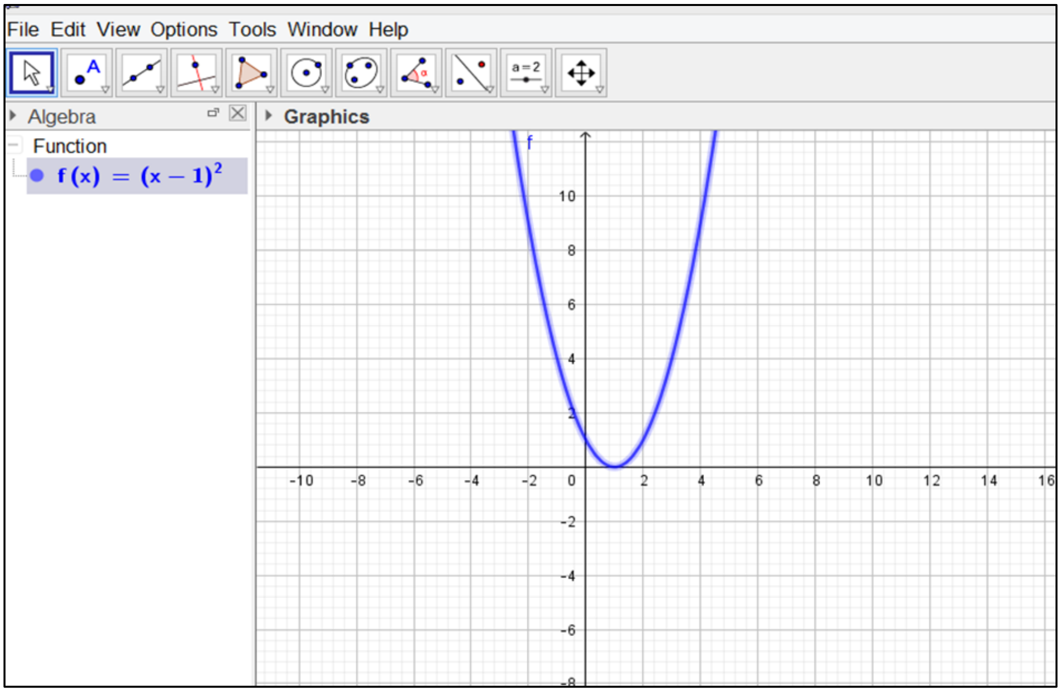


Figure 17: f(x)=(x-1)²

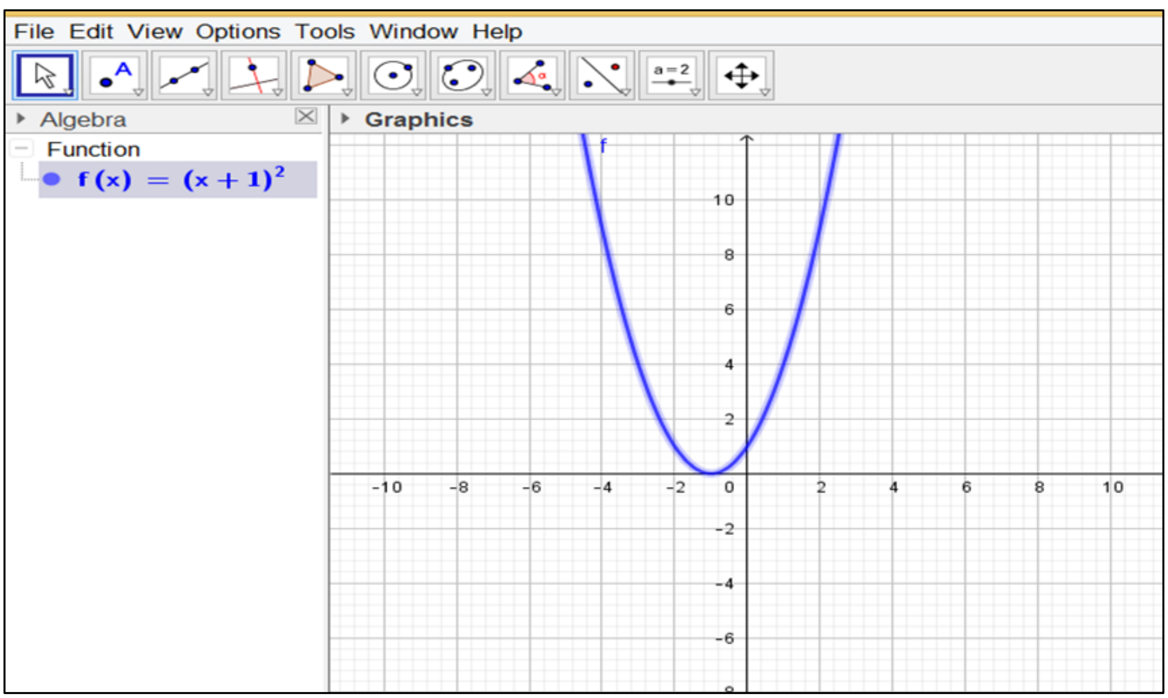


Figure 18: f(x)=(x+1)²

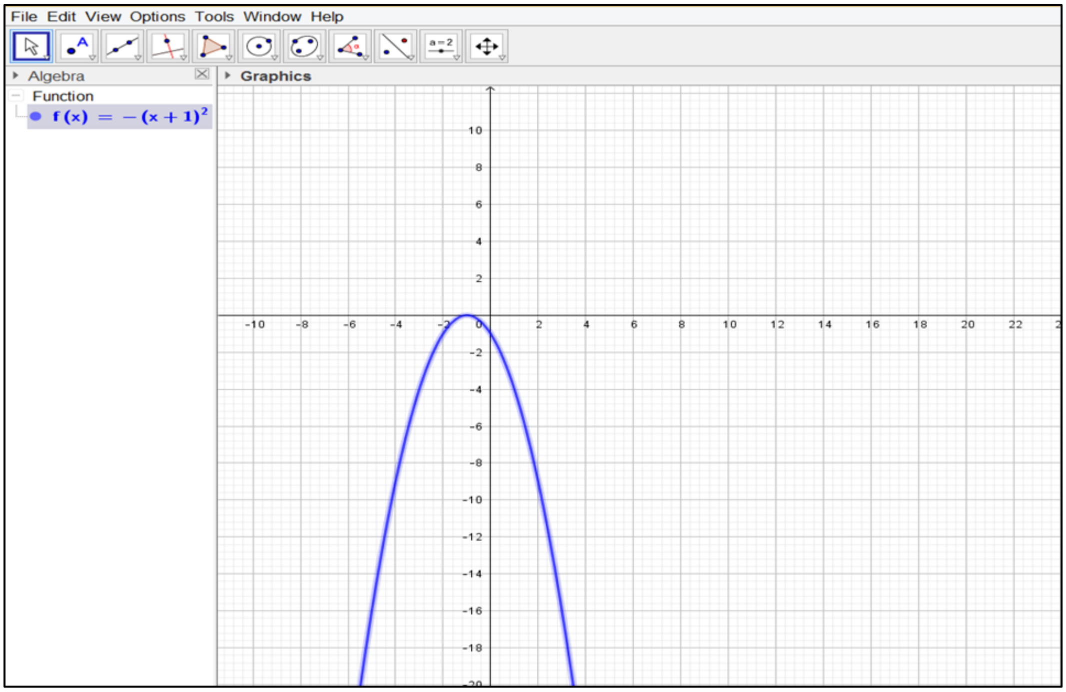
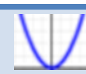
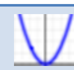


Figure 19: f(x)=-(x+1)^2

Table 17: Summary of Graph Transformation

Graph	Function	Graph Movement	Narration
Figure 14	$f(x)=x^2$		Parabola at original point (0; 0)
Figure 15	$f(x)=x^2+2$	↑	Translation by 2 units upwards
Figure 16	$f(x)=2x^2$		Divide x-coordinates by 2
Figure 17	$f(x)=x^2-2$	↓	Translation by 2 units downwards
Figure 18	$f(x)=(x-1)^2$	→	Translation by 1 units leftwards
Figure 19	$f(x)=(x+1)^2$	←	Translation by 1 units rightwards
Figure 20	$f(x)=-(x+1)^2$	↕	Reflection in the x-axis

The student further explained that teaching geometry using GeoGebra software creates models of terrestrial motion and the activities are practical. This software helps them building a fun interactive learning environment where they can explore the mathematical concept differently than in the traditional ways of teaching. With GeoGebra, students can construct shapes and draw graphs, tangents and angles more easily as the instructions are provided on the menu bar.

AS#2 mentioned that he has been exposed to use Photomath, however, he has never taught it in the classroom. He has shared the knowledge with his colleagues. He remarked:

> *Yes, Photomath. I had a chance to use it. It needs smart phones. If you do not have it, it will not work. Photomath is an app that only solves complex math equations and teaches how to solve them yourself. It uses the phone's camera to scan the math equation. Within seconds, it provides the answer or solution revealing step by step. I have shared this experience with others but not in a teaching environment.*

His remarks indicate enthusiasm for ICT; however, he lacks the formal training to transmit his passion effectively to the learners. A notable challenge is the use of smartphones, as not all students can afford them. This highlights the idea of costs as a hindrance to using ICT. Photomath uses the phone's camera to scan the math equation. However, it is fast and shows all the steps required. It seems that collaboration is required between lecturers and students so that ICT can be implemented in the classroom.

BS#4 mentioned that they are lucky in her university because they were supplied with tablets. They use these tablets to explore some mathematical software to enhance their understanding of mathematics. He said he has taught himself MATHEMATICA software and explained that MATHEMATICA is a very powerful software used to solve various mathematical problems. He remarked:

> *MATHEMATICA is an interactive software package that can perform numerical, graphic, and algebraic calculations. I use this software to find solutions for my assignments. It can show you step-by-step solution to a problem. I can demonstrate one or two examples of how to use MATHEMATICA software to integrate a calculus problem. It provides you with a space to enter your calculations and then you press shift and enter key to send the input to the Internet and the output will be returned.*

Figure 20 is a screen shot of a MATHEMATICA solution to an integral problem and the step-by-step calculations to find the final solution. BS#4 indicated that he uses MATHEMATICA software to find solutions for his assignments. He highlighted that the software is interactive in nature and shows all the necessary steps to a problem as shown in Figure 20.

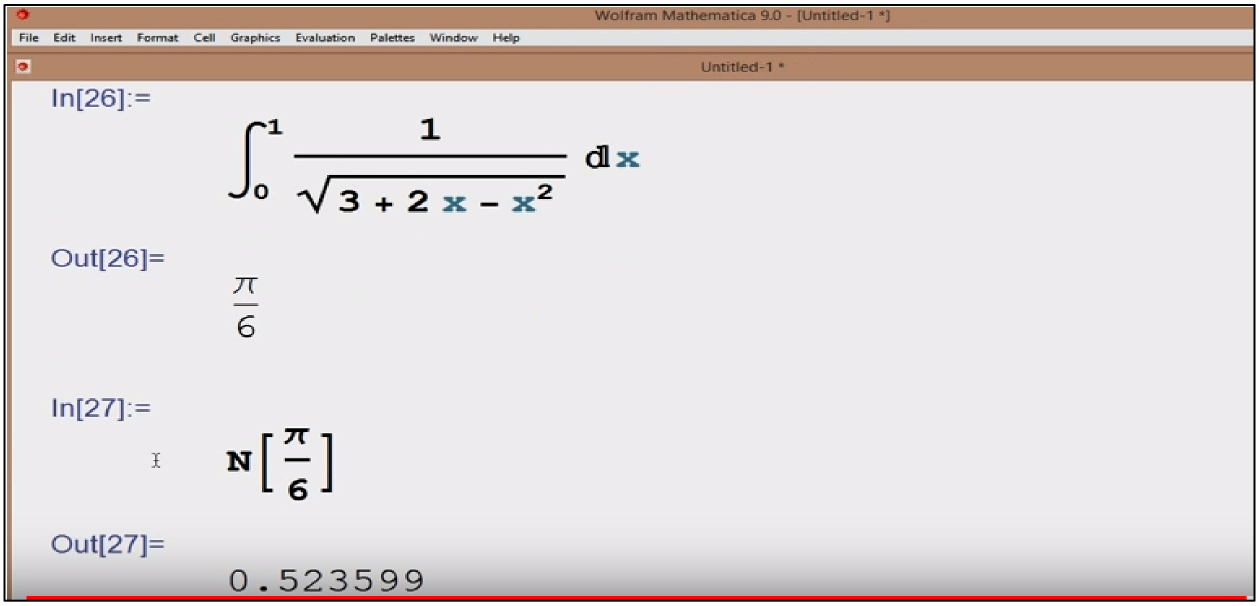


Figure 20: Screenshot showing step-by-step solution to an integral problem

All 20 pre-service teachers mentioned that for effective use of ICT in teaching, the training should start at their schools of education. Mathematics education lecturers play a leading role in demonstrating and modelling of how mathematics is taught using ICT to meet the 21st century skills. The ICT integration programmes need to be assessed both on campus and during the teaching experience. These contributions conveyed similar views.

AS#4 shared his thoughts about university programmes that pedagogically integrate ICT in teaching to foster confidence among pre-service teachers:

> *I think there should be programmes where we get exposed on how to use ICT devices because the world is moving towards that space. Lecturers should be at the forefront in harnessing ICT in their lectures. In some textbooks we see some mathematical problems being solved using computer programmes. We usually get lost when trying to follow such examples. Some schools in Gauteng have a smartboard that we struggle to use when we go for teaching experience.*

AS#4 noted that contemporary textbooks in mathematics give some worked-out examples using computer programming language. This implied that there is a gap between what they are taught to what is in the textbooks. Further, the classroom environment in some schools is smartboard driven, a technology that they are not equipped to use. Interactive digital simulations and other digital activities such as games have the potential to help learners to develop mathematics knowledge and gain access to learning resources beyond their physical classrooms.

BS#5 spoke of his personal experience of struggling to use the interactive whiteboard during the previous teaching experience. He commented:

> *Surely, our university should teach us how to use technology in the classroom. Last year I was embarrassed in front of the Grade 10 class as I failed to use the interactive whiteboard in front of the students. Unfortunately, there was no space for the chalkboard available. I ended up using the mobile whiteboard which had limited space.*

BS#5's statement reveals that he lacked the knowledge and skills to use a smartboard, therefore, it appears that the university is not adequately preparing the students to use smartboards. Consequently, students are forced to use the traditional methods of teaching. He noted the importance of technology in the classroom; however, he was embarrassed as he could not use it and had to use the normal board to continue teaching.

