

**THE EFFECTIVENESS OF USING DIGITAL TOOLS TO TEACH
GRADE 9 MATHEMATICS IN THE EKURHULENI DISTRICT**

by

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***Investigating the Effectiveness of Digital Tools to Teach Grade 9 Mathematics
in the Ekurhuleni District***

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I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

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ABSTRACT

This study investigated the effectiveness of the use of digital tools in the teaching of Grade 9 mathematics. Using digital tools in the teaching of mathematics could create a more positive attitude in learners and result in improved learner results. In an era of digital evolution where teenagers, like Grade 9 learners, use digital devices and digital platforms throughout the day, has meant the need for a change in school-based activities, assessments and examinations. Amending pedagogical approaches with the use of digital devices in the teaching of mathematics could engage with learners on a higher level and change the negative perception that teenagers have about mathematics.

Underpinned by a constructivist paradigm, this multiple case study within a qualitative approach, sought to explore the effectiveness of digital tools in the teaching of mathematics at the Grade 9 level. Educational technology theory together with the Technology, Pedagogy, and Content Knowledge model, commonly known as TPACK, formed the theoretical framework. Data were collected via the transect walks and informal interviews, observations and focus group discussions in three selected schools in the Ekurhuleni district in Gauteng with six participant teachers.

The findings revealed that with the introduction and implementation of digital tools, teacher need to incorporate technology (TK), pedagogy (PK), and content (CK) in their practice in order to ensure quality teaching in mathematics.

Key Terms: digital tools, mathematical learning management systems, mathematics visualisation tools, technology integration

LIST OF ACRONYMS

1IR	First Industrial Revolution
3IR	Third Industrial Revolution
4IR	Fourth Industrial Revolution
5IR	Fifth Industrial Revolution
Ai	Artificial Intelligence
CASME	Centre for the Advancement of Science and Mathematics Education
CK	Content Knowledge
COVID-19	Corona Virus Disease 2019
DBE	Department of Education
DIMAS	Digital Mathematics Applied in Defence and Security Education
ERTL	Emergency Remote Teaching and Learning
FET	Further Education and Training
GDE	Gauteng Department of Education
ICT	Information and Communication Technology
IoT	Internet of Things
LMS	Learning Management System
MINECO	Ministry of Economic Affairs and Digital Transformation
NCTM	National Council of Teachers of Mathematics
OCHA	Office for the Coordination of Humanitarian Affairs
OECD	Organisation for Economic Co-operation and Development
OHP	Overhead Projector
OU	Open University
PK	Pedagogical Knowledge
POPIA	Protection of Personal Information
SACMEQ	Southern and Eastern African Consortium for Monitoring Education Quality
SGB	School Governing Body
STEM	Science, Technology, Engineering and Mathematics
TDC	Teachers' Digital Competencies
TK	Technological Knowledge

TPACK	Technology, Pedagogy and Content Knowledge
UJ	University of Johannesburg
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISA	University of South Africa
USA	United States of America
WCED	Western Cape Education Department
WMC-P	Wits Maths Connect-Primary

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CHAPTER 1: ORIENTATION

1.1 INTRODUCTION

Moving into an advanced digital era, the young adult minds in our classrooms and learning environments are more digitally inclined as we operate in the Fourth Industrial Revolution (4IR) and move towards the Fifth Industrial Revolution (5IR). With the current generation of technology users, digital multitasking has become commonplace due to the rising portability and early acceptance of digital technology. In a recent Pew Research Centre survey, 95% of teenagers reported having access to a smartphone, and 45% said they use the internet 'almost constantly' (Anderson & Jiang, 2018).

Reinhold (2020) suggests that utilising digital tools enhances learning through interactive and scaffolded activities, which implies that digital tools can improve learning experiences and environments in the teaching of mathematics. Steen-Utheim and Foldnes (2020) suggest that digital tools such as geometry software can engage learners and improve their understanding of geometry concepts within mathematics. Sangwin and Groves (2020) state that using computers when teaching algebra can improve problem-solving skills, as these modern tools provide good feedback on mistakes in algebraic concepts, allowing learners to improve their performance. Digital tools enable learners to access content tailored to their individual learning styles, which can be particularly beneficial when learning new and abstract mathematical concepts in classrooms (Reinhold et al., 2020).

The COVID-19 pandemic saw an increase in the use of digital platforms as the pandemic closed schools and other institutions and there was a need to transition to online learning. Hrastinski (2019) mentions that when implementing curricula during a pandemic like COVID-19, blended learning, which allowed for computer-based instruction, became vital. The system of blended learning determines how it is designed and implemented. Learners through the accessibility offered by technology, should be able to access educational resources online, regardless of their geographical location. Daniel (2020) reaffirmed the above that the COVID-19 pandemic pushed all teaching and learning at all levels to online learning.

Zheng, Warschauer, Lin and Chang (2021) commented on the investments into digital tools and resources and how these are expected to improve the outcomes and learning experiences in mathematics through interactive and personal learning journeys. However, the transition in the teaching of mathematics has met with challenges. The use of digital technology in education, which increased with the move to online teaching, raised concerns about the type, scope and efficiency of this process of digitising education (Cachia, 2021; König, 2020). Lawrence and Tar (2018) state that although money has been spent on integrating technology into education, the results have not been encouraging and the desired goals have not yet been met. Bebell and O'Dwyer (2020) found that large amounts of money have been allocated to purchase resources and digital resources aimed at enhancing mathematics instruction but have not seen a major change in classrooms in South Africa.

In addition to the above, teachers face numerous challenges when integrating technology into the classroom, particularly in the teaching of mathematics. These challenges often include adapting lesson plans to incorporate technology and ensuring all learners have equal access to digital resources (Ertmer & Ottenbreit-Leftwich, 2020; Kimmons & Hall, 2021).

Seeing the evolution of technology within and outside the classroom, the link between education and digital technology or tools should have a positive effect on teaching and learning. The main aim of the study is to examine the effectiveness of digital tools and platforms that are used to teach mathematics at high schools in South African classrooms, particularly in the Ekurhuleni district in Gauteng where underperformance has been noted in mathematics achievement.

1.2 BACKGROUND TO THE RESEARCH

Studies internationally, in Africa and locally have revealed that digital technology is our future, in many vital parts of our community, for example, in business, clinics, hospitals, factories and schools. The utilisation of digital tools in mathematics education has been researched, primarily in developed nations such as the United States of America (USA), Britain and Australia; in contrast, South Africa lacks extensive research. Bower (2021) states that digital tools, such as interactive simulations and educational apps, have been found to increase learner engagement and motivation in learning

Mathematics. Lee (2020) found that adaptive learning technologies can tailor content and pacing to individual learner needs, promoting personalised learning experiences that cater to varying levels of proficiency. Studies conducted in Australian preschools and primary schools have demonstrated that drill and practice software can significantly enhance learners' academic outcomes (Smith, 2021). Furthermore, research in secondary schools indicates that digital tools supporting higher-order thinking skills positively influence mathematics achievement (Jones & Brown, 2020).

Traditional classroom instruction often falls short in providing an immediate learning environment, faster evaluations and increased engagement. Digital learning tools and technology effectively address these issues, offering efficiencies that traditional methodologies cannot match. With the widespread adoption of smartphones and other wireless devices, it is logical for educational institutions to leverage these technologies in the classroom. The adaptability and non-intrusive nature of modern technology make learning more appealing to the next generation (Bai, 2019).

In a study conducted in Australia, Hilton (2018) found that the use of iPads facilitates the addressing of diverse learner needs through apps that allow learners to work at their appropriate levels. While personalised learning can occur without digital devices, technology offers teachers the ability to vary instruction and provide learner-controlled learning paths. Graham, Stols and Kapp (2020) and Bond and Bedenlier (2019) support these findings, highlighting that contemporary education apps offer features like frequent formative assessment and progression data aligned with curriculum standards. Although there is a concern that learner-controlled learning paths may hinder progress if left unmonitored, recent literature emphasises the role of technology in supporting differentiated instruction and continuous monitoring (Kong, 2021; Lai & Bower, 2020).

Digital technology has been used in the teaching of mathematics for over four decades with calculators and early computers being the most basic tools and then moving to advanced digital software. Traditional teaching tools like pen and paper and older counting methods have progressively given way to advanced mathematical tools like scientific calculators, spreadsheets and statistical software that are easily usable at school. This shift reflects broader trends in integrating technology to enhance learning experiences and outcomes (Brown, 2023; Smith & Jones, 2021). Tokac, Novak and

Thompson (2019) examined the influence of video games on learners' mathematics performance and discovered that video games have a considerably more positive effect on mathematics achievement compared to traditional teaching methods.

According to Adler (2019) and Graven (2020), mathematics education has shifted its focus from theoretical concepts to practical applications, equipping learners with skills essential for solving real-world problems and fostering critical and creative thinking. As a result, there is a growing necessity for innovative pedagogical approaches that align with the digital age, emphasising effective strategies for teaching mathematics.

Research has looked at the issue of developing effective strategies for teaching mathematics in the era of digital advancement, with a particular focus on mathematics pedagogy. Hwang and Wu (2021) explored innovative pedagogical strategies that leverage digital tools, such as interactive simulations and virtual manipulatives, to foster conceptual understanding in mathematics. Liu (2020) examined new approaches to assessment and feedback facilitated by digital tools, aiming to provide timely and personalised feedback to learners. Siemens and Long (2023) used educational data analytics by AI algorithms to examine learner performance data, offering educators valuable insights into areas where learning may be lacking and the effectiveness of instructional strategies. AI-driven adaptive learning platforms are increasingly employed to tailor learning experiences in Mathematics, addressing the specific needs and learning speeds of each learner, as stated by Van Lehn (2020).

In Nairobi, Kenya, Mwangi (2021) examined the obstacles and issues to integrating technology in mathematics education and suggested strategies to address them. It highlighted the importance of a strong ICT infrastructure, training and ongoing support to achieve successful and sustainable implementation of these digital tools within classrooms. Secondary schools in Lagos, Nigeria found that the implementation of ICT tools in the mathematics classroom enhanced learner engagement and performance (Adewale, 2019). Nkosi (2022) found that digital tools used assist learners in a selected Pretoria school, were more available and usable to the learners. Dubes and Mavhunga (2022) indicate that ICT tools used in certain Gauteng schools, such as interactive whiteboards and educational software, substantially enhance learners' interest and ability in mathematics. This means that ICT plays an important role in bridging the gaps between theory and practical aspects in Mathematics.