CS#3 mentioned that the use of smartboard should be taught at the university. He commented:

> *I think the installation of smartboards and use should start at the university where we are trained and later be moved to schools. It does not make sense that we are expected to teach using smartboard but at the same time, we are not exposed to the same technology. What I am thinking is that before they could incorporate smartboards and stuff like that in the schools, they should start here at the university so that student teachers may implement them when going to schools. The use of smartboards should start with university students because at least by the time student teachers leave university, they will be prepared on how to use smartboards instead of getting to schools and start a new programme on how to use smartboards.*

BS#4 strongly felt that the university has a bigger role to play in preparing students to use ICT during their training. She emphasised that the lecturers were to be the leaders. She commented:

> *I think there should be ICT integration programmes at our institutions of training to get exposed on how to use these devices. Most of these ICT education programmes we teach ourselves and our teaching is still largely paper and pen. We solve our mathematical problems using the old method, yet nowadays ICT provides better ways. Our lecturers encourage us to go to the Internet to research further about a concept, but they have never, ever taught us a lesson using ICT. There are positive prospects of teaching using ICT as learners can grasp the concepts much quicker…..Computers provide images, sound, text, and one can play YouTube videos several times in trying to understand the concept.*

BS#4's remarks show that students teach themselves how to use the ICT integration programmes and that most teaching is still using the traditional method. Unfortunately, lecturers only encourage students to go to the Internet to carry out research about a concept without teaching them how to integrate ICT. However, ICT has positive prospects such as enhancing the grasping of concepts, are faster, provide images, sound, text and can play YouTube videos several times, thus allowing understanding of concepts.

In responding to the question on how pre-service teachers use Microsoft Excel in teaching mathematics, BS#5 mentioned that he has never used Microsoft Excel in teaching mathematics. He had noted that Excel can be used to teach some mathematical concepts through a YouTube video. He remarked:

> *We have seen on YouTube video on how to use Excel in teaching mathematics. But we only use it to do our assignments, not for teaching. We learned very little in Excel such as functions, but not that one that is advanced. In Excel, one can work out simultaneous equations, graph transformation, statistics, and trigonometry just to name a few. To be honest, we have not learned these things in a formal class, we just see them when researching on the Internet.*

BS#5 indicated that he has limited knowledge of using Excel. What he knows come from what he learned on YouTube. He learned little in terms of functions and advanced Excel during formal classes. This shows that his learning was done through trial and error using the Internet.

DS#4 said the following about Excel:

> *We did Excel during first year and we were doing simple things such as functions and plotting bar graphs. The primary reason was to equip us with ICT basic skills such that we could type our assignments on the computer and format them properly. We never had a lesson that taught us on how integrate ICT in teaching.*

DS#4 confirms the sentiments expressed by S#5U that the training was not adequate during their first year. They were only taught functions and plotting bar graphs. Consequently, students were equipped with basic ICT skills to help them type and format documents and assignments on the computer but were never taught how to integrate ICT in teaching.

Generally pre-service teachers were eager to use technology in teaching, but they were hampered by the training they received from schools of education.

6.4 ICT Affordance in the Classroom

Technology affordances form a significant part of the cognitive development and equipping of teachers for the 21st century classroom. The technology-enhanced learning environment supports knowledge acquisition and impacts the level of learners' engagement and attitude towards learning. BS#2 suggested that the use of ICT in the classroom increases learners' attention span. She explained that contemporary learners like to learn in an environment where there is play and that these lessons allow learners to collaborate with one another, yielding fruitful results. She explained:

> *Generally, the use of ICT in teaching can yield positive results. It captures learner's attention span. Usually, learner's attention span is limited in today's world full of technology. They need teaching that involves playing computerised game. You are*

> *playing but at the same time, you are learning. It saves you time to explain some concepts to the learners and it saves you time because everything is at their fingertips ….*

In the above contribution, BS#2U implied that teaching mathematics using computerised games provide learners with rich opportunities to grasp mathematics knowledge. It may appear as if they are playing, but the result is that they have learned something. Notably, using ICT may save time in trying to explain some concepts because students may learn on their own, thereby increasing their creative thinking. As for the teachers, they may use the available ICT tools to research information.

Interestingly, one student teacher mentioned that multimedia embrace inclusive education as it comes in the form of text, sound, video, and animation. He went on to explain that it captures learners' attention because of a video accompanied by sound and text. He explained how he sees ICT affordances in the classroom situation.

> *ICT affords us to capture, store, process, and provide information to learners and teachers in a variety of multimedia forms (i.e. in the form of text, sound, video, etc.). Multimedia captures learner's attention because animated pictures are accompanied by sound. Learners remember better things that they have seen compared to things that they have read from the textbook. Using multimedia is ideal in teaching mathematics where concepts are so abstract. Multimedia provides observable concepts that you can easily relate to one another. All learners are catered for when using multimedia.*

In his contribution, CS#2 indicated that teaching mathematics using ICT helps learners remember concepts faster compared to when they are taught traditionally. Further, visualised concepts can be easily related to one another. According to his comment, the immediacy of ICT facilitated teaching allows learning to happen quickly. He implied that immediacy had a positive influence on learner inquiry through embracing ICT in teaching. S#2V suggested that the use of ICT provided teachers with a fast way to explain difficult concepts.

AS#5 indicated that ICT saved teachers' time when drawing mathematical shapes. He commented:

> *ICT saves time. For instance, if I am using the traditional way of teaching riders in mathematics, it will take me up to 10 to 15 minutes to draw the rider on the chalkboard. Yet if I am using ICT, the system quickly draws it for me and my duty will be just to display it to the leaners.*

This contribution indicated that using ICT has the advantage of drawing some mathematical shapes faster than with the hand. Clearly, ICT can be a very powerful tool to use, however if pre-service teachers are to use this tool and the potentials it offers constructively and efficiently then they need to be taught how to pedagogically integrate ICT in the teaching of mathematics using the facilities and functions of a spreadsheet, graph plotting package, GeoGebra, Dynamic Geometry package or Graphical calculator. Teaching mathematics lessons can, therefore, help pre-service teachers develop their ICT skills, which they can apply in their teaching context.

6.5 Embracing ICT Should Start at Teacher Training Institutions

17 pre-service teachers indicated that ICT integration in subject-specific should be taught at teacher training institutions. Teaching how to use ICT in teaching mathematics is similar to taking an apprenticeship course where an experienced person demonstrates how to go about in performing a particular task. DS#2 commented:

> *Our lecturers need to take us through on how to use ICT in the classroom. We should be given an opportunity to observe our lecturers as they model and demonstrate the use of ICT in teaching mathematics just like what is happening in apprenticeship. Once we learn the skill to integrate ICT, we can work independently and chances are high that we may use the learned skill in our future profession.*

This comment indicates that lecturers should play a leading role in demonstrating the use of ICT in teaching mathematics. As pre-service observe and learn how to use the skill, they may use the skill when they join the teaching profession.

6.6 Hope for Using ICT in the Classroom

13 students who participated in the interview indicated that they hope to see teaching that embraces ICT. They indicated that the 'Net Generation' learners easily lose concentration when teaching using chalk and textbook method. This is what BS#3 and DS#1 mentioned respectively:

> *Teaching learners that are accustomed to traditionally using ICT tools is problematic. They lose concentration and start making noise, yet if you use ICT, you keep their concentration span active. (BS#3)*
>
> *Our institutions need to prepare us to use ICT because contemporary learners are so engraved into ICT use. So our teaching should be in line with their day-to-day activities. The government should also speed up in resourcing classrooms that require the needs of today's learners. (DS#1)*

6.7 Summary of the Chapter

This chapter presented the observations made by mathematics pre-service teachers about their experience of mathematics lectures at their universities. The following themes emerged frequently from the data: teaching is largely chalkboard and textbook based; skillset level in the usage of technology is limited; pedagogically integration of ICT should start at teacher training institutions; ICT affords students to enhance learning; and the use of Excel and PowerPoint in teaching. Experiences of the students from different universities were consistent, for example, integration of ICT in teaching of mathematics should start at schools of education.

The pre-service teachers appeared to have some skills in using ICT, which signifies that they expect their lecturers to teach them the skills that will prepare them to meet the demands of the 21st century classroom. There was a clear perception that if ICT were integrated into their lessons, it would have enhanced their understanding of how it will support them in their future careers. It is evident that ICT was not embedded in pre-service teachers' developing pedagogies, and there is strong evidence that there was a missed opportunity to gain knowledge about how ICT might contribute to enhance their learning in the overall programme. Thus, it will be a challenge for them to transmit knowledge that they did not learn. Figure 21 captures pre-service teachers' experiences in their lecture room and their perceptions of ICT integration in teaching and learning.

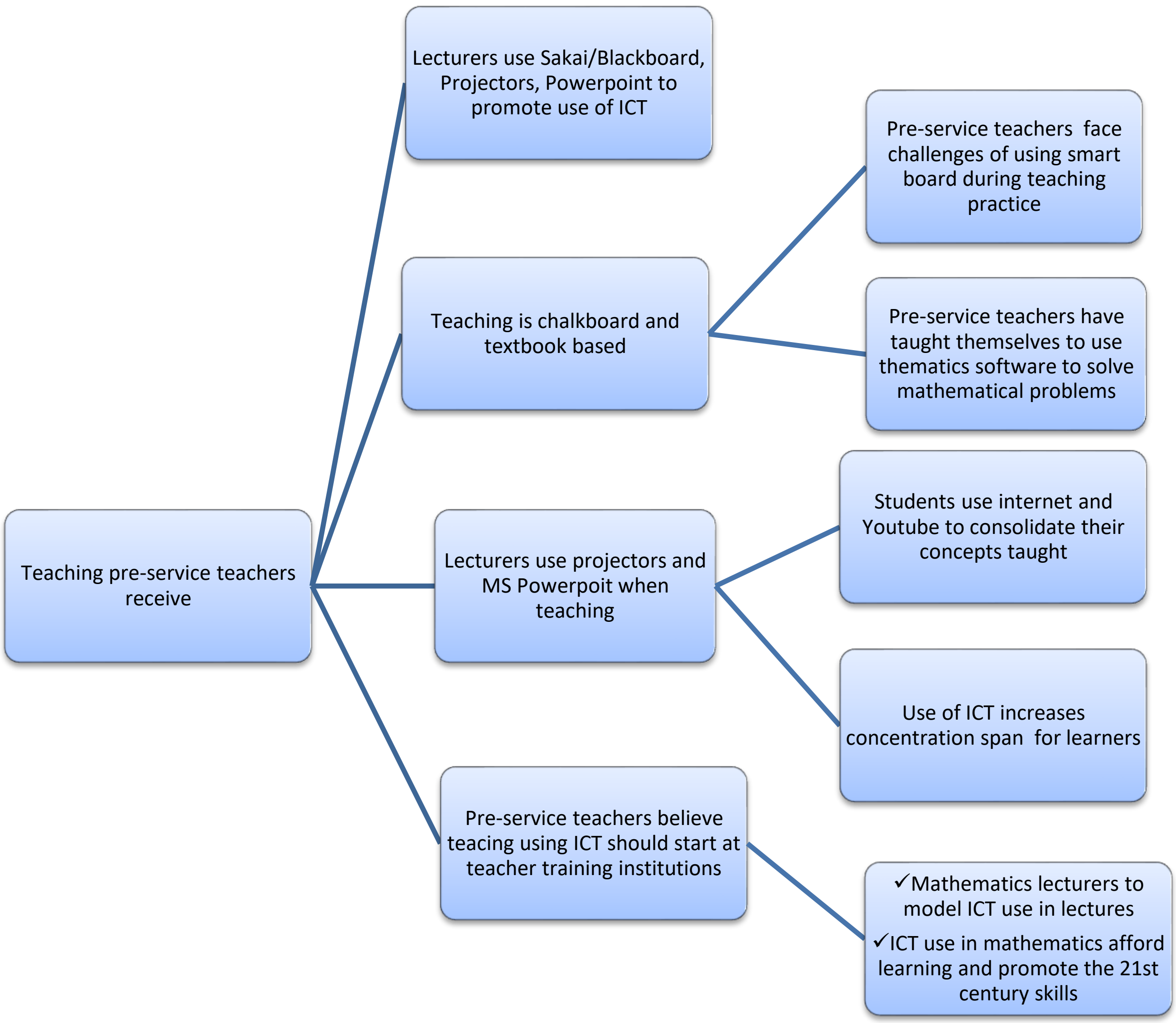


Figure 21: Pre-service teachers' experiences in classrooms and their perceptions of ICT use

Chapter 7 discusses an amalgamation of the findings and themes that emerged from the mathematics lecturers' and pre-service teachers' perspectives. All the contributions are revisited and reviewed with a lens focusing on how mathematics lecturers are using ICT in the teaching of fourth year FET B.Ed. degree students with relation to the literature.

CHAPTER 7: DISCUSSION OF THE FINDINGS

7.1 Introduction

This research used a qualitative interpretive approach to examine the perceptions of mathematics lecturers and pre-service teachers regarding the use of ICT in teaching. My interest was triggered by the aspects of their perceptions that reflected on the appropriation of ICT in lecture rooms. I analysed data based on the research questions listed below.

1. How do mathematics lecturers prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?
2. What ICT tools does mathematics lecturers need to adequately prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?
3. To what extent are the pre-service teachers being prepared to meet the demands of the 21st century classroom?
4. What ICT pedagogical model/structure is suitable for preparing pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

This study had 12 mathematics lecturers and 20 fourth year FET pre-service teachers (majoring in mathematics) as participants from four universities. Thematic analysis was employed to analyse the data. Thematic analysis (discussed in Chapter 4) is a method used to identify, analyse and report patterns (themes) within data and it allows data in the data set to be organised and described in detail (Braun & Clarke, 2006, p. 80). The findings of the mathematics lecturers' interviews were presented in Chapter 5, while the findings of the perceptions of pre-service teachers were presented in Chapter 6. This chapter focuses on the discussion and synthesis of the findings that emerged in these two chapters. All themes related to each of the research questions from both mathematics lecturers and pre-service teachers were discussed. For instance, professional development addresses research question 1. Research question 2 is related to ICT tools used as part of pedagogy. The Activity Theory, as a model for the appropriation of ICT in pre-service teacher training, is discussed together with the findings from both the mathematics lecturers and pre-service teachers. The Activity Theory was reconfigured and a model called Transformed Activity Model (TAT) for ICT integration in mathematics was developed (refer to Section 7.6).

In this study, both mathematics lecturers and pre-service teachers reported that they use ICT for various pedagogical purposes employing Sakai/Blackboard (for assessment). A lack of training, and data projectors and PowerPoint featured very strongly. The impediment that came out was that lecturers lacked the skills to fully utilise the repository systems. Table 18 displays the NVivo output (screenshot) of themes and subthemes with references. The table highlights the themes that emerged in Chapters 5 and 6 in relation to the research questions that guided the study. The files tab in NVivo indicates the number of source information (interviewees) coded for various themes and references is the total number of codes. NVivo checks whether a matching file already exists in the project and if there is a matching file it increments the count or creates a new file if there is no matching file. In other words, the file menu stores all the data and materials that need to be analysed. Nodes are the containers that are resolved in the process of coding to store topics or themes.