Amidst digital advancements, employing digital tools for teaching mathematics in South Africa highlights various themes and strategies. Studies by Chigona and Chigona (2021) indicate that integrating technology into mathematics education can boost learner engagement and comprehension. Baloyi and Motlhabane (2023) found a positive correlation between using ICT tools in the classroom in relation to their achievements in assessments within Limpopo schools. Khoza (2022) mentions that the adoption of digital tools correlates with enhanced problem-solving abilities and critical thinking skills among learners. Implementing these digital aspects and tools as a relatable aspect in Mathematics, ensures that the interest towards the subject grows.

Hoyles (2018) emphasises the importance of mathematics teachers actively participating as co-designers and teacher-researchers in the transformation process of integrating digital technologies into mathematical practice. Besides significant digital advancements, integrating technology in education can be challenging. Johnson (2020) argues that traditional instructors may be hesitant to incorporate contemporary technology and gadgets, viewing them as distractions rather than valuable learning aids. Smith (2021) acknowledges these challenges stating that the potential benefits of digital learning tools make them an indispensable part of modern education. A review on the use of tablets in mathematics revealed that educators struggle to design effective learning experiences that seamlessly integrate tablet technology with robust mathematical pedagogical strategies (Svela, 2019).

Gudmundsdottir and Hatlevik (2020) state that teachers perceive ICT as a tool that can both enhance and hinder learning, depending on its implementation and context. Herodotou (2021) goes on to show the potential of digital tools to increase learner engagement and motivation but also points to the challenges of ensuring that these tools are used effectively to avoid distraction and cognitive overload. A systematic review by Sailer (2021) discussed the dual-edged nature of ICT in education, highlighting both the pedagogical benefits and the potential for increased distraction and reduced attention spans.

The schooling system in South Africa is split into public schools and private schools; this is a major issue in digital advancements (Mhlanga & Moloji, 2020) as public school access to technology is affected. Mothibi and Makgato (2020) explored challenges in ICT in rural and township schools within South Africa and highlighted the different

needs of these schools in ICT resources and training as compared to urban schools, showing a gap in using digital tools. In addition, the issue of effective teacher training and a well-designed curriculum was raised as these are essential for the effective integration of digital tools into mathematics education, as stated by Adler (2019) and Graven (2020).

There remains a notable issue in research within developing countries, highlighting the need for increased attention to how digital tools can optimally augment mathematics education, particularly in the context of the significant challenges faced by rural schools (Gupta & Singh, 2023). Effective integration of these tools hinges on educators' willingness to adapt their teaching methodologies, underscoring the importance of pedagogical innovation in enhancing learning outcomes (Williams, 2022).

1.3 PROBLEM STATEMENT

As a developing resource economy, South Africa urgently needs more learners to enter the workforce with a solid foundation and confidence in mathematics. According to Maree (2021) and Mwakapenda (2022), it is vital that teachers who teach mathematics embrace more effective instructional and assessment practices to improve learners' mathematical ability. Modisaotsile (2021) acknowledges that integrating digital tools in mathematics education can be a challenge due to the country's dual education system, which include private and public schools. Strategies that are effective in one sector may not be suitable for the other due to resources and funds. Private schools typically have greater capacity to integrate digital tools effectively compared to public schools, which face more resource constraints, as noted by Bansilal (2020) and Ramabenyane (2022).

The COVID-19 pandemic revealed a significant gap that has influenced effective learning, highlighting challenges in advancing digital tools in mathematics education, as mentioned by Onyema et al. (2020). Graham and Sahlberg (2021) note that this period was particularly challenging for the digital transformation of mathematics teaching and learning. Nonetheless, the pandemic also revealed critical flaws and gaps, prompting teachers to identify areas that require improvement to effectively teach online and utilise digital resources (Trust & Whalen, 2020). Bond (2021) found

that as a result, educators gained insights into the basics of the digital world and the continued effectiveness of digital tools even after the pandemic.

Saavedra (2020) stated that funding is essential to ensure equitable access to technology for both learners and teachers, which will then prevent marginalisation in the learning process. Tondeur et al. (2020) point out how essential it is for teachers to be trained in effectively using these tools, especially for learners who do not have access to technology outside of school, to enhance mathematics education. The objective is to foster an inclusive environment where technology enhances learning experiences for everyone, as found by Damşa, Langford, Uehara and Scherer (2021).

The teaching of mathematics using digital tools facilitates learner-centred learning within the mathematics classroom. Zhou and Wu (2021) state that digital tools can be used to create individual mathematics learning, which excites learners as they have access to something more modern while working at their own level in the classroom. Similarly, Holmes and Prieto-Rodriguez (2021) state that adaptive learning technologies support learners in their learning journeys, contributing to an improvement in engagement, leading to better performance in formal tasks. Learners learn via digital platforms and apply their knowledge and skills obtained through these learning tools in their assessments and examinations. Therefore, this study explores the effective use of digital tools in the teaching of Grade 9 mathematics in the Ekurhuleni district.

1.4 RESEARCH QUESTIONS

The main research question is: *How effective is the use of digital tools in the teaching of Grade 9 mathematics in the Ekurhuleni district?*

The main research question necessitated the formulation of sub-questions:

1. How do teachers integrate digital tools in their teaching practice?
2. What are the benefits when integrating digital tools in the classroom?
3. How do digital tools influence learner performance in the classroom?
4. What challenges do the teachers experience when integrating digital tools in the classroom?

1.5 AIM AND OBJECTIVES

The aim of this study is to explore the effectiveness of digital tools in the teaching of Grade 9 mathematics.

The research objectives are to

1. Investigate how Grade 9 Mathematics teachers integrate digital tools into their teaching practices.
2. Highlight benefits when integrating digital tools in the classroom.
3. Understand how digital tools influence learner performance in the classroom.
4. Identify challenges experienced by teachers when integrating digital tools in the classroom.
5. Investigate whether digital tools are being used effectively in grade 9 mathematics classrooms?

Discover whether fear using digital tools to teach mathematics?

1.6 PRELIMINARY LITERATURE REVIEW

Over the years, there has been a shift from using textbooks to e-books and digital materials in the teaching of mathematics. As previously stated, the youth are frequent users of digital tools, regularly engaging in digital multitasking (Carrier Rosen, Cheever & Lim 2018; Lai & Hong, 2015). Magen-Nagar and Peled (2021) noted that using digital materials in mathematics creates alignment in educational settings which helps prepare learners with technological skills as they transition into the modern world.

Lawrence and Tar (2018) and Fernández-Gutiérrez (2020) found that education systems around the globe have expanded their investment in the integration of technology even though there are still barriers within the use of technology. The Europe Commission has placed importance on learners' educational needs and have adapted policies and strategies around ICT integration (European Commission, 2019).

Smith and Johnson (2021) and Lee (2022) suggest that learning is enhanced by digitisation, accomplished by increasing engagement and curiosity through better access and understanding, made possible by developing technologies that can be used in the classroom. Digital platforms allow for blended learning, considered as virtual learning, is widely applicable in curriculum implementation in situations where participants are separated by distance (Onwusuru & Ogwo, 2019).

Pillay and Maharaj (2021) documented that implementing digital tools in mathematics classrooms within South Africa provided better insights for effective usage and integration of ICT in education. Blignaut, Hinostroza, Els and Brun's (2021) research reported that teachers showed an improved usage of digital tools in mathematics education, which positively impacted the classroom environment.

Connor (2019) indicated that educators and parents use e-books as teaching tools to develop young children's learning strategies. Delgado, Vargas, Ackerman and Salmerón (2019) have shown that digital materials and tools have a positive effect on learning, with the younger generation preferring e-books over traditional textbooks in mathematics and other subjects as these are convenient and more usable. Cuesta, Abella-García and Grande-de-Prado (2020) showed that digital materials like e-books and online material engage with learners learning experiences and makes learning interactive, and this assists in gaining more insights into mathematical concepts. Radovic (2020) stated that by using mathematics e-books this could stimulate learners' ability in the subject.

GeoGebra and Cabri are tools used in Mathematics which are interactive allowing learners to explore Geometrical concepts (Shadaan & Leong, 2020). Farmer and Poyser (2022) state that tools such as Desmos and Mathway, help learners see functions, graphs and equations visually through digital means, engaging them more in the classroom. Moodle and Google Classroom are common digital platforms that have been integrated specifically in mathematics education, using it as a form to collaborate assessment in the classroom (Gikandi, Morrow & Davis, 2020).

1.5.1 Advantages of Using Digital Technologies in Mathematics Education

The advantages of using mathematical modelling with digital tools have been documented. Bakker and Akkerman (2019) show that the one significant benefit is that digital tools enhance learners' understanding of complex mathematical concepts by providing interactive and visual representations. Freeman (2020) agrees, stating that this allows learners to explore and manipulate models, leading to a deeper conceptual understanding and improved problem-solving skills. Reinholz and Shah (2018) go on to say that digital tools facilitate real-time feedback and adaptive learning, which can help tailor instruction to individual learner needs and pace.

Enhanced engagement and motivation with digital tools offer several advantages in mathematics education. Studies by Chigona and Chigona (2021) have shown that the use of interactive digital tools can make learning more engaging for learners, helping to sustain their interest and motivation in the subject. Khoza (2022) supports this statement by saying that digital tools such as educational games, simulations and interactive software provide learners with immediate feedback and a more personalised learning experience, which can lead to improved understanding and retention of mathematical concepts. Technology-enhanced learning environments can foster collaborative learning and develop problem-solving skills, as learners often work together on digital platforms, enhancing their communication and teamwork abilities (Adler, 2019). Graven (2020) also indicates that the integration of digital tools in the classroom can cater to diverse learning styles and needs, making mathematics more accessible and enjoyable for all learners.

Personalised and inclusive learning with digital tools in mathematics offers advantages. Chigona and Chigona (2021) state that digital tools can individually create educational experiences to meet learners' needs, according to their levels of understanding, therefore enhancing their understanding and retention of mathematical concepts. Khoza (2022) states that this personalised approach allows for differentiated instruction, catering to diverse learning styles and paces, which can significantly improve learner outcomes. Digital tools in mathematics education offer many opportunities for learners, enhancing learning experiences and skill development. These tools can increase learner engagement by making mathematical concepts more interactive and accessible (Chigona & Chigona, 2021).

1.5.2 Challenges in Using Digital Technologies in Mathematics Education

Implementing new technology in mathematics classrooms in South Africa is particularly challenging, given that every learner is required to take the subject (Spaull, 2019; Taylor & Coetzee, 2020; Van der Berg, 2021). The education system is split into two sectors namely, private and public schools, making technology integration time-consuming and difficult. Spaull (2019) states that in public schools, implementing technology is especially costly and demands extensive training and systemic changes. Financial constraints often hinder public schools' ability to afford new technology for mathematics classrooms (Taylor & Coetzee, 2020). Van der Berg (2021) agrees and

says the disparity between private and public schools exacerbates existing inequalities and complicates efforts to provide equitable access to digital learning tools.

Developing effective methods and ways for using digital tools to teach mathematics in the digital age within the classroom requires addressing resource limitations and inequality. The issue in access to technological resources between various schools and communities can deepen educational inequalities, making universal implementation of digital tools difficult (Graven, 2020). Adler (2019) also found that resource constraints in many schools hinder the acquisition of necessary technology and infrastructure, limiting the potential benefits of digital learning. Khoza (2022) says that the digital divide is particularly evident in under-resourced and rural areas, where learners do not have up-to-date devices and are unable to access reliable internet, creating significant barriers to equitable education. Even when resources are available, disparities in technological proficiency among educators can undermine efforts to effectively integrate digital tools (Chigona & Chigona, 2021).

Challenges in using technology in the teaching of mathematics are numerous. A significant obstacle is the lack of adequate infrastructure and resources in many schools, hindering the effective integration of digital tools (Graven, 2020). Chigona and Chigona (2021) explain that an additional issue is in teacher training and professional development, leaving educators unprepared to effectively incorporate technology into their teaching practice. Resistance to change among educators and administrators further impedes the adoption of new technologies in the classroom (Adler, 2019). Khoza (2020) investigated the issues related to digital equity and found that existing access to educational inequalities is major. It is clearly seen from studies by the literature cited that there isn't enough usage of digital aspects and tools in classrooms, hence my interest in exploring the factors that influence grade 9 mathematics teachers to not use digital tools, when it is available.

17 THEORETICAL FRAMEWORKS OR CONCEPTUAL FRAMEWORK

The theories and concepts that are important to this research are presented briefly under their relevant headings. Educational Technology Theory and the Technology, Pedagogy and Content Knowledge (TPACK) theory relate to this study, stemming from Shulman (1986).

1.7.1 Educational Technology Theory

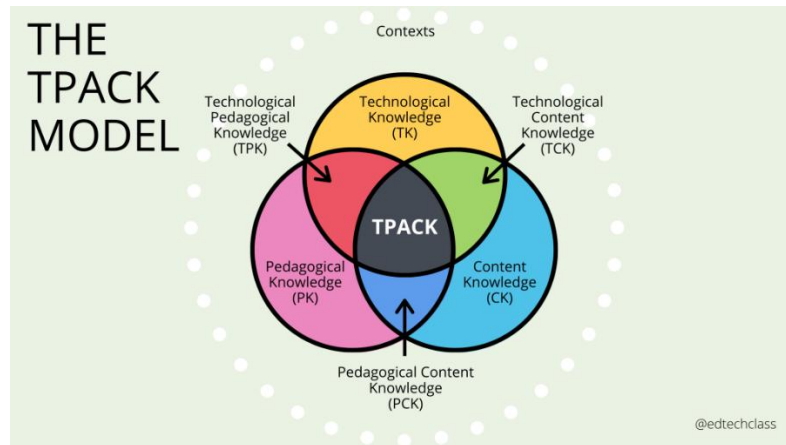
Educational technology theory is an interdisciplinary field that combines principles from cognitive and educational psychology, instructional design models, multimedia development principles, computer science technologies and related disciplines (Reiser & Dempsey, 2018). This multifaceted approach aims to enhance teaching and learning processes by leveraging technological advancements to create more effective educational environments.

The educational technology regarding mathematics, according to Simon (2021), shows that problem-solving and critical thinking occur when learners are given the opportunity to engage with complex problems through digital tools as they are interactive platforms. Simon (2021) goes on to say that tools such as GeoGebra and Desmos, which are embedded in Educational Technology Theory, allow learners to work through high-order questions through visualisation and interaction. Smith and Anderson (2020) explain that educational technology theory in mathematics has been closely related to Piaget and Vygotsky's learning theories, as through exploring, learners are able to create their own learning via digital tools to gain better conceptual understanding of mathematics.

This theory can link the educator, learner and digital tools with the subject of mathematics and the effectiveness it has in the classroom and on learner achievement.

1.7.2 Technology, Pedagogy and Content Knowledge (TPACK)

The Technological Pedagogical Content Knowledge (TPACK) model (Figure 1.1) is an extension of the concept of Pedagogical Content Knowledge (PCK), which Shulman introduced in 1986. TPACK represents the foundation of effective teaching, outlining the specific knowledge domains teachers must master to facilitate seamless technology integration. TPACK examines various strategies for developing teachers.



(Source: 2025:1)

edtechclass,

Figure 1.1: TPACK model

- **Content Knowledge (CK)**

Content Knowledge is a teacher's deep understanding of the subject matter they are teaching, including facts, theories, core concepts, evidence, and established structures of the discipline within a specific field, such as science, history, or mathematics.

- **Pedagogical Knowledge (PK)**

Pedagogical Knowledge (PK) refers to a teacher's specialized understanding of the processes, methods and practices of teaching and learning. PK enables teachers to create effective learning environments.

- **Pedagogical Content Knowledge (PCK)**

Shulman (1986) introduced the concept of Pedagogical Content Knowledge (PCK), which is where CK and PK intersect. He highlighted the importance of understanding how content and the pedagogy are needed to teach content effectively. In mathematics, this is having knowledge of mathematics as well as appropriate strategies to teach a topic, such a geometry.

- **Technological Content Knowledge (TCK)**

The intersection of TCK displays how teachers use technology to represent and teach specific content, such as teaching functions via the use of calculators in mathematics (Koehler, Mishra & Cain, 2021)

- **Technological Pedagogical Knowledge (TPK)**

Koehler et al. (2021) explain this part of the model by showing how teachers combine PK and TK in mathematics and other subjects. Exploring the use of digital tools to enhance methods of teaching.

Research by Mishra and Koehler (2019) highlights how TPACK emphasises the intersection of technological knowledge, pedagogical strategies and subject-specific content knowledge, empowering teachers to design meaningful learning experiences that leverage digital tools to enhance mathematical understanding. In the sphere of teacher education, the TPACK theory has been widely accepted. Based on Shulman (1986), Ball, Thames and Phelps (2008) ask the following: What kind of more comprehensive understanding of a mathematical subject and related techniques is required for long-term instruction? How do learners' concepts and behaviours evolve, and what does this suggest about content knowledge in the classroom, relating to TPACK and the teachers' mathematical work.

A study by Scherer, Siddiq and Tondeur (2020) emphasised the positive correlation between TPACK and teachers' self-efficacy in using technology in the classroom, hence the theory is applicable to the study on the use of digital tools in the mathematics classroom. Chai, Koh and Teo (2020) found that teachers with a strong TPACK background are better able to design and implement technology-enhanced learning activities that engage learners and enhance their understanding of complex concepts. Being able to identify the source of a mathematical error is necessary for effective instruction (Ball, Thames and Phelps, 2008). Additionally, they go on to say, teachers have to complete this work quickly and frequently on the spot since pupils in a classroom cannot wait while a teacher struggles with the mathematics, so having the correct knowledge will lead to better technological use in mathematics.

Teaching and learning are characterised in this AI-era as intricate processes involving the diverse application new information. In addition, as AI has developed, the methods for acquiring knowledge have progressively expanded, especially amongst teachers (Ning et al., 2024).

A few research studies have broadened their framework in the context of AI education to conceptualise teachers' technological integration expertise as the integration of AI

technology into technological pedagogical content knowledge, or AI-Technological Pedagogical Content Knowledge (AI-TPACK) (Ning et al., 2024).

1.8 RESEARCH METHODOLOGY AND DESIGN

This section offers a brief overview of the research methodology and design that guided the conducting of this research. Full methodology is presented in chapter 3.

1.8.1 Research Paradigm

Guba and Lincoln (1994) claim that a paradigm is a general philosophy that reflects people's perceptions of the universe and the essence of the potential connections that might exist in that environment. Each study's technique is determined by the selected research paradigm. Constructivism, interpretivism and positivism are primarily utilised in education. According to Turyahikayo et al. (2021), these research paradigms are helpful in explaining the identified problem to be investigated from ontological, epistemological and methodological viewpoints, respectively.

Kim and Hannafin (2018) explain that constructivist theories used in learning environments motivate learners to engage in challenging thinking and problem-solving activities, which are important for meaningful learning experiences. Through constructivism, the focus shifts to understanding how learners actively construct their knowledge, enabling a deeper exploration of the processes and strategies they employ when using digital technology for mathematics learning. According to a study by Jonassen and Land (2018), constructivist theories employed in learning environments that allow integration of digital tools, can significantly enhance learners' conceptual understanding and application of content in the broader world. Therefore, by using this paradigm in this research, an insightful understanding of the use of digital tools in classrooms is developed.

Adopting a constructivist paradigm, research methodology can incorporate qualitative methods such as interviews and observations, allowing for rich data collection and analysis that captures the complexities of digital technology usage in mathematics education. Smith and Greene (2018) found that interviews assist in developing an understanding of how digital tools impact learner engagement and learning processes in the mathematics classrooms. Brown and Wilson (2019) pointed out that observational studies offer a structured view of the interactions between learners and

digital technologies, showing the need and factors which influence the effectiveness of technology integration in educational settings.

1.8.2 Research Approach

A qualitative research approach utilises non-numerical methods to gather data. Consequently, it can capture information from a more detailed perspective and with a broader scope than quantitative research. According to Bhandari (2022), a qualitative research approach seeks to better understand ideas, opinions or experiences by collecting and analysing non-numerical data (such as text, video, or audio).