Table 18: Tabulation of themes and subthemes

Name	Files	References
Pedagogic ICT Tools	9	87
Data Projectors and Powerpoint Slides	9	21
Internet and Google	8	14
Traditional Methods of Teaching	6	16
Use of Sakai or Blackboard for assessment and uploading te	8	31
YouTube Videos	3	5
Policy Document	9	9
Professional Development	10	78
Attitudes and beliefs	8	14
Knowledge sharing space	5	5
Lack of Training and Support	7	15
Skill set level	10	35
Time constraint	6	9

Figure 22 shows the main themes presented using visual mapping in the form of a pie chart. A pie chart displays the proportional data (in percentage) represented by each theme category. NVivo has the capabilities of displaying the charts obtained from the coding. For the purposes to display the participants' concern about the use of ICT in the lecture room, the pie chart was adopted to show perspective themes, which are pedagogic ICT tools (50%), professional development (45%) and policy documentation (5%). The research questions 1 and 3 (Section 1.6) that seek to determine how do mathematics lecturers prepare pre-service teachers to integrate ICT to meet the demands of the 21s^{t} century classroom were captured by the pie chart. Research question 2 (Section 1.6) looks at ICT tools mathematics lecturers need to adequately prepare pre-service teachers to integrate ICT to meet the demands of the 21s^{t} century classroom. The question was addressed by the type of professional development mathematics lecturers need to have and the type of training they need thereof. Research question 4 (Section 1.6) was addressed by the need for mathematical ICT policy into teaching and learning and the model that can be adopted(Figure 24).

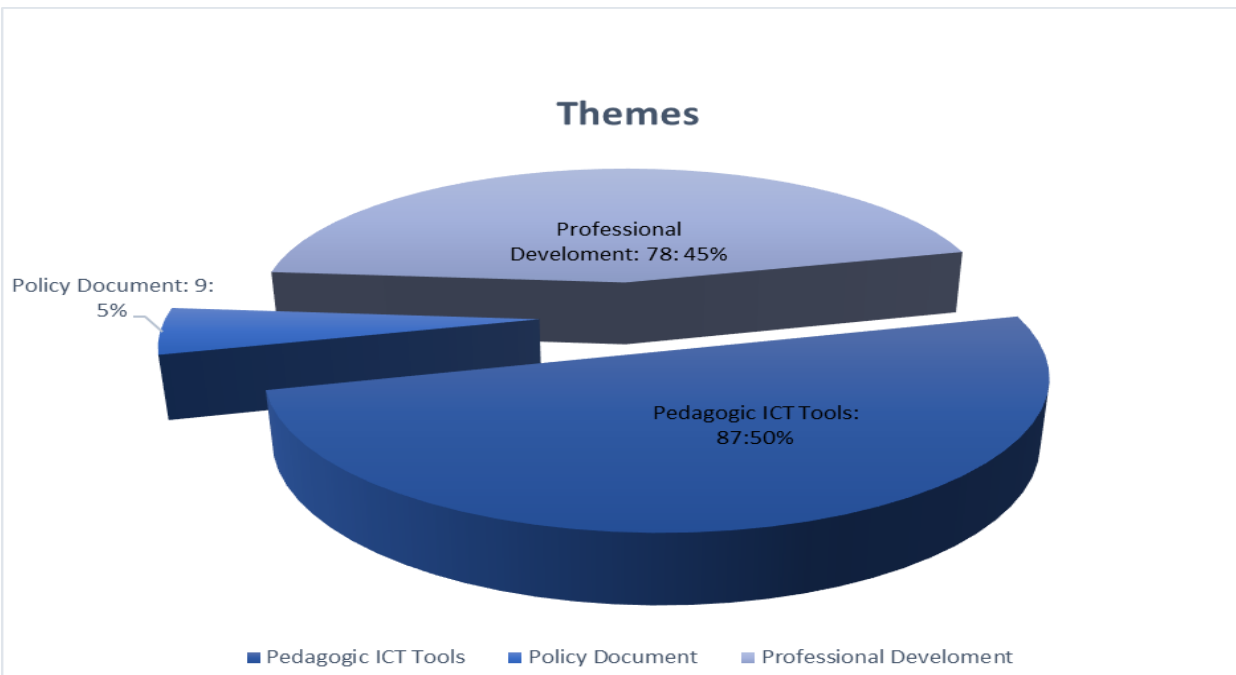


Figure 22: Themes that relate to the research questions

Figure 23 displays visualised connections, themes and relationship using a tree model. The main themes are called parent nodes, subthemes are called child nodes.

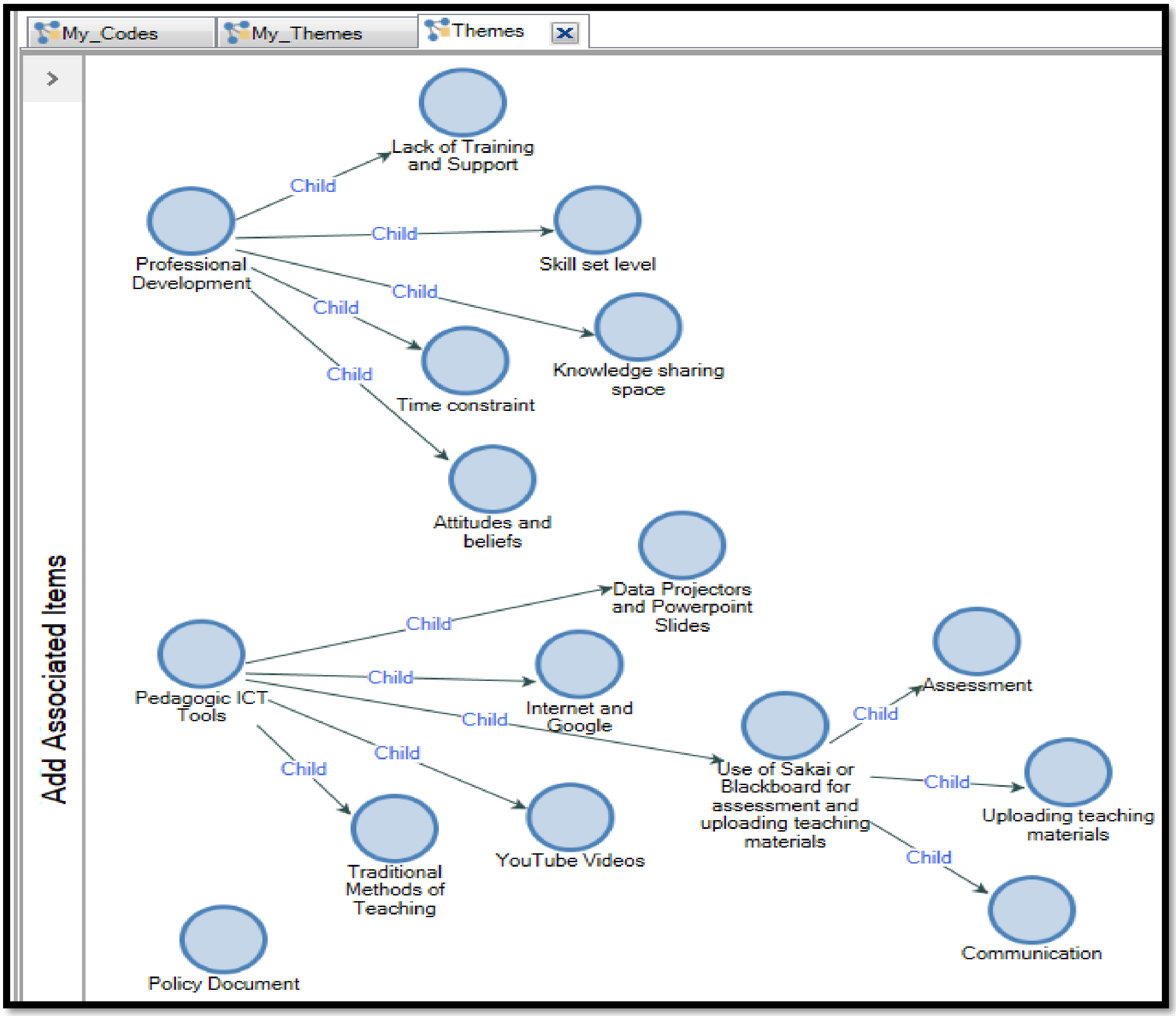


Figure 23: Tree model showing themes and subthemes

7.2 Theme 1: Professional Development

Research question 1 focuses on the experience of mathematics lecturers when integrating ICT in teaching. The majority of the mathematics lecturers indicated that they do not use ICT in the teaching of mathematics; however, they mentioned that they use ICT for administrative purposes. They reported that the lack of training for teaching staff in the use of ICT in teaching mathematics is the basic barrier and hindrance. The other themes emanated from the data were lack of support by the education school authorities, lack of a knowledge sharing space, attitude and beliefs, time constraints and low ICT skill level among mathematics lecturers.

7.2.1 Lack of ICT Training and Support by School Authorities

The inconsistent use of ICT in teaching mathematics featured frequently across the participants' commentaries. The fundamental reason for not adopting and using ICT in teaching was the lack of ICT training. Participants did, however, agree that ICT offers unlimited support in teaching and solving mathematical problems. ICT promotes central key skills such as readiness for collaboration, problem-solving, creativity and critical thinking. To equip the contemporary students with these skills, the educational mathematics lecturers need to undergo some ICT training. Valtonen, Kukkonen, Kontkanen, Mäkitalo-Siegl, and Sointu (2018) reiterated that to equip students with 21st century skills, lecturers should take advantage of ICT in pedagogically meaningful ways. However, instructors need ICT specific skills, and schools of education at universities, particularly in South Africa, have a big role to play in preparing new teachers with the readiness to use ICT for various learning purposes. Today's pre-service teachers are part of the Net Generation. The 'Net Generation' is the generation that actively uses ICT in everyday living but still lacks the skills to use ICT for teaching and learning (Valtonen et. al., 2018). Pre-service teachers use ICT applications, such as tablet, computers and smart phones, in their everyday lives, but despite the presence of all these applications, pre-service teachers still do not have personal experiences of teaching with ICT (Lei, 2009). A study conducted by Sang, Valcke, Van Braak, and Tondeur (2010) revealed that teacher education institutions are facing challenges in preparing pre-service teachers for successful integration of ICT into their teaching and learning. For the full integration of ICT in the lecture room, there is a need to reconcile mathematics lecturers' pedagogical competencies and pre-service general ICT skill level. In order to achieve this reconciliation, lecturers need specialised professional ICT training that provide the needed skill to help them successfully integrate ICT in their lecture rooms. From the fore going discussion, it can be inferred that lecturers currently lack sufficient training to implement ICT in their teaching. Thus, it is in view of this phenomenon that this study seeks to explore how education mathematics lecturers are preparing pre-service teachers for pedagogical ICT integration.

From the findings discussed in Chapters 5 and 6, mathematics lectures spoke of the variety of ways in which ICT can be used in the classroom such as for critical thinking and creativity; however, they are failing to fully implement it because of limited ICT skills. They mentioned software like GeoGebra, MATHEMATICA and Photomath that can be used to mediate teaching mathematics. But the skill set level to embrace it in teaching is not readily available. Thus, these software are not being used in most educational institutions. It is interesting to note that this software (GeoGebra, MATHEMATICA and Photomath) are installed in computer labs and mathematics lecturers' desktops but very few education mathematics lecturers try to use them in their teaching because they do not know how. Comparably, pre-service teachers are the ones who use this software on a trial and error basis. Mathematics lecturers alluded that they sometimes attend mathematics workshops in which the use of ICT in teaching is encouraged but there seems to be very little formal training offered. Additionally, with respect to the quality of training, satisfaction levels among mathematics lecturers are low as the concepts taught are beyond their ability.

Some education mathematics lecturers posited that workshops on ICT in teaching mathematics would add value to the teacher education programme. They inferred the benefits of ICT integration workshops to their teaching as it would provide them with skills to explore and learn before going to lecture rooms and eliminate a lot of mistakes during lectures. They would even welcome workshops organised by mathematics software developers to share their experiences of ICT use in teaching and learning. Pre-service teachers' commentaries highlighted a perception that it would be worthwhile for their mathematics lecturers to demonstrate the ways they can use ICT in the classroom. A number of lecturers mentioned that they lack innovativeness when it comes to use of ICT in the classroom. They want to learn about the different features ICT offers in teaching. They indicated that it would be beneficial to learn how to create attractive PowerPoint slides to enable them to teach with confidence.

Often the workshops that are held are attended by marketing agents from software companies who give a quick overview of how mathematics software without giving the lecturers sufficient time to use and judge the usability of the product. These workshop do not offer training at all, instead they simply show newly developed materials that can be used in the teaching of mathematics. One respondent mentioned that if they could be told the importance of the software and be taught how to use them, ICT integration could not be a challenge. They will develop enthusiasm to use the software and ultimately acquire knowledge and skills on various computer applications software packages to carry out classroom activities that are necessary to succeed in today's computing society.

Pre-service teachers mentioned the benefits derived from using ICT in teaching such as capturing learners' interest and providing a platform for learners to collaborate. The biggest concern was that they are not properly trained to teach using ICT. They highlighted the challenges they face when they go for their practicum, mentioning that some schools in Gauteng use interactive white boards that they do not know how to operate. They felt their lecturers are limiting them with the potentials that ICT offers. They view inclusion of pedagogical use of ICT as crucial to their pre-service training in order to meet learners' needs in an information society (Goktas et al., 2008). To them, the training they receive that is characterised using text books and chalkboard is incongruent with the needs of contemporary society. Training pre-service teachers at their training institutions to use ICT increases the chances that they will transfer their knowledge and the skills into their future classrooms (Goktas et al., 2008).

Both mathematics lecturers and pre-service teachers indicated the importance of training for the effective use of ICT in the classroom. Mathematics lecturers raised the concern of minimal training in the use of mathematics software in teaching, leaving them with limited space to apply it in their classroom. Pre-service teachers are blaming their lecturers for not preparing them enough in the use of ICT in the classroom to meet the demands of the 21st century classroom. This finding resonates with the holistic premise of proper pedagogical ICT training to meet the demands expected by MRTEQ (2015). It sits well with the notion of promoting pre-service teachers that are competent users of new and ever-changing technologies in their future practice. Brand (1998) mentioned that, "if students *[sic]* are going to be prepared for a technological society, they must be taught by confident and competent teachers". This can only be achieved by adequately training pre-service teachers for effective use of ICT in the classroom. Inherent in both mathematics lecturers and pre-service teacher commentaries was the view that ICT offers an unlimited number of benefits in the classroom; however, there is a need for proper training to give them confidence to start using ICT in the classroom. According to pre-service teachers the training should start at their schools of training. Mathematics lectures look for this support from their schools of education.

7.2.2 Absence of Knowledge Sharing Spaces

Findings from mathematics lecturers' commentaries indicated the importance of sharing knowledge practice. The mathematics lecturers highlighted that learning is a continuous process that can be achieved through social interaction with people with similar concerns or interests. The kind of knowledge that exists among mathematics lecturers is in the form of silos (knowledge exists within individual), where knowledge sits in one place and is not transparent or shared with another person. There is very few platforms for people with different knowledge sets to come together to share ideas. If these platforms become CoP, they will address the emerging concerns of lecturers because they can use the shared information to solve problems, and/or improve their work-based performance with regular interaction. Since, learning patterns in a community occurs through practice and interaction with others, in digital era it is ideal for professionals to help one another to solve problems through the leverage of ICT affordances to tackle development challenges facing South African education.

CoPs acts as a catalyst for professionals to internalise new knowledge, which eventually allows them "to reach different interpretations of the same knowledge" (Kapucu, 2012). CoPs provide an interactive mode for professionals to engage with each other about their practice and how they co-construct knowledge. CoPs can be used to build a solid base of training ICT experts among mathematics lecturers with relevant skills and knowledge in the use of effective learning and digital pedagogies. The setting up of integrated professional learning communities will serve as models for professional mathematics lecturers to continue sharing information and ideas and personal advancements at the subject level with their colleagues. Participants are equipped with the necessary skills to transfer and share information, tools and resources, successes and challenges with colleagues and in the process create an enabling environment in the initial teacher education programme. A CoP platform co-create a teaching practice resource that help both mathematics lecturers and mathematics departments to track, monitor and improve the teaching practice experience. The Sector Skills Plan 2016–2021 shows foresight and eagerness to drive change in technical, professional, and management skills by putting ICT infrastructure in place to nurture innovation and creativity (Northern Ireland Executive, 2016).

Mathematics lecturers noted that platforms for sharing information are not effective in their universities because in most instances where such platforms are organised, very few people turn up. The reason could be that they do not see the value or benefit it will add to their practice. In addition, some mentioned that the time given for such platforms is too short, usually a day or two, and when they come back from the training they have forgotten almost everything. Most mathematics lecturers place more trust in YouTube than in professional developments courses. Their perception is that playing YouTube videos provide better training than professional development. YouTube videos are always available as long as there is an Internet connection, and they have is that they can be watched over longer periods of time and whenever one feels like. YouTube videos also has the advantage that it can be replayed until the concept it fully grasped. It was apparent that they were failing to apply the skills learned at workshops in their work-based communities. There are also no follow up to confirm that what was discussed at workshops are being implemented.

Education/learning occurs in an environment where people are engaged in a network or relationship (Dewey, 1963). Dewey saw networking and connectedness playing a bigger role in educational activity and indeed for good teaching and learning practice. In contemporary society, there is abundance of information technologies such as social networking and online teaching platforms that can be used as venues for CoP as well as connectedness among mathematics lecturers and their departments (Rudestam & Schoenholtz-Read, 2010). These platforms can play a major role in equipping each participant in the community with the relevant knowledge needed for practice.

7.2.3 Time Constraints

Mathematics lecturers emphasised the importance of time in teaching. The majority of them expressed concern over their already full curriculums in their departments that need to be completed within a specific time. Using ICT in teaching appears to be an extra load on an already congested time table. Excessive workload was mentioned as a key negative contributor to the reluctance of pedagogical use of ICT in the classroom. To them, the use of ICT is seen as a new curricular that is detached from the main subject and needs its own time. Those that want to embrace it in their teaching practice have to allocate time to study how it can be used in enhancing teaching. The demands to meet the syllabus requirements pushes mathematics lecturers to use the teaching methods they are comfortable with rather than using a new method they are unfamiliar with. Yet, in most cases ICT can save time, as the work that has been done can be re-used in other aspects. The user has the task of updating the information to meet the environmental needs. The research conducted by PwC in England reported that effective use of ICT in the classroom could save instructors an average of 3.25–4.55 hours per week (Selwood & Pilkington, 2005). But as long as the instructors are not trained in how to use ICT they may not realise how much time they can save, instead without the proper skill, it takes them more time to use.

Some participants spoke of the affordances ICT offers in their commentaries noting that successful lessons are achieved by investing a lot of time for appropriate selection of materials and/or software to be used during teaching. The main drawback facing most mathematics lecturers is the time they need to take to understand the software. Some mentioned that the software are not user friendly and that they need more time to learn and apply it in a classroom environment. They do not have adequate ICT knowledge; hence they face have difficulty learning the software. This is why some prefer YouTube videos: It takes less time to be downloaded, listened to and shared with the students. Both Google search engine and YouTube were considered much easier tools to learn, a better approach to be used in the classroom and more user friendly. It is does not take much time to refer students to a link. Google was regarded as a useful tool for both mathematics lecturers-led research and for pre-service teachers to research their assignments. Indeed, inadequate time to develop ICT skills in teaching appears to be an acceptable reason for mathematics lecturers' failure to use ICT in their practice. The issue of time seems to be not available for their personal activities and it hinders their personal development for acquisition of the necessary ICT skills.

7.2.4 Attitudes and Beliefs

Findings from the mathematics lecturers' commentaries were that attitudes and beliefs are important when a new idea is brought in. The participants expressed doubt about the use of ICT in teaching mathematics and only a few expressed hope. They mentioned that ICT plays a pivotal role in today's education; however, many of them do not want to move from their comfort zone (traditional way of doing things) and embrace something new that may disrupt their day-to-day teaching routine. It appears that they fear the unknown when it comes to harnessing ICT in education. Some believe that it may affect students' performance while some just display negative attitude. In addition, some added that teaching with ICT may expose their weaknesses and create an impression among the pre-service teachers that they do not know the subject matter. Eickelmann and Vennemann (2017) defined belief "as a subjective element of knowledge that an individual considers true and important in relation to a specific subject". This feeling is usually influenced by people's past experience, history and emotions. Yet attitude is seen as simply people's positive or negative feelings about an effect or performing the target behaviour (Eickelmann & Vennemann, 2017). Mathematics lecturers' attitudes and beliefs are crucial with regard to innovations in education, especially in the contemporary era where a combination of pedagogies and ICT are called for.

Mathematics lecturers who participated in this study claimed that during their education or training there was no technology, thus they believe ICT is for young people, not people older than 60. The participant who were enthusiastic about ICT were the smallest group, while the doubters (those with negative view on ICT in education) formed the largest group in the sample. To them ICT is not necessary because they have been performing well with the current methods of teaching. ICT is ever changing with new software or programmes constantly being introduced to the market: There is always a new programme before the first has been mastered. This scenario makes it challenging as to choose the appropriate software/program for their students. There is a belief that ICT is difficult to understand, let alone integrate in teaching, spreading among the lecturers. Their schools of education or universities are not adequately providing them with the actual support such as training (discussed in in Section 7.2.1) for hardware and software and encouraging them to foster the use of ICT in their instructional settings.

7.2.5 Skill Set Levels

Mathematics lecturers indicated that their ICT skill set in teaching mathematics is limited. This implies that it is the root cause that hinders them to use ICT in lectures. Agyei and Voogt (2011) reiterated teachers to be trained in the use of ICT. If the pre-service teachers are not trained in the use of ICT in the classroom, it means that the number of teachers who do not have skills of ICT in the classroom will be amplified.

In summary, the majority of commentaries alluded to the congruency of ICT in the contemporary classroom in South Africa. Many participants mentioned that ICT use appeared to be beneficial in the classroom as creating collaborative learning, creative thinking and problem-solving tool. Despite the benefits and positive promises it offers, there was evidence that the two groups of participants do not have the knowledge and skill to pedagogically harness ICT in the classroom, therefore, to realise the promise that ICT offers, there should be some form of ICT training that should start at pre-service teachers training level. The knowledge sharing platforms that are in place are not effective and most participants in these communities are reluctant to attend workshops. However, with the advent of technologies, platforms such as online teaching and social networks can be used as venues for relationship building among mathematics lecturers and pre-service teachers.

7.3 Theme 2: Pedagogic ICT Tools

Research question 2 focuses on the ICT tools mathematics lecturers and pre-service teachers use for pedagogical purposes. Pedagogic ICT tools emerged as a main theme with five subthemes, namely data projectors and PowerPoint slides, Internet and google, YouTube, Sakai or Blackboard and traditional methods. I discuss these themes in the perspective of how mathematics lecturers develop pre-service teachers' use of ICT in their teaching practice and how they use ICT in their learning. In addition, this study describes aspects of ICT pedagogy pre-service teachers would like to learn through their teacher training programme. I further highlight the similarities and differences within the mathematics lecturers' and pre-service teachers' commentaries related to these themes.

7.3.1 Data Projectors and PowerPoint Slides

The use of data projectors and PowerPoint slides featured strongly in all the mathematics lecturers' commentaries. Data projectors and PowerPoint presentations appear to be cultural tools for teaching, which means that these tools are prerequisites in teacher training programmes. They see these cultural ICT tools as learning tools that bring excitement and spontaneity to learning. All the slides presented can be easily accessed again. They highlighted that presenting mathematics lessons with PowerPoint makes it easier for students to grasp the lesson's concepts because they are not distracted by taking notes because of the presentations available before the actual lesson. The use of animation and sound in the presentation can enhance the lesson; however, overuse of these will detract from the learning and the concepts being put across. Data projectors are devices that project the output of a computer onto an object mounted on a wall or any object; it is widely used for instruction and slide presentations. Digital projectors allow lecturers to concentrate on teaching without the need to constantly write on and erase the blackboard. Despite the advantages of data projectors and PowerPoint presentations, mathematics lecturers expressed concern about the technical hitches. There are times when these technology gadgets fail to work, thereby disrupting the lesson plan. Lecturers should always have another plan in case of technical glitches.

Pre-service teachers, on the other hand, indicated that they use PowerPoint presentations during their micro-teaching and teaching experience. However, they did not feel confident using PowerPoint to teach mathematics. They use PowerPoint to present the main concept of the topic, but when working out the problem, they use the traditional way of teaching. They posited that their training institution should come up with an apprenticeship programme where ICT integration in teaching of mathematics is demonstrated by experienced lecturers while student observes and practice the learned skill. The lecturer continues providing support in the form of coaching and mentoring, and finally, the lecturer fades his support as students gain more autonomy and work independently (Lee et al., 2016). Integrating ICT in teaching is a hands-on activity and a lot of time should be allotted to learning to teach using ICT, as it will be beneficial to their future. Pre-service teachers mentioned that they preferred hands-on learning when using embracing ICT in teaching.

7.3.2 Internet and Google

The mathematics lecturers' commentaries implied that the Internet and Google search engine is used as a part of the ICT enriching students' understanding of the taught concept. They take it for granted that when a mathematics concept is taught, it is normal to refer them to the Internet for further research. They also mentioned that they use the Internet to prepare their lectures and post relevant websites for their students through the Sakai/Blackboard portal. This gives the student the advantage of studying the material before the lecture. The Net Generation pre-service teachers can easily use the Internet and it does not take the students much time to find and download mathematical materials from anywhere around the world at any time of day or night, and the number of information available is enormous. Accordingly, it is implied that mathematics lecturers interfere minimally with the students when using the Internet for further research. It was apparent in mathematics lecturers' commentaries that they assume that the Internet and google play a pivotal role in enhancing students' research in trying to understand the taught concept and that the students do not have problems accessing the material using links. The Internet helps students to practice already learned skills and provides immediate feedback (Makonye, 2017). Mathematics lectures further mentioned that it is much easier and quicker to get information from the Internet than from textbooks or the library.

The pre-service teachers were confident that the Internet and google play a positive role in their learning. They believed that ICT has space in the 21st century learning and a place in learners' education. They mentioned that they use the Internet and google to access mathematical software such as GeoGebra, MATHEMATICA, Photomath, and MathsExpert, and the Internet provides them with the opportunity to learn how certain mathematical problems are solved. They indicated that ICT is a part of their lives and is beneficial to their educational endeavours. The opinion that the Internet was empowering them was a common theme inherent in the pre-service teachers' commentaries. They also felt that it provided them with various ways a mathematical problem can be solved, which could sometimes be a challenge to the lecturer. This knowledge and skills contribute to the widening of their cognitive development when faced with complex mathematical challenges.

Despite the evidence mentioned by mathematics lectures that ICT is not widely used in most of their lectures; pre-service teachers have access to abundant information on various topics through the Internet. The Internet is used as a tool for further research and to complement what they have learned during lectures. Information on the Internet can now be accessed from computers, laptops, smartphones or iPads. Universities in South Africa have good Internet connectivity through Wi-Fi and this provides pre-service teachers with the opportunity to easily access information from the Internet using smartphones or iPads anywhere within the university (Owusu-Mensah & Quan-Baffour, 2017). The university learning management system(Sakai/Blackboard) can be accessed at any time anywhere as long as there is Internet connectivity.

7.3.3 Use of YouTube Videos

Mathematics lecturers mentioned that YouTube videos are the mainstay of teaching using ICT because they are easy to access, are free and easy to search for by logging into the Internet and searching for the videos by typing appropriate keywords. A list of videos will appear, and the onus is on the user to select the appropriate video for the student. The fact that YouTube videos explain concepts step by step featured strongly in mathematics lecturers' commentaries. The concept is developed from simple to complex (Makonye, 2017). The advantage that YouTube videos provide is that they can be replayed several times and paused to gain an insight into what is being presented. It was noted that most mathematics lecturers encourage students to use their links to get videos. However, the mathematics lecturers were not open on how they use YouTube in the lecture room to support pre-service teachers' understanding. They probably see YouTube videos as a tool for comparing ways of teaching a certain topic, therefore, it is not necessary during the lecture. Students can only use them to supplement already taught concepts.

Two mathematics lecturers indicated that they sometimes used software such as GeoGebra to teach trigonometry and functions on the movement of the graphs, changing of the amplitude or determining the minimum and maximum values and how to change the degrees. But, because of the calibre of the students they have in their universities, the use of mathematics software is not recommended. They should rather ground them with the content before they use technology. They agreed that the use of YouTube videos enhances students' concentration and help them to understand concepts they would have missed during the lecture. However, when I interrogated them further, given that the students they are teaching have a weak mathematical base, it emerged that they have stopped using YouTube during lectures. They mentioned that they are not completely convinced of the effectiveness of ICT in teaching mathematics. They believe in a blended approach when it comes to pedagogy and that traditional, face-to-face teaching when solving some mathematical problems are most effective. It seems that they regard YouTube videos as a good teaching tool for various mathematics topics; but it is an advanced tool to be used by students with low mathematical cognitive capacity. According to the mathematics lecturers, pre-service teachers are not fully utilising YouTube, as most of them spend their time watching movies and music; this distracts their attention.