Merriam and Tisdell (2018) noted that qualitative methods are suitable for exploring how learners construct knowledge through interactions with their environment and peers, aligning with Piagetian principles. Qualitative research methods, such as interviews and observations, are good ways to measure the learners' progress first hand and see what is working within their environment as signified (Creswell & Poth, 2018). Denzin and Lincoln (2018) argue that qualitative research's interpretive approach enables researchers to gain an overview of learners' performance levels, which is essential for investigating the individual and active learning processes outlined by constructivism.

1.8.3 Research Design

Using a case study design allows for a thorough understanding of the research by examining it across multiple contexts and settings. This method allows for examination of detailed comparisons and contrasts across cases, thereby enriching the overall analysis and conclusions (Thomson, 2014). Yin (2018) highlights that multiple case studies strengthen research conclusions by incorporating different sources of information and evidence. Stake (2019) notes that this approach displays patterns and themes that may not show from a single case study. Baxter and Jack (2020) suggest that using multiple case studies is effective and offers a detailed and in-depth understanding of complex educational factors.

Using a multiple case study research design allowed for a comparative analysis of data. Three schools representing the segmented tiers found in the South African education system were selected, each to form a case. Selected schools included a private school, a former Model C institution and a government school, and

where digital tools are used for in the teaching of mathematics at the Grade 9 level. This allowed for a comparison through the identification of commonalities, differences and patterns in how the tools are integrated, the effectiveness of their usage, and the outcomes for learners.

1.8.4 Research Methods

Data collection methods refer to the techniques and instruments a researcher uses to gather data for a study (Sukmawati, 2023). In this qualitative study, the aim was to gain in-depth knowledge, utilising interviews and focus groups for data collection.

1.8.4.1 Sampling

This research focused on the educational landscape of South Africa, with a particular emphasis on Johannesburg's East Rand region. To ensure a representative sample, three high schools following the general schooling systems in the country were selected and included a private school, a former Model C school (previously known as a white only school, now remains public yet semi-independent) and a government school collectively representing the varying socio-economic backgrounds, educational policies, and resources available within the South African context.

Within each selected school, the target population were Grade 9 mathematics teachers. Participant selection in research involves identifying individuals who meet specific inclusion criteria for a study (Dahal, 2024). According to Jones (2018), proper participant selection is crucial for minimising bias and enhancing the trustworthiness of findings. Researchers often use random sampling techniques or purposive sampling. Purposive sampling, a non-probability sampling technique (Stratton, 2023), was used to select participants based on characteristics or qualities relevant to the use of digital tools in the teaching of mathematics. This method ensures that the sample accurately reflects digital usage in Grade 9 mathematics, based on predetermined characteristics to select participants, as suggested by Creswell and Creswell (2017). Three teachers from each school, nine participants in total, allowed for the gathering of a substantial and diverse range of perspectives and experiences.

1.8.4.2 Data Collection Methods and Techniques

This section presents a brief overview of the data collection methods used to conduct this research.

- **Transect Walks**

Transect walks, developed by Chambers (1997) enabled the navigation of the digital landscape within a Grade 9 educational context, actively engaging with teachers and the various digital platforms, tools and resources that they use. According to Creswell and Poth (2018), this allows for real-time data collection on teachers' perceptions on learner interaction with digital tools, revealing their preferences, challenges encountered and usage patterns. The transect walk method was used when accompanying participants as they navigated their teaching spaces or classrooms and answered questions through informal interviews. Chambers (1997) suggested that using the knowledge that already exists within a community is vital in research. This walk occurred in non-teaching time or after school, at a time where informal interviews were held with the teachers. Transect walks complement other data collection methods.

- **Observations**

Observations are important for collecting data on digital engagement. According to Creswell and Poth (2018), observing learners' interactions with digital devices, applications and online content allows researchers to analyse trends, preferences and challenges in digital usage. By adopting this method, Merriam and Tisdell (2018) state its capacity to promote a good understanding of how Grade 9 learners engage with digital resources, fostering insight into their learning behaviours and technological interactions. Merriam and Tisdell (2018) agree that providing detailed information into how Grade 9 learners navigate digital spaces and utilise technology for learning and communication, offers educators and researchers a deeper understanding of their technological behaviours and interactions.

- **Focus Group Discussion**

Conducting a focus group discussion with Grade 9 teachers is an effective method for gathering qualitative data on their experiences, perceptions and attitudes in using digital technologies. By facilitating discussions and group interactions, researchers

can explore teachers' preferences for specific platforms or applications, and challenges encountered in digital learning environments (Mhlongo, 2023). Focus group discussions in educational research emphasise the ability to capture diverse perspectives and produce good qualitative data (Hennink & Mann, 2018). Morgan (2020) speaks about the benefits of focus group discussions in exploring learners' evolving relationships with digital tools and their implications for educational practices. Engaging Grade 9 teachers in focus group discussions includes a participatory approach to understanding their digital world and shaping educational interventions accordingly. Questions focused on teachers' experiences with implementing technology in the teaching of mathematics at Grade 9 level.

1.8.4.3 Data Analysis

Thematic analysis is a robust qualitative data analysis method extensively utilised across various disciplines, including educational research. When applied to research on the usage of digital tools in the teaching of mathematics to Grade 9 learners, thematic analysis on the collected data revealed patterns, themes and insights. Braun and Clarke (2019) and Nowell, Norris, White and Moules (2019) point out the efficacy of thematic analysis in educational settings, proving its ability to find meaningful trends and experiences. This method enables researchers to systematically identify and interpret key aspects of the data, providing a deeper understanding of learner interaction with digital technologies. Clarke, Braun and Hayfield (2020) stress thematic analysis's flexibility and suitability for analysing qualitative data. This makes thematic analysis an important tool for exploring the impacts of digital tools on learning processes in the mathematics classroom. (Terry, Hayfield, Clarke & Braun, 2019).

Braun and Clarke (2019) add that this method is known for its systematic approach to identifying and interpreting qualitative data which is accurate and useful to the study. Utilising thematic analysis allowed for the identification to key themes, patterns and insights, contributing to a deeper understanding of how digital tools are being used and their impact on teaching and learning in this context. Terry et al. (2019) agree and showed the approach's effectiveness in educational research is well-documented, providing great insights into digital tool integration within the classroom.

1.9 MEASURES FOR TRUSTWORTHINESS

Credibility, transferability, dependability and confirmability are four strategies for establishing the trustworthiness of qualitative research, originally proposed by Guba and Lincoln (1981), Krefting (1991) and Creswell (1998). By establishing credibility, transferability, dependability and confirmability, qualitative studies can achieve high standards of rigour. Techniques such as member checking, prolonged engagement, and triangulation help mitigate the potential bias introduced by researchers. According to Nowell et al. (2019), these practices contribute significantly to the trustworthiness of qualitative research. Lincoln and Guba (2020) agree with these practices and emphasise that using these strategies assists in limiting the researcher's access and influence, enhancing the trustworthiness of qualitative findings.

Credibility is often enhanced through techniques such as member checking and prolonged engagement as stated by Connelly (2019). Korstjens and Moser (2018) explain that *transferability* is achieved by providing detailed descriptions and contexts, enabling others to assess the applicability of findings to different settings. *Dependability* involves maintaining a detailed audit trail to demonstrate the consistency and repeatability of the research process (Nowell et al., 2019). Moon et al. (2019) state that *confirmability* is supported through practices such as reflexivity and triangulation, ensuring that findings are influenced by participants' perspectives rather than researcher bias. By adhering to criteria that promote trustworthiness and limit researcher influence, thereby reducing bias, qualitative research ensures good and valid outcomes.

1.10 ETHICAL CONSIDERATIONS

In conducting qualitative research, researchers need to adhere to ethical guidelines to protect participants' rights and ensure they are not harmed. When conducting fieldwork or interviews with participants, researchers and scientists should abide by a code of ethics (Bhandari, 2021). Therefore, research ethics safeguards the interests of participants, strengthens the reliability of findings and guarantees the continued progress of scientific knowledge.

Ethical research practices involve obtaining informed consent, ensuring confidentiality and minimising any potential risks to participants (Resnik, 2019). Researchers must also be transparent about the purpose of the study and the use of the data collected.

Permission was requested from the University of South Africa (UNISA) to conduct the research as well as to the Gauteng Department of Education (GDE) to conduct the research in selected schools. Permission was also requested from the head/principal of the selected schools within the Ekurhuleni district in Gauteng. As the researcher, I required the permission of each participant according to the POPIA Act.¹ The POPIA Act ensured that personal information of both individuals and juristic entities is sufficiently protected, used in a manner for which it was gathered and that facilitates transparency. This limited the use of people's names and other information pertaining to the individual. As participant information needs to remain confidential, participants need to sign consent. All participants had a choice to be part of research and if needed, to withdraw from the study at any time of the research process. The participants were offered the opportunity to view the research information once the study was completed.

1.1 KEY CONCEPTS

To ensure understanding through the dissertation, key concepts are defined:

1.11.1 Digital Tools

Digital tools such as virtual manipulatives and dynamic geometry software, enhance learners' abilities in mathematical reasoning and problem-solving (Johnson & Johnson, 2021). These tools enable learners to interact with virtual objects and investigate mathematical connections, fostering a more intuitive grasp of abstract concepts like algebraic equations and geometric transformations (Hwang & Choi, 2018). Chen (2019) indicates that these interactive environments promote active learning and improve retention rates, thereby supporting more adaptable and responsive teaching methods. In this study, digital tools refer to digital projectors,

¹ The POPIA Act is an all-inclusive piece of legislation, a privacy law, that safeguards the integrity and sensitivity of private information. Companies are required to carefully manage the data capture and storage process of Personal Information.

polypad, moodle platform, MS teams, Desmos, AdvLearn and a few others mentioned by participants.

1.11.3 Mathematical Learning Management Systems

Mathematics Learning Management Systems have become important in modern education with digital evolution and the 4IR. There are two commonly used systems within the classroom and adapted to mathematical instruction; these systems are Blackboard and Moodle. Johnson, Adams, Becker and Estrada (2021) explain that Blackboard allows teachers to use the tool interactive content delivery which encourages learners to engagement through the digital tools. Moodle, an open-source system which allows for interactive lessons, supports the teacher in adapting the system according to learner needs (González & Sánchez, 2022). Moodle is seen as an effective tool in this study and blackboard is mentioned as one of the useful tools to teach mathematics.