Pre-service teachers considered YouTube videos as a mediation tool. It assists them to catch up or connect with missed concepts much easier. They mentioned that sometimes their lecturers provide them with link where they can get YouTube videos they can watch to extend their understanding of a concept. Two students highlighted that they learned how to use GeoGebra and MATHEMATICA software through YouTube videos. They found that these videos are sometimes more explanatory and detailed than their lectures. They revealed that they understand YouTube video lessons better, because when they do not understand something, they can pause the video and replay it until the tricky part is clarified. When I asked them to confirm whether they are ready to use GeoGebra and MATHEMATICA software in their future classes, it emerged that they are not ready. They are only beginning to understand how this software could be used in a classroom environment. It appears that they are not adequately prepared by their mathematics lecturers on how to use such software during their learning.

The analysis of the pre-service teachers' commentaries indicates that their lecturers hardly ever teach mathematics lesson using ICT to provide them with needed skills and knowledge for their future practice. It appears that the students teach themselves how to use the software through YouTube videos. Most lecturers are still grounded in the traditional method of teaching (discussed in Section 7.3.5) and have little faith in teaching using ICT. One lecturer commented that, "Even township schools which have best ICT equipment, they still do not perform very well in mathematics". This implied that ICT is a mediation tool in teaching, but it does not guarantee better marks. Inherent in both mathematics lecturers' and pre-service teachers' commentaries was the notion that YouTube videos are used for self-learning and sharing links to colleagues through the Sakai or Blackboard portal.

ICT use in teaching and learning encourages students to explore concepts on their own partly because it provides instant feedback, which helps to provide an informed explanation of the concept. Furthermore, it provides both mathematics education lecturers and pre-service teachers with the space to try the concept repeatedly and come to a conclusion. As they do these 'trial and error' iteratively, there is a possibility of establishing abstract connections in mathematics that ultimately improves conceptual understanding.

7.3.4 Sakai or Blackboard Portal

Most universities in South Africa have adopted Sakai or Blackboard Learning Management Tool to manage the teaching and learning of modules within their departments. Most mathematics lecturers who participated in this study mentioned that they use these platforms to communicate, assess students and upload teaching materials. Software resources like Sakai or Blackboard are actively used to engage students to socially construct their own ideas through social experiences shared during teaching and learning (Owusu-Mensah & Quan-Baffour, 2017). Assessment, communication, and uploading of teaching materials dominated mathematics lecturers' commentaries.

Assessment

The use of ICT for assessment, particularly submitting and capturing students' marks, appeared as a common theme in all lecturers' comments in this study. At times students are required to do their assignments on Sakai or Blackboard at a specified time, and if they fail to meet the deadline, the system shuts them out. After submitting the assignments, the system gives them instant feedback. The system provides model answers so they can see where they went wrong. These assessments assist students to prepare for mathematic tests and assignments.

The hallmark of education of the 21st century education is hinged on the use of ICT and the current trends are to use it in the assessment of learning outcomes (Okonkwo, 2010). Mathematics lecturers' comments indicated that technology is central to assessing students: Students can manipulate a pool of questions stored in the database and do self-assessment; after completing the questions, the system provides solutions to give the students an opportunity to analyse the problems and where they got lost. With the advent of ICT, knowledge is no longer sitting in one source but now it can be found everywhere where there is an Internet. Learning materials and resources are loaded on Sakai/Blackboard, including revision material and past examination papers for students to access them and do self-assessment.

Makonye (2017) claimed that he finds that ICT provides a better way to manage students' exercises and assignments and to check how often they engage with the learning materials stored in the system's database. Some lecturers were pessimistic about the use of ICT in assessment, as some students can abuse the system by allowing knowledgeable students to do the assessments on their behalf, which will then not give a true reflection of students' performance. However, if the system is used correctly, it can yield positive results. Ongoing assessment, when employed fruitfully, can improve students' results (Mpungose, 2017). Students get exposed to past examination question papers and can practice writing assessment exercises, revision exercises and tests. It is students' responsibility students use ICT to their advantage as it does not guarantee direct learning improvement (Owusu-Mensah & Quan-Baffour, 2017). The limitation of the Sakai and Blackboard platforms is that it only offers mathematics assessment questions that are in the form of true/False and multiple-choice. Generally, mathematics lecturers' use of Sakai/Blackboard in assessing the students is limited and tends to focus on structured exercises rather than a student-centred approach. Their concern in mathematics is that when open-ended questions are loaded on Sakai/Blackboard, the system cannot mark or provide instant feedback. This leaves the lecturers with no choice but to revert to traditional ways of teaching where all the steps and processes used in solving mathematical problems are shown. Current practices and the latest mathematics textbooks show worked mathematics problems being solved using the traditional way and computer-based programmes. Students put in the algorithm first and translate it to a programming code. Thus mathematics lecturers should respond to this change, and given the call by the South African government to harness ICT, it is inevitable that they should be seen using ICT in their teaching.

Communication

In addition to the assessment tools, the Sakai/Blackboard platforms can also be used for communication purposes. Mathematics lecturers use the email tool that allows them to send a message to site participants, or a section or group thereof, and also has a provision that provides a field to specify non-site participant email addresses. The email tool works using the sender's account details. Generally, the email address is the institution's email account. When composing a new message in the email tool, there is an option to select recipients in the course by role, section, or group. All the official university communication is sent from an institution's email address. Students, on the other hand, receive email messages through their university email account. This was confirmed by two mathematics lecturers who mentioned that they use the Sakai/Blackboard tool to reach the students quicker.

Pre-service teachers confirmed that they do use ICT platforms to communicate with their lecturers. Inherent to their commentaries was that they use the Sakai/Blackboard tool to communicate with their lecturers when submitting assignments and viewing their assignments or course results. They also mentioned that they use Sakai or Blackboard to access course outlines.

Uploading teaching and learning materials

Sakai or Blackboard is a web-based application system that provides an interactive interface between lectures and students at the university. In addition, it supports collaborative teaching and learning that is based on open sharing of knowledge. Through Sakai/Blackboard, students can view announcements from the lecturers, assignments, and grades. Sakai/Blackboard provides resources to both students and lecturers so that they have a full view of what is happening in their classes. Mathematics lecturers mentioned that they use these platforms to post teaching and learning materials, course outlines and other relevant materials. The information that could have been covered during lectures is also posted for students to access it. Most mathematics lecturers indicated that they use these systems mainly for administration purposes, rather than for teaching. Students that do not hand in their assignments or are frequently absent from the lectures can easily be identified on Sakai/Blackboard. On the other hand, students can submit their assignments and examinations electronically and their work can be downloaded and marked. Despite the functionalities like discussion forum, chatroom and podcast that Sakai/Blackboard offers, it was noted that most mathematics lecturers who participated in this study do not know how to use these functionalities.

The other aspect that mathematics lecturers were pleased about is that all assignments submitted through the Sakai/Blackboard platforms could be checked for plagiarism. This is to facilitate preserving academic integrity. The course lecturer creates a link where students will submit the assignments using a button called ‘Turnitin’. Turnitin is an Internet-based plagiarism detection service. It uses proprietary search technology to compare the textual similarities of students’ assignment submissions. Each submission is compared with vast numbers of web pages, journals, and student paper submissions. The submitted assignments are uploaded to generate a detailed report indicating the students’ original work percentage and sections of the document that are plagiarised.

7.3.5 Traditional Method of Teaching

Mathematics lecturers’ commentaries indicated that they were still entrenched in traditional modes of teaching. They did, however, acknowledge the use of ICT as a mediation tool in teaching mathematics but were quick to mention that their students are not ready to learn mathematics through the use of ICT. The reason they provided was that most of the ICT mathematics software and applications provide final solutions, skipping a lot of steps needed to reach a solution. The other possible reason is that most lecturers lack the confidence and skills to utilise the technology (Valtonen et al., 2018). The traditional way of teaching clearly shows all steps and the lecturer has the opportunity to work face-to-face with students, clarifying missed points. They added that the traditional method provides more interactivity between the lecturer and students, paving a way to get to know each other. Best performing and struggling students can be easily identified through traditional teaching and assistance can be offered immediately.

Mathematics lecturers concurred that contemporary education is characterised by techno-centric discourses of socioeconomic reform (McGarr & Gavaldon, 2018) where technology takes the centre stage as opposed to pedagogy. Teacher training institutions are expected to prepare pre-service teachers entering the profession to “fit into the expectation of societal needs” (p. 200). They mentioned that the current crops of pre-service teachers are digital natives who are expected to use technology as part of their teaching. For instance, they suggested that for these students to use ICT in teaching and learning, they first need to ground themselves with mathematics content knowledge. This will provide them with a clear idea of what they are looking for when using ICT in their future practice. There was a suggestion that hands-on learning is a better way of learning when compared to the theoretical aspect, which is too abstract and difficult to understand.

Pre-service teachers mentioned that their lectures contained limited information about the pedagogical uses of ICT. They emphasised that the teaching method at their schools of education is the same method they were taught at primary and secondary schools. Teaching is still dominated by chalkboards instead of smartboards. Furthermore, they mentioned that there had not been a clear emphasis on learning about ICT pedagogical affordances in the teaching of mathematics in their training programmes. They complained that their training programmes did not prepare them enough about harnessing ICT in the classroom. Some schools in which they have been deployed for teaching experience are equipped with interactive whiteboards/smartboards that they were not equipped to use in teaching. In some instances, students are provided with iPads and tablets to use, however, pre-service teachers struggled to use these facilities. The learners that they will teach in some schools are already taught using ICT, and they will be expected to teach using ICT when they qualify as teachers and their knowledge will have to be beyond what leaners need to know. They spoke of mathematical concepts that are quite abstract and suggested that incorporating ICT into their lectures may help them better understand the concepts. For instance, teaching transformation using GeoGebra provides images that can be easily interpreted when the function is explored. GeoGebra can enhance teaching and learning through its dynamic, interactive, and engaging content; and it can provide real opportunities for individualised instruction. ICT has the capability to accelerate, enrich, and deepen students' skills; to motivate and engage students in learning; to help relate school experiences to work practices; and to provide opportunities for connection between the school and the world (Yusuf, 2005). Overall, the participants indicated that ICT can complement teaching and learning processes, especially outside the traditional classroom environment. Lack of skills needed to make effective use of ICT tools limits their potential on students' learning.

The lack of proper communication from the policymakers in South Africa on how these ICT tools can be used is holding back ICT implementation. Individuals teach the way they see fit. They perceive that if students are well grounded with the content, it is easier for them to use ICT in learning. In thinking about how the teacher training programme works, the findings suggest that mathematics lecturers still teach using traditional methods and there is a need to prepare pre-service teachers to use ICT for their teaching practice. Pre-service teachers' commentaries indicated the view that the responsibility is on mathematics lecturers to ensure that they use ICT more often in their teaching practice. They mentioned the pervasive nature of ICT, which means it could be used to support learning.

7.4 Theme 3: Policy Documentation

Participants in this study emphasised that they have no policy guidelines either from the universities or from the government as to how ICT can be integrated into the teaching of mathematics. The ICT policies are only mentioned in meetings and educational conferences by colleagues who have seen the benefits of teaching using mathematics software. It is up to the individual to teach using ICT or not, depending on the knowledge he has about that mathematical software. But at the moment there is no strict policy that necessitates mathematics lecturers to use it. They expressed hope that in the future there would be a policy that could be used as a guide to integrating ICT in during lectures. They mentioned that it would be good if a policy is available because it will act as a law or framework that obliges mathematics lecturers to use ICT in their practice. Due to rapid technological expansions and changes in pedagogical paradigms, ICT policies are seen as the cornerstone for the full implementation of ICT in education (Eickelmann, 2018). Policies provide a holistic view as to why that particular instance should be included in the curriculum. Higher education institutions are aware that ICT is an important aspect of teaching, learning, and research. The authorities of these intuitions know the strategic role played by ICT and how they should be used to benefit the students to fit well in an information super-highway society (Khouja, Rodriguez, Halimab, & Moalla, 2018). The South African "White Paper on e-Education" only states that every South African educator and the learner will be ICT capable by the year 2013 (DoE, 2004), but it does not specify how this ICT capability can be achieved. In addition, MRTEQ (2015) policy emphasises the notion that all teachers who enter into the teaching programme are expected to be ICT competent; again, the policy is silent on how this competency can be achieved. The policies do not indicate how institutions of higher education should implement and monitor the integration of ICT to both pre-service and in-service teachers.

As a way to harness the potential of ICT, countries must have a national ICT policy that functions as a framework for ICT integration in education (Yusuf, 2005). South Africa is not an exception to this practice. According to Tairab and Ronghuai (2017), countries and regions like the USA, Europe, Asia, Tanzania, Kenya, and Egypt have ICT policies that are applied in educational integration (p. 73). There is a demand for higher institutions of education to have ICT tools that can be used in teaching. Nevertheless, for these tools to work effectively they need to be guided by policies and master plans that show the steps of the implementation process (Tairab & Ronghuai, 2017). The widespread use of smartphones, laptops, and tablets by South African students suggests that it is high time for the educational institutions to develop ICT policies and practices that harness these devices in teaching and learning.

7.5 Transformed Activity Theory (TAT) Model—A Template for Mathematics Lecturers' Adoption of ICT

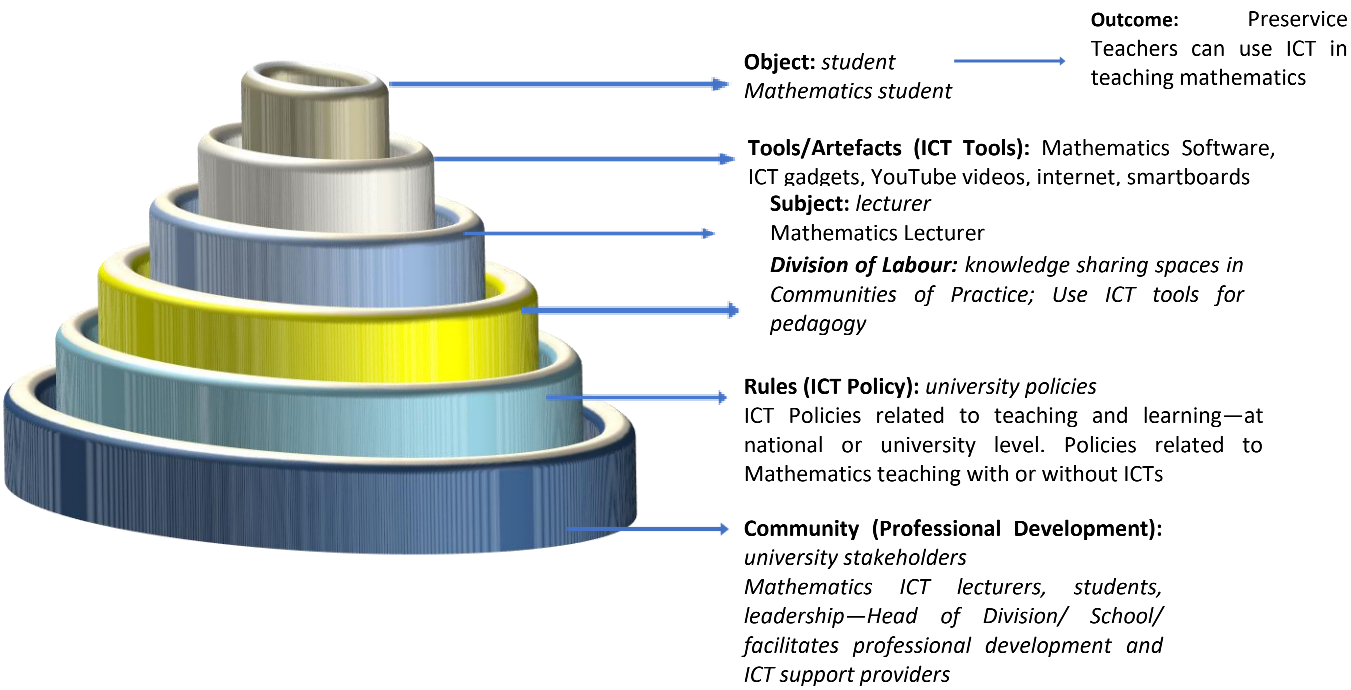
I hope that TAT will provide education mathematics lecturers with a model that they can use to appropriate ICT for pedagogical purposes and provide the curriculum designers in pre-service education an informed picture as to how to include ICT as part of pedagogy. In this chapter, findings drawn from both mathematics lecturers and pre-service teachers' data were used together with literature to explain TAT. TAT in this study is portrayed as a human-computer interaction tool used as a mediation to support collaborative learning by education mathematics lecturers. It borrowed the constructs that are found in Activity Theory (refer to Figure 6) and constructed in the disc that is placed on top of the other, that is, the lower disc supports the one on top and so on. Figure 24 shows the TAT with constructs as discs placed on top of another.

Integrating ICT requires mathematics lecturers to interact with each other in pursuit of new knowledge in their practice. It is this social gathering practice that links them in sharing new knowledge in relation to pedagogical ICT integration. TAT constructs unpack ways in which learning settings can be understood and influenced by aspects of the community, rules, and division of labour. Every community has rules, thus Issroff and Scanlon (2002) described Activity Theory as “a philosophical and cross-disciplinary framework for studying different forms of human practices” (p. 78) with a desire to develop one another through use of artifacts acting as mediating roles. An activity is a practice of doing focused on an object with the aim of transforming the object into an outcome, which could be a material thing or intangible, such as an idea (Issroff & Scanlon, 2002). Its central tenet is that human behaviour is situated within a social context that influences actions. Actions are mediated by the rules of the community and the division of labour within the community influences the ways in which we perform actions (Scanlon & Issroff, 2005). In the TAT model (Figure 24), mathematics lecturers are the major actors as they need to select appropriate ICT tools to be used in their lectures. They formulate mathematical problems and solve them either manually or using the software. Therefore, education mathematics lecturers possess the knowledge to select the software tools to be used in solving a particular problem. Whatever a human being wants to achieve, they should first consider the appropriate tools that can assist them to reach the goal set. Not all software can solve a particular mathematics problem.

TAT (which borrows the construct of Activity Theory, see Figure 24) is strongly situated in the context of teaching because it is interactive by nature. Activities are driven by the digital demands of the 21st century to prepare students to be critical thinkers, problem posers and solvers, and collaborators. Engestrom (1987) defined activity systems as “communities engaged in activities which share common goals” (p. 129). In conceptualising the TAT, the activity is initiated and implemented by education mathematics lecturers. First, they formulate mathematical problems with the intention to solve them. Then, they select the appropriate tool(s) to assist them to achieve the result. The tool is used to develop the relationships and can be either a material object or a tool for thinking (Issroff & Scanlon, 2002). This having been said, it must be remembered that ICT tools are appropriated in different contexts and used for different purposes and need to be continually upgraded and refined to meet the growing demands of the digital society. Therefore, to enable education mathematics lecturers to keep up to date with environmental change in the education sector, it is imperative to understand how to appropriate ICT in the teaching of mathematics rather than mastering it. This enables education mathematics lecturers to integrate relevant ICT software tools into their teaching practice, thereby responding to the needs of pre-service teachers who in turn will take advantage of the affordance of ICT tools in their future classrooms.

7.6 Detailed Constructs of Transformed Activity Theory (TAT) Model

Within TAT, it is proposed that mathematics education lecturers' and pre-service teachers' practices in teaching and learning using ICT for pedagogical purposes are constrained by community rules and the division of labour. The three main themes (professional development, pedagogical ICT tools, absence of ICT policies, refer to sections 7.2, 7.3 and 7.4 respectively) discussed earlier in this study were looked at to see how they influence the adoption of TAT in appropriating ICT in the teaching of mathematics. Mathematics education lecturers must not be focusing on the ICT gadget to solve the problem, but the mediating role it has in helping the pre-service teachers to understand and connect abstract mathematical concepts. The ICT gadget only becomes the focus of attention when operating it is a problem. Figure 24 provides a wider context overview of the TAT constructs together with mediation elements.



The proposition that underpins the TAT is that when the six elements (community, rules, tools/artifacts, subjects, division of labour and objects) come together within a mathematics teacher education programme, they likely contribute to preparing pre-service teachers who are grounded with ICT knowledge for pedagogical purposes and use the ICT affordances to support teaching and learning practices.

Professional development concerns are addressed by the subject constructs where mathematics lecturers and their HoD organise training workshops with service providers to upgrade the skills needed to integrate ICT. The training includes the software that mathematics teachers need to know such as MS Excel and other mathematics applications such as GeoGebra, Statistica, Maxima etc. Community defines university stakeholders, mathematics education lecturers, students, leadership, such as Head of Division/School/Faculty/administrators, and ICT support providers. These provide enablers or infrastructure needed by lecturers when teaching in the classroom. Rules define the ICT frameworks that guide the application of ICT in preparing pre-service teachers during their training. Division of labour facilitates the interaction of mathematics lecturers in sharing knowledge about the use of particular software in solving mathematical problems. The lecturers can identify lecturers who are experts among themselves in certain ICT skills and assign them to teach using that knowledge space. The object outcome is the ultimate result that lecturers are preparing for: lecturers are expected to produce pre-service teachers that will be ready to integrate ICT in their future classes.

The concentric rings are placed on each other from small to big showing relationships within the activity system and how they support each other. The three themes identified in this study are derived from mathematics education lecturers' and pre-service teachers' comments on what they would like to see for the successful integration of ICT in the teaching of mathematics. The major components they would like to see for future implementation of ICT are professional development, pedagogic ICT tools and policy documentation (refer to Section 7.2, 7.3 and 7.4). Here, these are viewed as mediational means that will contribute to the appropriation and integration of ICT into teaching practices when they are present in pre-service teacher programmes.

Table 19 show how the TAT model for ICT works in a hierarchical structure.

Table 19: Role of construct in TAT model

Constructs	Roles or responsibilities
Community • Teacher training institution Mathematics ICT	University stakeholders provide support needed by lecturers in the lectures.
Rules • Framework and ICT service providers	The teacher training institutions play a bigger role by providing lecturers with tools such as syllabus, curriculum, and policies and the needed infrastructure.
Tools/Artefacts • Mathematics application software • ICT multimedia	Mathematics education lecturers identify tools that can be used to aid teaching. They may use human-interaction mediating artefacts to complement learning.
Division of Labour • Communities of practice • Mathematics HoDs and lecturers	The university departments provide mathematics HoDs and mathematics lecturers with platforms for sharing ideas in order to meet the emerging ICT

	trends.
Subjects • Mathematics education lecturers Education mathematics HoDs	Mathematics education lecturers organise training to upgrade their current skills. Mathematics HoD works on the content to be covered.
Object Outcome • New ideas acquired and used for future practice	Produce ICT competent students who can proficiently demonstrate the use of digital technology in the teaching of mathematics.

Professional development

ICT is here to stay and plays an important role in enhancing teaching and learning in teacher training settings. Mathematics education lecturers play a leading role in supporting students on how to pedagogically use ICT in teaching and learning. A major aspect of TAT is that effective ICT integration requires that mathematics education lecturers be equipped with adequate knowledge and competence to make an appropriate selection of relevant software for use in the teaching of mathematics. Mathematic lecturers are seen as significant actors that trigger or motivate interaction with the rest of the activity system. For example, they pose mathematics problems to the pre-service teachers who are expected to use the appropriate software available to solve the problem. Furthermore, both the mathematics lecturers and pre-service teachers are engaged in different activities guided by some rules towards resolving the problem. Consequently, the pre-service teachers are given the opportunity to explore and interact with the software, thereby developing confidence and competence to use the software in their future practice. Research from the report of NCTM (2000) stated that "if teachers are to learn how to create a positive environment that promotes collaborative problem-solving, incorporates technology in a meaningful way, invites intellectual exploration, and supports student thinking, they must experience learning in such an environment" (p. 24). Departments of mathematics education in South African universities should endeavour to craft programmes within their schools that ensure mathematics education lecturers and pre-service teachers have opportunities to acquire the knowledge and experiences needed to use mathematics software in the context of teaching and learning.

Regular professional development empowers mathematics lecturers to improve their practice in the use of ICT and make informed decisions in the choice of suitable software. I found this representation useful for considering the interaction between the subject and tools. The top triangle was used to depict the activity system structured for professional development within which the selection of tools that solve particular problem is discussed with the aim of disseminating information and supporting the adoption practices (Venkat & Adler, 2008); the upside-down triangle was used to represent the interaction between subject and object mediated by the teacher training institution as a setup with the aim of transforming (processing) the object (student ideas) to adopt ICT in their future practices (refer to Figure 7). Put it in another way, the integration of ICT in the teaching of mathematics should be part of on-campus courses and practiced during teaching experiences (Li, Guy, Baker, & Holen, 2006). The interaction among the constructs ensures that the goal is achieved.

Pedagogic ICT tools

Tools in the TAT include any implements that are used to mediate the activity, while community rules guide and limit the activity (Rouleau, 2017). The community in this study is people, who comprise the social context in which the subject belongs (teacher training institutions, education mathematics lecturers and pre-service teachers). Within TAT the concept of the tool is premised on Vygotsky's (1978) perception that tools play a role in learning. This view is propelled further by Fisher, Denning, Higgins, and Loveless (2012) who viewed emerging technologies as "complex set of cultural tools or 'mediational means'" (p. 311) with the hope to provide affordances or assisting 'subjects' (education mathematics lecturers and pre-service teachers) to engage in goal-oriented activities with regards to learning. The affordances these tools provide depend upon what education mathematics lecturers see as a desirable tool to achieve the goals. In other words, what new ideas (object of activity) do they want to impart to pre-service teachers together with the inherent potentials perceived in the technologies as tools to achieve those objects. Examples of tools used frequently in this study include data projectors and PowerPoint slides, YouTube videos, Internet and Sakai/Blackboard. Pre-service teachers mentioned a similar set of tools; however, few mentioned that they use mathematics software such as GeoGebra and MATHEMATICA to do their assignments. The idea that pre-service mathematics teachers use some software to do their assignments sends a strong message to their lecturers that there is a need to include ICT in their teaching within the settings. Pre-service teachers certainly demonstrated serious zeal and understanding of the affordances provided by the ICT tools that could be integrated into their learning practices. Their community (teacher training institutions, education mathematics lecturers and pre-service teachers) appears to be limiting them towards the extensive exploration of ICT within their studies. This suggests, therefore, that successful ICT implementation in the teaching of mathematics should begin at teacher training institutions which in turn will plant a growing tree among pre-service teachers.

Conole and Dyke (2004) argued that digital technologies contribute to activities such as capacitating, interactivity, accuracy and credibility in helping the practitioners to make an informed decision about how they might use digital technologies in teaching. It is therefore important to consider the affordances of digital technologies in contexts of use in order to gain greater insight into how these tools support purposeful learning activities within learning environments. Being ICT capable means understanding and having valuable knowledge in the use of digital technology in dealing with information. Put differently, it means having intelligence about ICT tools that can be used to perform a task or a source of power for making a choice in selecting tools used to achieve the directed goal. Mathematical applications (apps) are sprouting every day and are becoming commonplace in educational settings (Larkin & Milford, 2018). Despite their increase and availability, their use is limited in the educational setup because of a lack of skills and knowledge among education mathematics lecturers in supporting and choosing the correct applications in their pedagogical decisions regarding. There is a need to train education mathematics lecturers to uplift their ICT skills so that there is homogeneity among the use of ICT mathematics apps and other mathematical software, thus providing education mathematics lecturers opportunities to make decisions regarding which apps might be most appropriate for a given topic or concept to enhance pre-service teachers' mathematical learning and ultimately their future practice.

It was noted that education mathematics lecturers displayed knowledge of their content. This is required as Shulman (1987) mentioned that knowledge is a requirement in teaching practice. His pedagogical content knowledge is an exclusive form of knowledge for teaching and the blending of content and pedagogical knowledge allows education mathematics lecturers to support learning. Later Mishra and Koehler (2006) adapted Shulman's work by including technological knowledge. They postulated that the expertise of teachers (education mathematics lecturers in this study) involves the blending of technological knowledge, pedagogical knowledge, and content knowledge, which they called technological pedagogical content knowledge. Education mathematics lecturers' data revealed that they lack the 'know-how' to ICT use in teaching mathematics. It is evident in their comments that technological knowledge would allow them to conduct their teaching practice with more ease, especially with the use of Sakai/Blackboard (Section 5.3.1). The pedagogical content knowledge the education mathematics lecturers described included how ICT could be used for mathematics activities. The pre-service teachers expressed what they would like to learn about ICT for pedagogical purposes and explore the affordances and potentials of various ICT software tools in supporting their pedagogy (Section 6.6).