1.11.2 Mathematical Visualisation Tools

Freiman and Berenson (2021) explored how useful and effective interactive mathematical visualisation tools, like an interactive board and projector. The projector is a device that mirrors/displays a screen from a connected device such as a smart phone or laptop. Interactive board: a touch screen whiteboard onto which a projector screen displays through which the computer screen can be controlled to annotate a lesson. These visualisation tools enhance learner understanding and engagement in geometry education. Noss and Hoyles (2019) investigated the integration of technology-rich environments in mathematics education, focusing on the role of visualisation tools in supporting mathematical thinking. So, in this study visualisation digital tools used to teach mathematics are relevant as it enhances particular sections like geometry in grade 9 mathematics.

1.11.1 Technology Integration

Farjon (2019) emphasises the critical need for educators to receive practical support to effectively navigate and overcome barriers associated with integrating technology in educational settings. Technology integration is when teachers use digital tools to teach in classrooms. Hoyles (2018) examined the role of professional development

and resources in enabling educators to design instructional content that effectively integrates technology while maintaining pedagogical integrity.

1.12 CHAPTER DIVISION

Chapter 1 presented the introduction and outlined the background information to the research with the problem statement. The research questions stated aim and objectives were outlined. A brief overview of the review of literature and the supporting theoretical framework was given. Thereafter, a brief outline of the research methodology which includes the research paradigm, the research approach and research design were presented. Research methods such as sampling, data collection and data analysis were outlined. Methodological norms and ethical considerations were briefly outlined. The final sections defined key terms and delineated the dissertation structure.

Chapter 2 reviews the literature for this study and explores the teaching of mathematics internationally, regionally and locally. The chapter also reviews literature on the use of digital technology in the teaching of mathematics as well as challenges faced in technology integration into teaching practice. The theoretical framework is anchored in the Educational Technology theory and Technology Pedagogy and Content Knowledge (TPACK) model.

Chapter 3 presents the research methodology used to guide this research. Underpinned by an interpretivist paradigm, the qualitative approach within a case study research design, allowing the researcher to gain insight into the personal experiences of learners and teachers in mathematics classrooms. Methods of data collection are described and include transect walks, observations and focus group discussions. Thematic analysis is explained to analyse the data collected. Final sections of this chapter discuss the methodological norms for trustworthiness and ethical considerations.

Chapter 4 presents the findings emerging from the analysis of the collected data in conjunction with existing literature. This chapter focuses on demonstrating the effect that the adoption of digital tools and platforms has on the teaching of mathematics in the digital age, and how this influences learner performance in mathematics.

Chapter 5 presents a summary of findings derived from the study on the utilisation of digital tools in the teaching of mathematics at Grade 9 level, focusing specifically on the mathematics context. The chapter delves into the outcomes of using digital tools, highlighting their effectiveness and impact on the teaching-learning process. This section draws meaningful conclusions regarding the benefits and challenges associated with digital tool integration in mathematics education.

1.13 CHAPTER SUMMARY

This chapter outlined the need for studying how digital tools are used in the teaching of mathematics at Grade 9 level. As indicated earlier, a foundation was laid for the research, with a background and problem statement that led to the research questions, aim and objectives. A brief review of literature was given and the theoretical framework was outlined. In addition, the research methodology that guided the research, was briefly outlined. Methodological norms and ethical considerations were also outlined with the final section describing key concepts.

CHAPTER 2

DIGITAL TOOLS IN MATHEMATICS EDUCATION: EMPIRICAL PERSPECTIVES AND THEORETICAL FOUNDATIONS

2.1 INTRODUCTION

Mathematics is a core subject at school level. As we move towards and into a digital world, approaching the eras of the 4IR and 5IR, mathematics teachers need to adapt their teaching methods to suit learners' needs. Viberg and Mavroudi (2018) assert that digital tools combined with good pedagogy might have the potential to ensure the development of learners' thinking and problem-solving skills.

Chapter 1 gave an overview of the literature that will be discussed in detail in chapter 2. This literature gives deeper findings according to the relevant study of digital tools used in mathematics and the effectiveness of these tools.

Literature suggests that utilising digital tools to teach mathematics within a school in an era of technological advancement should be accompanied by careful regulation of these strategies. Khoza (2022) states that proper regulation ensures that digital tools are used effectively and equitably, promoting consistent teaching standards, and reducing disparities in educational outcomes. This approach could help mitigate potential negative effects and address constraints related to personal beliefs and the professional status of teachers (Adler, 2019; Chigona & Chigona, 2021). The focus of this study is to determine the effectiveness of the use of digital tools in the teaching of mathematics and how this influences learners' performance.

Research has indicated that there are gaps in terms of conceptual and methodological considerations related to engagement in learning settings (Bredow, Roehling, Knorp, & Sweet, 2021b). Lo and Hew (2017); Muir (2017), and Cevikbas and Kaiser (2020) highlight that different aspects of learner engagement in digital mathematics classrooms have been insufficiently examined. Recent studies by Lo and Hew (2017) and Bond (2020) indicate that future studies should focus on digital learning, especially in secondary school education.

When using digital tools, it is important to build strong learner engagement in technological environments as it is critical for the delivery of effective teaching as

learner engagement is a prerequisite for successful learning as stated by Lam, Hew and Chiu (2018). Ryan and Deci (2020) suggested that research should focus on the design of learning technology and digital tools to motivate engagement and learning within learners. This chapter reviews the literature on the teaching of mathematics in high schools and strategies used, internationally, in Africa and in South Africa. A further section focuses on reviewing the literature on the use of technology in the teaching of mathematics again, internationally, in Africa and in South Africa. It is vital to examine successful applications of digital tools that enhance learner learning and engagement, as well as the resistance faced in adopting these technologies in educational settings. The chapter covers international perspectives, highlighting how various countries have embraced or resisted digital innovations in education, and addresses specific challenges and advancements within African countries, including South Africa. Through this comparative approach, the chapter aims to provide a comprehensive understanding of the role of digital tools in contemporary mathematics education globally and regionally.

The Technological Pedagogical Content Knowledge (TPACK) framework outlined by Mishra and Koehler's (2006) is discussed in detail with relevance to the study as well as Ball, Thames and Phelps (2008). Educational technology theory is explored according to its applicability to digital tools in the teaching of mathematics. This theory draws from multiple disciplines such as pedagogy, psychology and communication, ensuring technology use is aligned with educational goals. Using the two theories above and the review of literature, this study investigates the effectiveness of digital tools in the teaching of mathematics, specifically at Grade 9 level.

2.2 THE STATE OF MATHEMATICS EDUCATION

This section reviews literature on the state of mathematics education internationally, in Africa and in South Africa. The review of literature examines the use of digital tools used in the teaching of mathematics and how these tools are used to improve learner learning and performance in high school classrooms.

Figure 2.1 below the overview of the chapter.



(Source: Author's own design)

Figure 2.1: Topics discussed in the chapter

The Council for Quality Assurance in Education and Training has identified a concerning trend of poor learner performance in mathematics at all grade levels (Volmink, 2020); as a result, this study aimed to investigate the effectiveness of using digital tools in the teaching of mathematics at the Grade 9 level.

2.2.1 Mathematics Education Internationally

In Japan, Japanese mathematics education has gained global recognition for its structured 'lesson study' approach, where teachers collaborate to define learning goals understand curriculum standards and carefully plan lessons. This system emphasises a structured cyclical approach allowing teachers the opportunity to improve their teaching practice through reflection and observation (Ono & Ferreira, 2019). This approach allows teachers to plan lessons which present challenging problems and guide learners through multiple solution methods, encouraging deeper understanding (Stigler & Hiebert, 1999; Ono & Ferreira, 2019) and improves classroom dynamics and learner performance, which is considered highly effective.

In the USA, various pedagogical approaches in mathematics education have been implemented, with a major influence from the National Council of Teachers of Mathematics (NCTM). The '5E Model' (engage, explore, explain, elaborate, and evaluate) encourages active participation in lessons (Bybee, 2019), which emphasises conceptual understanding through inquiry-based learning. 'Math talks' is a strategy where learners explore and discuss concepts collaboratively, allowing them to articulate and justify their reasoning. This approach involves diverse problem-solving

strategies and assists in deepening conceptual understanding. This approach addresses diverse learning needs, tailoring lessons to support each learner's understanding and growth in mathematics (Tomlinson, 2020; Sun, 2021).

The mathematics education approach in Canada particularly in Ontario, combines interactive strategies like math talks and manipulatives, as in the USA, but with greater emphasis on learner-led learning. Educators focus on 'concept-based learning', where learners actively explore and relate mathematical ideas to real-life situations, typically without heavy reliance on technology (Scardamalia, 2019). Canadian teachers use open-ended questions and 'guided discovery' methods, encouraging learners to work in groups to explore mathematical concepts and share various solutions to a single problem (Orrill, 2019).

Singapore uses the 'Concrete-Pictorial-Abstract' (CPA) approach which focuses on helping learners grasp mathematical concepts by moving from hands-on examples to visual representations and then to abstract symbols, supporting a gradual, layered understanding of mathematics (Ng & Lee, 2019a). Gan (2020) states that this method often uses bar modelling as a visual tool which uses rectangular bars to represent known and unknown quantities, allowing learners to simplify and tackle complex mathematical word problems more effectively. Singapore's emphasis on mastery learning means that learners are encouraged to fully understand each concept before advancing, especially in mathematics, building a solid foundation that enables deep comprehension (Mote, 2020).

Orrill (2019) and Gan (2020) suggest that the use of visual tools in the teaching of mathematics classrooms creates more interest, particularly with the move away from traditional methods of mathematics instruction towards a learner-centred approach where learners work in groups. Changing teaching strategies to groupwork allow for collaboration, hence making the mathematics classroom a better environment to learn in and with the evolution of digital tools, new teaching strategies are introduced.

2.2.2 Mathematics Education in African Countries

Teachers across Africa are working to improve mathematics and other subject outcomes by maximising available resources, often in challenging environments

Rapid industrial and technological advancements of the past century and a half have transformed society from traditional methods of teaching to a knowledge-driven, globalised world with a hands-on approach (Bayode, Adebola & Oluwatope, 2019). To prepare learners for the 4IR, an era marked by advanced digital and physical integration, education systems worldwide require learners from primary school level to equip learners with relevant knowledge and skills (Voskoglou, 2020).