Policy document

TAT contends that the subject (in this case education mathematics lecturers and pre-service teachers) is influenced by the type of tool (software), which has an impact on the object (outcome). The influence of the tools was evident in both education mathematics lecturers' and pre-service teachers' descriptions of ICT integration. Though there is enthusiasm about the use of ICT, education mathematics lecturers explicitly indicated that they are not confined by an educational policy that spells out the integration of ICT in teaching. For the successful integration of ICT, a policy (ICT policy) should be in place to serve as a framework for ICT integration in educational settings (Yusuf, 2005). Shiohira, Keevy, and Gibbs (2018) highlighted that South Africa championed the integration of ICT into education in sub-Saharan Africa; however, there is no audit report to support it. They also cited Wallet (2015), who mentioned that South Africa was among the first to formally integrate ICT into its national curriculum. However, this idea contrasts with Kafyulilo et al. (2015) who indicated that ICT in South Africa is mainly taught as a subject instead of being integrated as a pedagogical tool for teaching and learning in subject areas. The South African Presidential Advisory Council on Information Society and Development identified education as one of three priority areas for developing ICT, together with health and small, medium and micro-enterprises. The National Integrated ICT Policy White Paper developed the initial framework to support the National Development Plan in actualising the perceived role of ICT in education by 2030 (Department of Telecommunications and Postal Services, 2016). Despite how good these policies look on paper, it appears that the universities selected for this study are unaware of these policies (Section 5.5). The demands placed on the teachers (such as being able to use tablets, interactive whiteboards, integrating ICT in teaching) are changing; yet the type of education received from teacher training has remained relatively static. The system of education is still characterised by the traditional model of education.

ICT has the potential to improve learner achievement in a subject like mathematics. According to Umalusi (the Quality Council for General and Further Education and Training that oversees the National Senior Certificate), mathematics is the most problematic subject for learners in South Africa (Shiohira et al., 2018). This problem affects the education mathematics lecturers who prepare mathematics teachers. Education mathematics lecturers have the biggest influence on what pre-service teachers are learning. An ICT-based approach in teacher education is anticipated to have all set of the solution in place that acts as enablers, including the framework that specifies teacher professional development, adequate infrastructure (including appropriate tools) and CoP.

Pre-service teachers' comments indicated they wanted an education that integrated ICT in their teacher education programme so that they could develop skills and knowledge in that space. Furthermore, they indicated that they would like to practically explore the pedagogical uses of ICT while they are still in their teacher training programme. It is worthwhile to note that students feel there is a vacuum when it comes to the pedagogical usage of ICT within their training programme. There is a belief (though debatable) that once they graduate and become practicing teachers, they will not have enough time to learn new concepts; a trend also displayed by their mathematics lecturers. Education mathematics lecturers' data revealed that they try to learn ICT on their own (on the job) within an already overcrowded working environment because during their training there was no ICT (see Section 5.4).

7.7 Conclusion

The chapter merged the findings that were identified in Chapters 5 and 6. Notably was that mathematics education lecturers use ICT more often as an administrative tool to handle their teaching materials. In some instances, ICT is used as a mediating tool to reinforce the concepts taught using traditional methods. Findings from the students concur with the findings from mathematics education lecturers, namely that their lecturers do not teach them using ICT. Hence, the first research question was addressed as both mathematics education lecturers and their students confirmed that teaching was still done the traditional way. It was not evident in the findings that they teach mathematics using ICT; however, pre-service teachers indicated some knowledge in using ICT to solve mathematical problems.

The second research question addressed in this chapter looked at the support mathematics lecturers need to adequately prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom. It was noted that mathematics lecturers mentioned that there is a lack of support both from the departments and schools of education to uplift their ICT competency skills to meet the demands of the 21st century classroom. Hence, the students are not getting support from their lecturers on how to integrate ICT in the teaching of mathematics because their lecturers are not capacitated to meet the needs of the Net Generation students. Thus, the lack of support to learn skills on how to use ICT in the teaching of mathematics is currently a barrier to the implementation of ICT in the classrooms.

The third research question was also addressed in this chapter, and it required a confirmation from the pre-service teachers that they are being prepared to meet the demands of the 21st century classroom. The findings from pre-service teachers indicate that the mathematics lessons are conducted in the traditional way. ICT is used to submit assignments and to do research on the Internet. This will prevent the pre-service teachers to take the 21st century with them into their future classrooms. Teachers teach as they were taught (International Society for Technology in Education, 1999, in Bowers et al., 1994). For the pre-service teachers to adopt ICT in the classroom, they need to learn the appropriate skills and knowledge from their teacher training programmes (Agyei & Voogt, 2011; Tondeur et al., 2012).

TAT provides an opportunity that education mathematics lecturers should strive to use in order to achieve the desired outcome. Pedagogy utilises the affordances available within the TAT. The model empowers mathematics education lecturers to carefully consider the tools they need to enhance their teaching. The data in this study revealed that ICT provides affordance in teaching and further exposes pre-service teachers to explore and learn how to appropriate ICT into their teaching practice. However, mathematics education lecturers are adamant that they need some form of training so that they can effectively use ICT in their teaching. TAT was considered in this study because integrating ICT involves a lot of activity, hands-on experience and connectivity. Lecturers need the skill to select tools that will enhance learning for their lectures.

7.8 Chapter Summary

TAT was developed to support the appropriation of ICT in the teaching of mathematics during pre-service teacher training programmes for pedagogical purposes. Lack of ICT skills and knowledge in teaching and learning dominated both mathematics lecturers' and pre-service teachers' commentaries. Much of the mathematics lecturers' data revealed that the available mathematics software were not clearly explained to them and that they did not know how to use the software for pedagogical purposes and to engage students in creative and critical thinking. In addition, they believe that the use of mathematics software will skip critical steps in solving mathematical problems. Both mathematics lecturers and pre-service teachers' comments revealed an appreciation and understanding of ICT affordances in teaching and learning; however, schools of education are doing little to ensure that ICT tools are used for pedagogical purposes. The findings also highlighted the need to ensure that there should be workshops for mathematics lecturers to cement their knowledge on the use of software to appropriate and integrate it into teaching practice.

All three themes, that is professional development, pedagogic ICT tools, and ICT policy documents are relevant to the adoption and appropriating of ICT in teaching practice. The lack of ICT tools usage in lectures featured prominently in pre-service teachers' comments. The pre-service teachers expressed concern about the challenges they will meet when going for teaching experience. Their argument was based on the notion of 'what they would have been taught' in their teacher training programme, such as the use of interactive whiteboards or smartboards. It appeared that their training programme was not adequately equipping them to use such devices.

Mathematical software learning tools to support teaching were present in the pre-service teachers' data. This indicated that pre-service teachers were aware of the technological developments that can be used in education because of increased ICT awareness in our everyday lives. On the mathematics lecturers' side, the time came out strongly as a limiting factor in the implementation of ICT in teaching. They mentioned that teaching with ICT needs a lot of time that they do not have. Although these three themes featured more predominantly in some data than others, it all played a pivotal role in the understanding of how the mathematics lecturers view these themes in the use of ICT in their teaching practice. The availability of digital computational tools in mathematics education raises awareness among mathematics education lecturers of the need to change their teaching methods to include the material resources available and to adapt to the existing ecological space that favours 21st century tools.

CHAPTER 8: CONCLUSION AND IMPLICATIONS

8.1 Introduction

This study was particularly concerned with how mathematics education lecturers in schools of education prepare pre-service teachers to integrate ICT for pedagogical purposes. The study was premised on the assumption that there is a policy that provides guidance on how ICT tools can be used effectively in the teaching of mathematics. This chapter provides an overview of the study. Firstly the chapter reflects on the objectives of the study, it then moves on to summarise the findings, and eventually sets out the study's contribution to understanding how mathematics education lecturers prepare pre-service teachers to support, appropriate and integrate ICT for pedagogical purposes. The limitations of the study, the implications of the research for pre-service teacher education, mathematics education lecturers, pre-service teachers, and policymakers are discussed, and suggestions for further research made.

8.2 Reflection on the Study

The study explored mathematics education lecturers and pre-service views about their use of ICT in the teaching and learning of mathematics and what they think should be done to fully appropriate and integrate ICT in their future practices. The intention was to gain insight into how they use Microsoft Excel and ever-evolving mathematics application software in the teaching of mathematics. The results obtained were used to develop a model that can be adopted by education mathematics lecturers to foster the effective integration of ICT in teaching. Lack of scientific evidence in the integration of ICT in preparing mathematics pre-service teachers triggered the need to investigate their ICT knowledge space and professional development. There is a lot of literature evidence about ICT integration in schools, but very little, if not none, look at education mathematics lecturers' methods of appropriating ICT in their teaching. In addition, there is evidence of unorganised and unsystematic policies that attempt to harness ICT in teaching.

The study was purely qualitative and used the interpretive paradigm to investigate the participants' experiences with integrating ICT in teaching in their natural settings. The interpretive paradigm focuses on how people construct meaning in their own local context without manipulating their setting. In the interpretive paradigm, the researcher seeks to understand the participants' experiences by interacting with them through processes that allow participants to express their views, knowledge, and motivations. Individual interviews with mathematics education lecturers and pre-service teachers and analysis of their comments provided the knowledge and skill level they have in using ICT. Thematic analysis was used to identify patterns that came from the data. The use of literature and models helped to pick three main themes that affect pedagogic ICT integration within Schools of Education in South Africa. The main themes were pedagogic ICT tools, professional development, and the absence of ICT policy documents.

The focus of the research was to understand how mathematics education lecturers in the schools of education prepare teachers to integrate ICT in the teaching of mathematics. The findings found that both mathematics education lecturers and pre-service teachers are keen to use ICT in teaching and learning. The findings further provided evidence that pre-service teachers are knowledgeable in the use of mathematics software as a tool to solve some problems. However, mathematics education lecturers' ICT knowledge varied. Some indicated that they refer pre-service teachers to the Internet and provide YouTube videos links to supplement what they learned during lectures. Use of Sakai/Blackboard featured strongly among mathematics education lecturers who indicated that they use it for administrative purposes and seldom for pedagogical purposes. They all valued the use of ICT in teaching; however, they are limited by their skills and knowledge. The study found that both education mathematics lecturers and pre-service teachers appear to have knowledge of ICT affordances but lack hands-on skills connected to practicum. It was further noted that teaching using ICT is individualised. In the South African context, there are limited policy documents that enforce the use of ICT in teaching mathematics. Pre-service teachers' use of ICT was not connected to their day-to-day teaching and learning experiences or to their teacher training programme. They indicated that learning to use ICT during teacher training was central as it empowers them to use ICT for teaching and learning purposes.

I used TAT to encourage education mathematics lecturers to adopt and appropriate ICT in the teaching of mathematics. The five constructs in TAT (objects, tools, community and rules, knowledge sharing space, and object outcome) were explored in this study in order to give education mathematics lecturers deeper insight to use when drawing up mathematics syllabi that harness and adopt ICT within teacher training programmes. Because education mathematics lecturers plan the content to be covered by pre-service teachers. the TAT model places mathematics education lecturers as the foundation and core determinants of what should be taught (refer to Figure 25). The second concentric ring indicates ICT tools that can be used in the teaching of the topics to be covered; the tools could consist of mathematics application software, Microsoft Excel, YouTube videos, PowerPoint presentations, just to name a few. The third concentric ring shows the community and the rules (teacher training institutions, policy or framework) that determine to what extent ICT can be used in the teaching of mathematics. The knowledge sharing space concentric ring shows how education mathematics lecturers interact to solve a complex math problem that can include, among other things, training and forming CoPs. TAT provides an analytical tool to help education mathematics lecturers with ways to adopt and integrate ICT into their teaching practice. Lastly, the object or outcome is to transform the pre-service teacher by acquiring new knowledge or ideas in ICT pedagogical practices. It is important to not that TAT in this study was used to bridge the gap that exists in terms of ICT usage in the lecture room within South African teacher training programmes.

The objective of the study was to explore the level of ICT competency among education mathematics lecturers and their readiness to integrate ICT in their classrooms to prepare pre-service teachers for the contemporary classroom, and to use the data gathered to develop a generic ICT model that can be appropriated in the mathematics curricula. The evidence obtained indicated that education mathematics lecturers are not well prepared to use ICT in their teaching because of their limited knowledge of ICT space and professional development. Therefore, there is a need for a model that will guide mathematics education lecturers to come up with effective ICT integration programmes. It was further established that education mathematics lecturers are aware of ICT tools that can be used in the teaching of mathematics to assist in enhancing pre-service teachers to solve some complex mathematical concepts. Consequently, it will be easy to identify ICT tools to be used for specific concepts. However, they have struggled to use this ever-evolving mathematics application software. Another reason for not effectively integrating ICT in their teaching is that currently there is no policy document that compels them to harness ICT in their teaching; integrating ICT is an optional, individual choice. The "White Paper on e-Education" proposed that every South African educator and the learner will be ICT capable by the year 2013 (DoE, 2004) is obsolete and right now (2019) there is no evidence of a revised version. The DHET (2013) and the South African Revised Policy on the MRTEQ (2015) recognised ICT as a fundamental learning area that all graduating South African teachers are required to be competent in, but never state how these graduates should learn how to use ICT during their training. The DHET (2013) stated the need for new generation of teachers coming from higher educational institutions with knowledge to "integrate and use ICT in their (subject) teaching in schools" (p. 17). There is a need to do away with recommendations that lecturers integrate ICT in their subject method course (Jita, 2016) without defining the stipulations of the type of ICT needed in the programme. Thus, the Schools of Education in South Africa needs to come up with adaptable ICT models that are effective for teaching mathematics using ICT (Dlamini & Mbatha, 2018). Furthermore, teaching practice is regarded as a useful platform to provide a training ground for pre-service teachers to build their confidence and competence in the use of ICT.

Response to the findings

The study responds to the research questions as follows:

1. How do mathematics lecturers prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

Mathematics education lecturer indicated that they are operating at the lowest level of integrating ICT in teaching and learning. They still use the traditional method of teaching that is characterised by the use of chalkboards and textbooks. On a few occasions, they refer students to websites where they can find related information to enhance their understanding.

2. What ICT tools does mathematics lecturers need to adequately prepare pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

There is a lack of knowledge on how to use the available mathematical software in teaching and learning. The schools of education in South African universities appear not to be providing sufficient support to mathematics education lecturers to keep up with the potentials that teaching mathematics with ICT have. They mentioned that currently there are no policies that oblige them to integrate ICT when teaching mathematics and neither is there a mechanism in place that can assist them to learn on how to use some mathematical software in teaching.

3. To what extent are the pre-service teachers being prepared to meet the demands of the 21st century classroom?

Mathematics pre-service teachers stated clearly that there is limited use of ICT pedagogical integration during their learning. They emphasised that they were never taught how to teach mathematics using technology. The use of ICT in teaching mathematics is an individual skill. Mathematics lecturers use the existing learning management tools (Sakai/Blackboard) for administrative purposes to upload mathematics lecture notes and communications.

4. What ICT pedagogical model/structure is suitable for preparing pre-service teachers to integrate ICT to meet the demands of the 21st century classroom?

Although the educational policies from the Department of Higher Education are in place, there is absolutely nothing that spells out how ICT should be integrated in the teaching and learning of mathematics. The policy tends to be aligned with the theory failing to provide guidance to mathematics education lecturers on how they should integrate potentials that are offered by ICT in the lecture room. The TAT model was developed in an attempt to guide mathematics education lecturers in preparing their students for ICT pedagogical purposes. The model provides the opportunity for mathematics education lecturers to model and explain the concepts and to use ICT tools to enhance the concepts that seem abstract.