We are currently in the midst of the 4IR and with technology moving at such an incredible rate, there are signs that we are already entering the 5IR. The 4IR era is defined by the convergence of digital, physical, and biological systems, driven by innovations like AI, cloud computing, robotics, 3D printing, the Internet of Things (IoT), and high-speed wireless networks (Fomunyan, 2020). Ning et al. (2024) describes artificial intelligence as radically altering the techniques of teaching and learning with AI being regarded as one of the most useful instruments in the educational process for both teachers and students, both within and outside of the classroom.

With over half the world's population now online and close to 60% of the global economy digitised as of 2022, the shift toward digital transformation is undeniable. However, while developed countries have modernised their education and training systems to meet 4IR needs, many developing nations still struggle with the lingering challenges of the Third Industrial Revolution (3IR). Bayode et al. (2019) as well as Uleanya and Ke (2019), have identified countries like Niger, Togo, Lesotho, Nigeria, Ghana and Ethiopia as lagging in 4IR readiness, underscoring the pressing need for ICT integration to enhance mathematics education and foster growth in an increasingly digital global economy. Technological advancements have brought about a change with the move from the 1IR to the 5IR. leading to new robots and AI-based technology, smart industries, and other advancements. Human well-being will be enhanced by the 5IR (Ziatdinov, Atteraya & Nabiyev, 2024).

Addressing the lack of digital tools used to teach mathematics is essential not only for economic advancement but also to support the United Nations' Sustainable Development Goal for Quality Education (Akintolu & Uleanya, 2021).

In African secondary schools, educators are optimistic about the potential of ICT to enrich mathematics teaching and learning. Research has shown that ICT integration can improve learner understanding, boost interest in mathematics, and enhance

classroom engagement (Nihuka & Bussu, 2015; Bhattacharjee & Deb, 2016b; Netsianda & Ramaila, 2021). Despite these benefits, challenges remain in fully implementing ICT in African mathematics education. Netsianda and Ramaila (2021) report that teachers face significant hurdles when incorporating ICT, primarily due to limited resources and insufficient training on digital tools. Research by Ziatdinov et al. (2024) have stated that from the pre-industrial revolution through the many stages of the industrial revolution, digital aspects amongst humans have evolved, from the first to the fifth industrial revolution, technological advancement has continued to be a vital factor for human well-being. Expanding access to technological resources and improving teacher training in schools are essential steps toward successful ICT integration in mathematics education across Africa we move towards a more advanced revolution.

2.2.3 Mathematics Education in South Africa

Many South African learners continue to struggle with mathematics concepts, despite some gradual improvements at the primary and secondary levels (Reddy, 2015; Spaull, 2019; Van der Berg & Gustafsson, 2019). However, significant progress is still needed to achieve consistently high-quality outcomes across all schools. Research by Van der Berg, Gustafsson and Malindi (2020) suggests that South African school performance often resembles that of low-income countries rather than a typical middle-income nation, revealing a mismatch between resource investment and academic results.

South Africa's substantial investment in educational subjects like mathematics, spending over 30 times more per primary school learner than Uganda has not yielded proportionally better outcomes. Taylor and Robinson (2019) found that both countries have shown similar progress on Southern and Eastern African Consortium for Monitoring Education Quality (SACMEQ) assessments over the last two decades. In order to study this performance gap, issues that affect mathematics education need to be identified.

Research by Gustafsson and Mabogoane (2020) highlights factors such as teacher qualifications, uneven resource allocation and curriculum alignment which significantly impact learners' success in mathematics. By systematically addressing these issues, South Africa can make meaningful strides toward aligning mathematics performance

more closely with its economic standing. Improving mathematics outcomes also calls for a stronger focus on teacher training and support. Spaul and Jansen (2019) emphasises that the gap in educators' pedagogical skills and content knowledge contribute to learning disparities, underscoring the need for continuous professional development and robust instructional support systems. Tackling these challenges is essential for raising the quality of mathematics education and empowering learners to excel.

2.4 THE USE OF DIGITAL TOOLS IN THE TEACHING OF MATHEMATICS

As previously indicated, the competence, effective and efficient use of new technologies enhances learners' abilities to apply and transfer knowledge, thereby increasing their confidence in the learning process in core subjects like mathematics (Hazaymeh, 2021). Rapanta (2021) suggests that capability and creativity are essential qualities for ensuring high-quality teaching and learning with ICT in mathematics. According to Serhan and Alam (2022), digital tools and ICT enable teachers to create their own content, affording them greater control over course materials than traditional classroom environments allow. When learners independently engage with ICT, they take ownership of their education and improve their ability to work both autonomously and collaboratively.

This section reviews literature on the use of digital tools in the teaching of mathematics internationally, in selected African countries and in South Africa.

2.4.1 Digital Tools to Teach Mathematics Internationally

Research has revealed that the use of digital tools enhances teaching mathematics, thereby improving learner results. Smith and Brown (2020) investigated how GeoGebra was used in high schools in the USA and discovered that it helped pupils grasp algebraic ideas better. According to their findings, learners who used GeoGebra showed notable gains in their ability to solve problems and comprehend concepts when compared to those who received traditional mathematics teaching (Smith & Brown, 2020). Johnson and Wang (2021) investigated the integration of interactive mathematics software in USA classrooms and found increased learner engagement and higher academic performance results in geometry.

In Australia, Nguyen and Lee (2021) investigating the role of digital learning tools in teaching geometry to high school learners, found that digital resources significantly enhanced learners' understanding of geometric concepts, which led to improved performance in assessments and examinations. Similarly, Tan and Lim (2022) in a study of mobile learning applications in mathematics classrooms reported that the tools promoted engagement amongst learners which led to interactive, flexible learning opportunities and positively impacted the learning experience and improved overall achievement.

The integration of mobile learning tools has also taken place in Singaporean high schools. Tan and Lim (2022) agreed that mobile apps facilitated personalised learning experiences, enhanced learner engagement and interaction and provided immediate feedback, significantly boosting learner achievement in subjects like mathematics.

Software used in Swedish high schools called 'MathAid', a digital, interactive, and self-instructional mathematics tool, is available on learner's mobile devices. This software is used to assist learners in their independent mathematical studies both within and outside of the classroom (Viberg, Grönlund & Andersson, 2023). The application can be used by learners as a stand-alone resource that adheres to the curriculum or as an addition to the most widely used high school mathematics textbooks. MathAid includes a theoretical section that presents learners with specific mathematical ideas, real-world examples of the phenomenon under study, related learning exercises with answers, and useful tips that help learners complete specific tasks (Viberg et al., 2023). Teachers can utilise MathAid's capabilities to monitor learner usage, both individually and in class. The interactive and self-instructional learning activities of MathAid include moving graphs that illustrate mathematics, explanations and calculating methods (Viberg et al., 2023).

In Spain, teachers have adapted their teaching to make mathematics digitally friendly and usable. According to Cabero (2020), digital competence is a critical skill that citizens, and particularly mathematics teachers, must acquire to participate fully in future society. The recent National Plan of Digital Competences (MINECO, 2021), launched 2021, is a strategic roadmap under the Digital Spain Agenda 2026 aiming to ensure 80% of citizens have basic digital skills. This initiative highlights the development of Teachers' Digital Competencies (TDC) across all educational stages,

including higher education, as a strategic goal aimed at fostering sustainable and inclusive economic growth. Teachers play a vital role in the adoption and use of ICT within classrooms and are instrumental in the integration of technology when teaching mathematics, as the advancement of education depends on their ability to implement effective digital competencies in a pedagogically meaningful way.

2.4.2 Digital Tools to Teach Mathematics in African Countries

Digital tool usage in mathematics classrooms in African countries has seen growth. However, Abdullahi and Sirajo (2022) state that while there is much knowledge about the use of digital tools in developed countries, there is not much information and access on the introduction of these tools in schools in developing countries. Certain countries in Africa have been selected to discuss how digital tools have been introduced and used to teach mathematics in the next sections.

2.4.2.1 Nigeria

The use of technology in Nigeria has been successful to an extent within the mathematics class. A study by Adegoke and Akinola (2021a) on Nigerian learners in high schools observed that the use of digital technologies in their classes resulted in better class participation and comprehension of even the most difficult mathematical concepts. Nwosu and Anikwe (2022) found that the learners' ability to solve mathematical problems was greatly enhanced with the use of interactive digital means while their interest in learning mathematics was also heightened. In the same way, Okereke and Ifeanyichukwu (2023) discovered that the use of technology in teaching mathematics promotes group learning among learners who assist one another. In agreement, Eze and Okwu (2020) maintained that the use of digital resources makes it possible to practise individualised teaching approaches for diverse learners in the same classroom.

2.4.2.2 Rwanda

Rwanda has made a concerted effort to integrate the digital world into their education systems. They have introduced the 'one laptop per child' programme together with the setting up of 'smart classrooms' to improve the learning processes (Rwanda Education Board, 2015b). The importance of technology in effective teaching and learning is also illustrated by the studies conducted by Vásquez, Martínez and Salinas (2017) as well as Elmahdi Alhassan and Elshahed (2018). Both authors found that using technology

in classrooms are valid and teachers should embrace this as it effects learning and teaching of mathematics.

The use of digital tools/ICT in Rwandan secondary schools has been transformed mathematics teaching and learning by enhancing both physical and digital classroom environments. Modern ICT studies show that the integration of various technologies in the teaching of mathematics includes software, hardware, delivery systems, and multimedia, all of which improve the educational experiences (Niyibizi, Uwitatse, Sibomana & Mutarutinya, 2023). Das (2019) noted that embracing digital technology such as computers, Smartboards, handheld calculators, overhead projectors, smartphones, and cloud computing, along with applications like simulators, spreadsheets, virtual environments, and video conferencing are advancements contributes to a more dynamic and interactive mathematical learning process.

Technology plays a crucial role in enhancing mathematics teaching practices, and its effective integration supports learners in meeting their learning needs, as mentioned by Niyibizi et al. (2023). In addition, the use digital tools in mathematics also increases the attention of learners and their participation in learning activities (Iyamuremye, Tuyizere & Uwizeyimana, 2022; Nsabayeze, Gafaranga & Ngabonziza, 2022).