5. To what extent are mathematics education lecturers preparing pre-service teachers for pedagogical ICT integration in Initial Teacher Education in South African universities?

The most notable finding from the context of my study is the lack of professional development which is a notable determiner that makes ICT pedagogical integration so low among mathematics lecturers, which again results in low digital competence in the South African population. The other findings that are major setbacks to ICT integration are limited ICT knowledge spaces and lack of clear ICT policy in education. However, the successful implementation of the component of pedagogy requires the facilitators to be proficient in the ICT space. Furthermore, the ICT policies cited in the study say very little about ICT integration in the teaching of mathematics in South Africa. Therefore, in an attempt to speed up ICT integration in the teaching of mathematics, a TAT model was developed to empower mathematics lecturers with the necessary ICT skills.

Considering that integrating ICT in the teaching of mathematics requires hands-on experiences and knowledge of ICT tools, the main question was, "What kind of fitting model can mathematics education lecturers use in facilitating the adoption of ICT integration for pedagogical purposes?" The Activity Theory was revisited and customised to come up with the TAT model that provides education mathematics lecturers with possibilities to harness ICT in their teaching practice. The TAT is interactive by nature (see Figure 24), thus fitting very well with the integration of ICT which is a hands-on activity during teaching and learning.

8.3 Contributions of this Study

My study contributes to current knowledge in four ways. Firstly, I establish the digital competency skills of education in mathematics lecturers. Secondly, I identify the barriers education lecturers encounter when using ICT. Thirdly, I looked at the ICT competence for fourth year B.Ed. pre-service teachers. Finally, I developed a model/structure of learning ICT to capacitate mathematics lecturers to be digitally competent. The relationship among the constructs within the TAT model provides what the education lecturers consider significant in integrating ICT in teaching.

The results from the study indicated that mathematics education lecturers need some form of capacitation to improve their skills and knowledge in order to adopt and appropriate ICT into their pedagogical practices. Universities, through liaising with mathematics department divisions, may provide the needed support that mathematics lecturers are looking for so that they meet the demands of the 21st century classroom. The findings indicated the need for a structure or model that can be followed when there is a need to teach using ICT. The model includes mathematics ICT policy, which spells out the information and materials that are needed when teaching particular content in mathematics. In addition, the model provides the lines of communication for efficient and effective integration of ICT. The framework includes the components that facilitate professional development and knowledge sharing spaces to support the holistic approach of teaching using ICT. Activity Theory was customised and tailored to develop a new model called TAT, which was adopted to help and support education mathematics lecturers understand how ICT can be used in the teaching of mathematics. TAT is based on themes drawn from the data generated in this study. It takes into account the interactability and connectivity of the constructs of the theory leading to objective outcome through:

- The education mathematics lecturers' personal experiences and what they need in relation to the use of ICT for pedagogical purposes in teaching.
- ICT integration in teaching settings needs continuous learning or establishing learning communities where people of similar interests gather together to share their expertise.
- South African ICT policy serves as a foundation for ICT pedagogical practices, detailing and specifying mathematics software that can be included in the teaching of mathematics to pre-service teachers.
- For successful ICT integration in schools, particularly in the teaching of mathematics, the programme should start at teacher training institutions. Pre-service teachers will then be assessed during their course programme and during practicum. This practice empowers them to implement the learned concepts in their future practices. When these pre-service teachers leave the universities as professionals, it is hoped that they will teach their future learners in their prospective schools the correct methods of

pedagogically integrating ICT in the teaching of mathematics, resulting in a more ICT skilled and competent learners.

8.4 Implications for Policy Makers and ICT Service Providers

While universities encourage ICT integration in their policies, it is evident that many lecturers are silent on the use of ICT during class sessions and teaching practice. There are so many theoretical models that relate to ICT uptake in education; however, they do not assess how education university mathematics lecturers appropriate and use ICT for pedagogical purposes. Jita (2016) observed that “there are few empirical studies that have focused on the problem of the integration of ICT in teacher education and even fewer that specifically focus on such integration of ICT during teaching practice, in particular” (p. 17), and very few that focused on integration of ICT in the teaching of mathematics during on-campus learning, in particular. Many mathematics education lecturers are facing challenges on what mathematics software to use in teaching because of a lack of knowledge and skills. It seems they are struggling to use ICT in their lectures to transmit the knowledge that pre-service teachers are expected to have when teaching using ICT. It appears that South African universities are producing teachers that are not confident in using ICT for pedagogical purposes (Kerckaert et al., 2015).

With the use of TAT, education mathematics lecturers may identify the tools or software that are required for teaching a particular concept in time through interaction with the policy requirements. If there is a challenge in using some software, education mathematics departments can arrange for staff development workshops in advance before the topic is taught. In addition, the division of labour lecturers who are knowledgeable with the software can demonstrate to others how to use the software in teaching. This professional development can provide pre-service teachers with a productive opportunity to explore the use of ICT for pedagogical practices. On the other hand, ICT service providers could be invited by mathematics departments within schools of education to train the staff on the use of their products in teaching with the aim of embedding ICT for pedagogical practices. Basically, the possibilities of using ICT should start in lecture rooms where teaching takes place. As pre-service teachers explore various mathematics software tools, they can discover the most suitable tools that can be used for teaching and learning purposes. Consequently, ICT can provide mathematics education lecturers with the opportunities for selecting a wide range of products that pre-service teachers can use in their learning and during practicum. In addition, the TAT provides a coherent interactive and connected frame for education mathematics lecturers to address the aspects that need to be attended to in order to add value to pre-service teachers' appropriation and integration of ICT for pedagogical purposes.

As discussed in the study, evidence shows that a number of lecturers indicated a lack of awareness of ICT policy in the teaching of mathematics, thereby making the use of ICT in the teaching of mathematics volitional. Therefore, ICT policies should be clear and precise on how ICT should be integrated into teaching and learning. Hence, there is the need for continued review and strengthening of policies to align with current environmental trends in education and the country's economy at large. However, it is imperative to note that several of the software manufactured and marketed by various ICT service providers have failed to meet the needs of the 21st century teaching and learning requirements. There seems to be no synergy between the educational mathematics software produced by ICT service providers and the teacher education mathematics curriculum used for pre-service teacher training in teacher training institutions. For both education mathematics lecturers and pre-service teachers, the suggestion from the findings implied that the potential of ICT in supporting teaching and learning could be a stronger focus in teacher training programmes. Consequently, ICT programmes offered at teacher training programmes need to shift from ICT literate skill-based to more of a pedagogical approach. Basically, the contemporary Net Generation already has the skills to use ICT, the vacuum they have is the effective use of ICT in learning. Thus, mathematics education lecturers are needed to guide pre-service teachers towards the successful integration of ICT in their learning and teaching.

8.5 Limitation of the Study

One major limitation that was perceived in the study was that the sample was small and was based in one province of South Africa. Information that was provided does not guarantee generalisations to the fact that ICT integration in pre-service education is low across the breadth and width of the country. Only 12 mathematics lecturers were interviewed and so the generalisability of the findings is limited to the nature of their settings since the research was a case study.

The other limitation is that the study was conducted in one department (department of mathematics). In addition, the study had no lesson observations to confirm that indeed there is limited use of ICT for pedagogical purposes. Fourth year pre-service teachers majoring in mathematics at FET level were part of the study leaving out non-fourth year pre-service teachers. These pre-service teachers believed that learning integration of ICT is influenced by mathematics education lecturers.

8.6 Recommendations

The policymakers should engage ICT service providers who seem to be developing mathematics software for pedagogical use. Policymakers should make it clear to ICT service providers what content their product should cover and should make arrangements to train the implementers thereof. There is a need for a collective collaboration and communication among education stakeholders (Department of Basic Education, Department of Higher Education and Technology, curriculum planners, teacher education personnel, and ICT service providers) to play a significant role in developing and informing mathematics education lecturers with the ICT aspects pre-service teachers need to be competent in. The study revealed the need for training whenever a new product is launched within teaching practice; otherwise, its potentials will go unnoticed by education stakeholders. There is also the need for a technical support team that will deal with technical problems that arise during lectures. Just like in private sector organisations, there is a need for trained and knowledgeable technical personnel whose job it is to provide assistance and keep the ICT systems running so that the rest of the organisation can make the most effective use of these ICT resources. The help desk should be operational throughout the day to avoid frustrations that mathematics education lecturers may face when the technology devices malfunctions. This study needs to be extended to other departments within teaching programmes in order to determine the level at which ICT integration is implemented for pedagogical use. This will help policymakers to develop a generic ICT framework that could be used across all subject disciplines.

8.7 Conclusion

TAT was developed to help mathematics education lecturers to plan the use of ICT integration in their lectures. TAT provides an interactive framework for mathematics education lecturers to use in the designing of their teaching programmes, which in turn will help pre-service teachers to integrate ICT into their teaching practice in a meaningful way. According to Ertmer and Ottenbreit-Leftwich (2010), some sectors of government have begun to yield the results of using ICT. One example is the police, where ICT is used to detect speeding cars or determine the validity of a driver’s licence or the number of outstanding tickets issued. However, it appears in education that ICT has not been utilised for the benefit of learners and there seems to be tension among stakeholders on how ICT can be used for pedagogical purposes. In answering the main research question for this study, it was found that there is no systematic way of integrating ICT in the teaching of mathematics for pedagogical purposes. Unfortunately, the ICT policies in place are not clear on how ICT integration should be achieved for pedagogy practices. Contemporary learning is no longer residing on human appliances; however, it may reside in non-human appliances (Siemens, 2014). This means human beings can acquire knowledge as they interact with technology.

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Appendix I: Interview Schedule for Mathematics Head of Department (HoD) Lecturers

1. What is your understanding of pedagogical ICT integration in the lecture room?
2. As the mathematics HoD, do you pedagogically integrate ICT in your teaching? If yes, How often?
3. Is it a mandatory for you to include ICT tools during your teaching of mathematics?
4. Conceptual concerns ("What are mathematics teacher educators' perspectives on ICT as a pedagogical tool? What types of skills are required by the mathematics teacher educators during the pedagogical integration of ICTs?")
5. Pedagogical concerns ("How are ICT used for teaching and learning? What are the best practices for improving quality in the context of pedagogical integration of ICTs?")
6. Are you supporting your teachers by workshopping them on how to integrate ICT in the teaching of mathematics?
7. As the HoD, do you foresee any value of integrating ICT in the teaching of mathematics in this era?
8. In your opinion, what could be the reason why mathematics teacher educators are facing challenges in integrating ICT?
9. Affective concerns (What are ICTs perceptions by teacher educators? What are mathematics teacher educators' attitudes on ICT? What are the main barriers of ICT to the successful pedagogical integration of ICTs in the teaching of mathematics at your university?)
10. Professional Development concerns ("What are the professional development needs of mathematics teacher educators that would support adoption, appropriation and implementation in the lecture room? What factors influence the effectiveness of ICT training for mathematics teacher educators?")

11. Logistical concerns ("To what extent is your institution equipped with ICT infrastructure?")

12. Organisational concerns ("How do your university lecture rooms to support the use of ICT integration in the teaching of mathematics? How can ICT be used as part of what we already do in the lecture rooms?")

Appendix II: Interview Schedule for Education Mathematics Lecturers

1. What is your understanding of pedagogical ICT integration in the lecture room?
2. Do you regularly use ICT tools in the teaching of mathematics?
3. Conceptual concerns ("What are mathematics teacher educators' perspectives on ICT as a pedagogical tool? What types of skills are required by the mathematics teacher educators during the pedagogical integration of ICTs?")
4. Pedagogical concerns ("How are ICT used for teaching and learning? What are the best practices for improving quality in the context of pedagogical integration of ICTs?")
5. Technical concerns ("How do mathematics teacher educators use the ICT in the lecture room? What kind of ICT support is available to teacher educators?")
6. Can time be a contributing factor as to the reason why you would not integrate ICT in the teaching of mathematics? Please elaborate if possible.
7. Technical concerns ("How do mathematics teacher educators use the ICT in the lecture room? What kind of ICT support is available to teacher educators?")
8. What are the needs of pre-service mathematics teachers in teaching mathematics with ICT at your institution?
9. Affective concerns (What are ICTs perceptions by teacher educators? What are mathematics teacher educators' attitudes on ICT? What are the main barriers of ICT to the successful pedagogical integration of ICTs in the teaching of mathematics at your university?)
10. What do you think are the affordances of using ICT in the teaching of mathematics at your institution?
11. Professional Development concerns ("What are the professional development needs of mathematics teacher educators that would support adoption, appropriation and

implementation in the lecture room? What factors influence the effectiveness of ICT training for mathematics teacher educators?")

12. Logistical concerns ("To what extent is your institution equipped with ICT infrastructure?")
13. Organisational concerns ("How do your university organise their lecture rooms to support the use of ICT integration in the teaching of mathematics? How can ICT be used as part of what we already do in the lecture rooms?")
14. What could be the other reason why mathematics teacher educators are not pedagogically integrating ICT in the teaching of mathematics?
15. Instructional concerns ("How are the available ICT tools used in teaching and learning to help learners learn in different ways? To what extent are Interactive Whiteboards (IWB) used in the classroom?")
16. What kind of a model that mathematics teacher educators are looking for as a guide for the successful integration of ICT into their teaching?

Appendix III: Interview Schedule for B.Ed. Fourth Year Mathematics Pre-Service Teachers

1. This is your final year as B.Ed. Mathematics student at this university. Do you think your university and your lecturers have prepared you enough to pedagogically integrate ICT in the teaching of mathematics? How do you see ICT as a relevant tool in the teaching of mathematics?

2. Today's learners are natives of technology. They interact with technology to almost everyday in their lives. Even some of you teachers, spend most of your time using technology. Drawing from your past experience as a student at university, do you think universities should include programme that pedagogically integrate ICT in teaching and enable you to be confident in preparing learners whose future is already technologically driven?

3. What do you think are the affordances and advantages of ICT usage in the classroom? Please elaborate on how the ICT affordances can be used in teaching mathematics.

4. What are mathematical application software that you are aware of? Which one among those that you have mentioned does your mathematics lecturers use in teaching mathematics?

5. As mathematics student, have you ever consider teaching yourself to solve some mathematical problems using any mathematical software. If not give the reasons why?

Appendix IV: Interview Schedule for B.Ed. Fourth Year Mathematics Pre-service teachers

Wits School of Education

WITS UNIVERSITY

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02 November 2017

Student Number: 1375255

Protocol Number: 2017ECE031D

Dear Alton Dewa

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:

Towards a Framework to Support Information and Communication Technology Integration into Mathematics Teaching in Initial Teacher Education

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

cc Supervisor -Dr Reuben Dlamini and Dr Nokulunga Ndlovu