2.4.2.3 Ghana

Ghana is seen as a developing country when it comes to digital usage within classrooms even though the integration of ICT into mathematics teaching and learning is in its early stages (Antwi, Bansah & Franklin, 2018). The authors contend that this approach can enhance teaching and learning. However, interruptions due to power outages could be a challenge. Hamajoda (2018) therefore suggests that providing solar power and backup generators can support e-learning by addressing the electricity challenges often faced in rural areas. Although academics may initially be reluctant to adopt e-learning in school subjects such as mathematics, there is a growing need for them to adapt positively to technological changes in classrooms (Flavell et al., 2019).

To encourage adaptive mathematical learning in technology Solangi, Shahrani and Pandhiani (2018) suggest enhancing both teacher and learner self-efficacy. Flavell et al. (2019) state that encouraging academics to engage with technology in leisure activities, such as reading on digital devices, gaming or social media, could help them

become more comfortable with e-learning. Ngai, Lee, Ng and Wu (2018) note that collaborative e-learning could foster an exchange of experiences and ideas among learners, promoting teamwork, improving academic competence, enhancing self-efficacy, and building social and cognitive skills essential for e-learning, especially in mathematics.

2.4.2.4 Zimbabwe

During the COVID-19 pandemic, the global education system was compelled to shift from conventional in-person methods to virtual and online platforms. In Zimbabwe, school closures due to the pandemic impacted approximately 4.56 million learners who depended on in-class instruction (OCHA, 2020), which led teachers to moving towards using WhatsApp as a teaching tool to teach mathematical concepts via text messages. WhatsApp primarily was used because it was affordable and accessible. This aligns with Ngalomba (2020), who highlighted that WhatsApp is user-friendly and requires less expensive data bundles compared to other online platforms.

Research in Zimbabwe was carried out by Suzuma, Zezekwa, Mutambara, Chagwiza and Gwizangwe (2022) who found that the increasing use of digital tools, primarily smartphone, has assisted in the teaching of mathematics. Learners use their phone to access digital apps such as GeoGebra to develop understanding and the use of WhatsApp enhances allows for communication between students and teachers which leads to greater learner understanding of complex concepts.

Figure 2.2 illustrates how teachers conveyed mathematical concepts through text messages, prompting learners with questions to which they responded via text. Image A shows how the teacher used text messages in their instruction. Another instance of text message-based teaching is depicted in Image B.

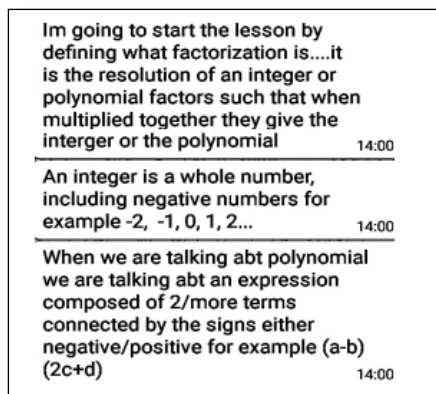


Image A

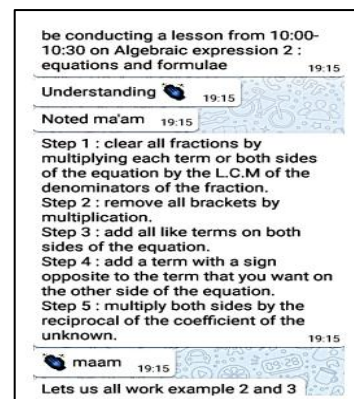


Image B

(Source: Suzuma et al., 2022:5)

Figure 2.2: WhatsApp Chats

However, Wahab (2020) suggests that educational systems must swiftly adopt new technologies to support learning initiatives and ensure better learner performance.

2.4.3 Digital Tools to Teach Mathematics in South Africa

The use of digital technology and ICTs have been appraised as a powerful tool in the educational sector, as they are a combination of technologies which can be feasible and flexible (Nanbam, Ringim & Ringim, 2018). Mavhunga and Naidoo (2020) investigated the impact of digital tools, interactive software and online resources being used in mathematics. They found that technology boosted learner participation and understanding which improved their results. Furthermore, Botha and Erasmus (2019a) indicate that the use of digital tools in assessments allows for generated feedback in high school mathematics. Giving feedback to learners assists them in identifying their weaknesses in a topic, giving them motivation to continue working with digitals tools to achieve overall learning efficiency.

During the COVID-19 pandemic, teachers without access to computers and the internet used their cellphones and WhatsApp to continue with the learning process. Bonsu et al. (2021) noted that the use of WhatsApp facilitates the teaching anytime and anywhere. The Department of Basic Education (DBE, 2020) suggested that learner groups be formed using WhatsApps via their digital devices to create online learning groups to encourage learners to work together and learn with their peers. Mathematics teachers reported that WhatsApp provided a conducive environment for

peer teaching, allowing them to use audio recordings to explain selected mathematics topics, save discussion texts, and share images and videos (Naidoo, 2020).

A drive to implement educational technology in mathematics education is seen by projects by adopting a research-driven approach. The Wits Maths Connect-Primary (WMC-P) project, launched in 2011, is a drive led by Professor Hamsa Venkat, who holds one of the 10 Chairs in Mathematics Education sponsored through a partnership of the First Rand Foundation, the Department of Science and Technology, the National Research Foundation and Anglo-American South Africa (CASME, 2019). Progress has been seen in schools that use this resource. The Wits Maths Connect-Primary project was implemented to introduce digital tools into mathematics via research, initiated by the professor. This was a big move in implementation of digital usage in mathematics.

In the next sections, certain provinces in South Africa have been selected to discuss how digital tools have been introduced and used to teach mathematics. However, it should be noted that within each of the provinces, there still exists a discrepancy with resource provision between affluent urban areas and impoverished rural communities.

2.4.3.1 Western Cape

To explore the successful use of digital tools and ICT in teaching mathematics at high schools in the Western Cape, recent literature and regional initiatives provide valuable insights. The Western Cape Education Department (WCED) has led multiple projects since 2019 to integrate digital technology across schools, including the development of 'Smart Classrooms' and expanding access to e-learning resources in core subjects like mathematics. This includes the use of digital tools aimed at enhancing mathematics instruction, such as interactive applications, virtual simulations, and digital assessments, which have helped increase learner engagement and improve learning outcomes in mathematics across the province (WCED, 2019).

The WCED in Circular: 0038/2016, identified three key steps to create a technology-rich environment in its schools, namely, to provide high speed broadband in most schools by the end of 2016, to equip schools with Wi-Fi and to create an enabling environment in which learners, teachers and parents have access to digital resources (WCED, 2016). Based on the report, Lesch (2015) highlights three vital issues which include the upgrading of school facilities to support digital integration, teacher

development through training to ensure that teachers in mathematics and other subjects receive training to enable them to use smart classrooms and e-learning technology optimally and learner engagement to personalise learning, improve engagement and provide access to a range of content.

2.4.3.4 Gauteng

As the world of work evolves, educators are tasked with preparing learners for a future shaped by rapidly changing technologies; Gauteng has been one of those cities adapting to digitisation in subjects like mathematics. This signifies the onset of a revolution that is transforming lives digitally (Schwab, 2016). However, teachers who engage in professional development related to digital technology acquire the skills essential for the digital age, which will enable them to integrate these competencies into their mathematical teaching and learning approaches. Bates (2015) agrees that various skills are needed in the digital era, including collaboration, adaptability, critical thinking and digital literacy.

The integration of ICT in the classroom promotes a learner-centred approach. For example, project-based learning requires learners to tackle real-world mathematical problems using diverse technologies. As learners build confidence in using ICT, they are better equipped to apply and share their knowledge effectively (Bhattacharjee & Deb, 2016a).

Training on GeoGebra, a software tool, was provided to mathematics teachers in Gauteng. This tool facilitates interactive lessons across various mathematical domains, including geometry, algebra, calculus, and statistics. This software is also compatible with Smart Notebook, enhancing its usability in teaching contexts (Kheswa, 2020). This shows us that Gauteng has adopted the use of digital tools and has implemented in schools, where possible. The current status of digital tools seen from literature informs us as teacher, that the use of digital tools in the province are effective.

2.4.3.3 Kwa-Zulu Natal

Research has found that many teachers demonstrate strong content knowledge and effectively utilise traditional methods to teach mathematics in a productive manner (Aliustaoglu & Tuna, 2021). However, it is essential for mathematics teachers to move beyond memorisation, repetition and recitation of correct answers. They need to develop the ability to guide learners in reasoning, communication, and other 21st

century skills, which are key to preparing them for the 4IR. Through mathematics instruction using digital tools, teachers should encourage collaborative learning, enabling learners to tackle complex, real-world problems (Naidoo 2019).

Newly qualified teachers are equipped with the knowledge and skill to instil 21st century learning skills, as higher education institutions increasingly emphasise these competencies (Leikin & Elgrably 2020). Leikin and Elgrably (2020) go on to highlight that teachers' expertise is crucial, particularly in the use of digital tools in the teaching and learning process. Use of digital tools would foster the development and promotion of mathematical knowledge and engagement. Mathematics educators, therefore, need to integrate concepts from various educational theories and with their knowledge and skills assist learners in acquiring and developing mathematical abilities (Aliustaoglu & Tuna 2021).

2.4.3.2 Limpopo

Limpopo, a more rural province, has been faced with issues in the implementation of digital tools in classrooms. However, Mwapwele, Marais, Dlamini and Van Biljon (2019) report that despite infrastructural challenges and lack of institutional support, rural teachers strive to use technology for mathematical teaching and learning. Hence one can deduce that teachers have the willingness to use technologies in their teaching; it can be argued that if digital resources are available and accessible, then implementation of blended learning can be possible in schools.

Mathematics departments need to facilitate the establishment of ICT-enabled classrooms and schools must provide teachers with adequate support, resources, and technical assistance, as Goh and Sigala (2020) emphasise, especially with provinces like Limpopo. The review of literature, reveals that integrating ICT into their teaching practice, teachers' primary responsibilities include setting up computer labs with the support of technology learning specialists or assistants and thereafter, restructuring their courses to ensure they are learner-centred and have the ability to develop learners' mathematics understanding.

2.5 CHALLENGES IN USING DIGITAL TOOLS IN THE TEACHING OF MATHEMATICS

A range of factors are responsible for the challenges that teachers face in the use of digital tools in their teaching practice. In this section challenges experienced in the use of digital tools is reported from an international, African countries and a South African perspective.

2.5.1 Challenges in Using Digital Tools in the Teaching of Mathematics Internationally

Digital tools have been incorporated into aspects of life in many countries abroad yet still face challenges when used as a teaching tool. The USA seemed to adopt digitisation easily. However, Ertmer (2019) reported on the resistance that teachers have towards adopting ICT in mathematics education, highlighting factors such as lack of training, fear of technology and entrenched pedagogical beliefs (Ertmer, 2019). Anderson and Thompson (2021) add that the reluctance of the use of digital tools in teaching mathematics by mathematics teachers in the USA is due to the fear of new age technology integration in the classroom which replace traditional teaching methods.

Australia is technically inclined but certain digital practices still experience opposition. Wang and O'Connor (2023) investigated technical issues in Australian schools, where mathematics teachers face challenges with using digital tools. Davis and Nguyen (2021) also noted that mathematics teachers in Australia, resist using digital and ICT tools even though these tools can be beneficial as they are used to traditional methods within the classroom.

India has been faced with many resource issues as well as access to digital tools. Rao and Mehta (2022) report on significant infrastructural limitations in schools in India which limit access to and use of digital tools in mathematics education. Due to being under resourced, inadequate training and lack of support to mathematics teachers results in teachers lacking confidence using these digital tools in their classrooms (Kumar & Singh, 2020a). Research by Hernawati and Jailani (2019) highlighted unmet objectives, revealing that teachers still require a deeper understanding of how to design technology-integrated lesson plans that align with 21st century learning.

2.5.2 Challenges in the Use Digital Tools in the Teaching Mathematics in African Countries

Ghana, Nigeria and many other African countries have shown progress in digitisation yet still encounter resistance. Acheampong and Boateng (2020) indicated that in Ghanaian High Schools, digital tools were integrated yet barriers in using digital technologies to teach mathematics were identified. Furthermore, Adegoke and Akinola (2021a) in a study in Nigerian schools, identified factors such as inadequate infrastructure, limited teacher training, and a divide in suburbs causes issues in integrating digital tools in such settings. As Nigeria deals with the challenge of delivering quality education to its rapidly growing youth population (World Bank, 2018), the secondary school phase emerges as a pivotal point in learners' academic development digitally.

E-learning in subjects, like mathematics in Malawi has expanded partially in response to the demand for greater access to higher education and the limitations of teaching staff, as higher education institutions face significant capacity pressures (Maere, 2011; Chawinga & Zozie, 2016; Kayange, 2019). Interest in e-learning was motivated with the closure of educational institutions during the COVID-19 pandemic. However, it is concerning that only 0.8% of Malawi's population currently accesses in education (World Bank, 2019).

A major challenge faced by teachers in Zimbabwe is covering internet costs from their limited salaries while using personal devices to manage hundreds of assignments (Matimairé, 2020; Vurayai, 2022). Research has shown that quality teaching and learning in Zimbabwe is hindered by the digital divide and factors contributing to this divide include limited to no internet connectivity, affordability issues, ICTs gadgets and data costs, inadequate infrastructure and a skills gap in utilising ICT tools. These challenges restrict students' access to quality ODeL. However, to those with access, virtual learning offers convenience and flexibility (Kurebwa, Moyo & Lumbe, 2025).

The nature of mathematics, lack of ICT and digital knowledge, lack of interaction and human interruptions were some of the educational challenges faced by the teachers during the teaching of mathematics. While WhatsApp is a useful, accessible tool for communication and peer support, the nature of mathematics with its abstract concepts, precise symbolic notation, visual representations (graphs/diagrams), and

step-by-step logical, procedural steps, poses challenges when teaching mathematics, (Suzuma et. al., 2020). This could mean that the use of WhatsApp often fails as a primary instructional medium due to its limitations in handling complex, non-textual information. In addition, Okeji and Alex-Nmecha (2021) found that teachers did not have control over who would attend and when they would exit the lesson. Since the WhatsApp platform is free and can be used freely, both learners and teachers need self-discipline as well as being more responsible, which might be a challenge when learning mathematics.

2.5.3 Challenges in the Use of Digital Tools in the Teaching Mathematics in South Africa

According to Prof. Ndlovu, from the University of Johannesburg, the benefits of implementing Emergency Remote Teaching and Learning (ERTL), necessitated by the COVID-19 pandemic, have strengthened the argument for Education 4.0, a future-oriented, student-centred approach aligned with 4IR, focusing on artificial intelligence, robotics, and smart technology to enhance learning. which is where digital resources are useful (UJ, 2023). Popular digital resources with features for use as online communication platforms in mathematics classes include learning management systems like Blackboard, Moodle, Sakai, Google Meet, Google Classroom, and conferencing applications like Zoom, MS Teams (UJ, 2023).

Young learners appear to find mathematics instruction in a modern digital environment difficult to comprehend (Wang et al., 2023). Teachers are accustomed to using a traditional approach in the teaching of mathematics, which entails using an ink marker to display problems and formulas on a whiteboard (Fuentes-Cabrera, Parra-González, López-Bemonte & Segura-Robles, 2020). This method is difficult to duplicate in an online learning environment, though. Additionally, a major obstacle is the inability to write mathematical calculations. The best teaching and learning software must be carefully considered and chosen to provide sufficient and interesting examples (DIMAS, 2024).

Although digital technologies have been used at different phases of schooling (Murcia, Campbell & Aranda, 2018) as well as in adult education (Gegenfurtner, Schmidt-Hertha & Lewis, 2020a), insufficient resources contribute to the negative ICT usage in some South African classrooms (Hansson, 2018). Core subjects like mathematics

require resources, such as ICT and digital tools which has the potential to improve learner achievement in mathematics (Khan, 2020). However, the Department has admitted that ICT-integration efforts nationally are poor due to a shortage of funds (Parliament of the Republic of South Africa, 2018).

Research has highlighted the lack of continuous professional development (CDP) as the primary obstacle to effective mathematics teaching (de Freitas & Spangenberg, 2019). Additional challenges include curriculum changes (Venkat & Spaul, 2015), the issue of unqualified mathematics teachers (Long & Wendt, 2019), insufficient resources in disadvantaged schools (Ndlovu, Wessels & De Villiers, 2013), and the influence of teachers' beliefs on mathematics instruction (Pfeiffer & Ndlovu, 2018). These challenges are prevalent to some degree in each of the provinces.

2.5.3.1 Gauteng

Technology is seen as essential for building 21st century digital literacy skills (Hogenbirk, 2016), especially within the mathematics classrooms. The use of technology in some Gauteng township schools is still hindered by issues such as network connectivity, availability of digital devices and high connectivity costs, particularly affecting township and rural schools (Ferreira, 2013). Van Dyk and White (2019) explain that the quintile-based ranking of schools reflects economic disparities: quintile 1 and 2 schools are the most under-resourced, while schools in quintiles 3, 4, and 5 have relatively stable funding. In Gauteng, most quintile 1 and 2 schools are in townships and informal settlements. Van Dyk and White (2019) also note that high poverty levels restrict access to the financial and material resources needed for digital remote teaching and learning in all subjects. These factors affect mathematical learning through digital platforms. In Gauteng, specifically the Ekurhuleni district, it was seen through this study that there are still challenges faced by schools and mathematics teachers in implementing the tools when teaching grade 9 mathematics. This study showed through the data collection methods and analysis what schools and teachers have said about digital tools in grade 9 mathematics classrooms.

2.5.3.2 Kwa-Zulu Natal

Despite the advantages of incorporating digital tools, some teachers show limited interest in using technology in their mathematics classrooms (Daher, Baya'a, & Anabousy, 2018). Research suggests that teachers face obstacles like low confidence, restrictive beliefs, limited skills, and attitudes toward technology in teaching

mathematics, which affect their ability to fully integrate ICT in their classrooms (Thomas & Palmer, 2014). Additionally, de Freitas and Spangenberg (2019) identified four key barriers hindering ICT usage which include confidence, time, access to resources, and professional development. Teachers in the uMkhanyakude district in northern KwaZulu-Natal, continue to struggle with integrating ICT into mathematics teaching due to inadequate infrastructure (Dzansi & Amedzo, 2014).

2.5.3.3 Limpopo

Teachers in Limpopo have attempted to prompt the integration of ICT into classrooms (Helmets, 2017). Munje and Jita (2020) provide evidence that the South African government has long recognised the necessity of ICT integration in education, especially core subjects like mathematics. Many believe that young people are so accustomed to technology that they may feel lost in environments without it (Hogenbirk, 2016). However, this assumption does not apply to all learners in South Africa, given the country's diverse socio-economic conditions. Research by Olatoye, Nekhevha, and Muchonyerwa (2021) emphasises that the ICT skills in mathematics will help learners develop can benefit them if or when they pursue higher education.

Despite this, most discussions on ICT integration in education tend to focus on STEM subjects, science, technology, engineering and mathematics (Carrim, 2022). There are, however, arguments supporting ICT use in language classrooms as well (Floris, 2014, Huang & Hong, 2015; Fariyah & Fauziyah, 2018) and not only for science and mathematics; this is a need also recognised by UNESCO. Although the integration of ICT is viewed as beneficial, evidence suggests that South Africa has not made substantial progress in driving this in the classroom, as confirmed by Munje and Jita (2020) who report that that digital advancements in South African schools have been limited.

2.5.3.4 Eastern Cape

In a report to the Portfolio Committee on August 20, 2013, the Department of Basic Education (DBE) indicated that only 10% of schools in the Eastern Cape Province had computers available for teaching and learning (Mweli, 2013) which shows the challenge of accessible resources for the schools. By June 2016, this figure had risen by just 0.82%, reaching 10.82%, showing a very small percentage of digital tools being used and available to schools. By August 2019, the percentage increased by a further 1.65%, reaching a total of 12.47%, as illustrated in Figure 2.1 below (DBE, 2019). The

progress over the years illustrates a slow progress which has challenged in the use of digital tools for the teaching of mathematics.

In 2017, the Eastern Cape launched the Teacher Laptop Initiative, providing teachers with laptops and data for educational use (George & Linden, 2017) to improve student performance and the quality of education by enhancing teacher productivity, professional development, and administrative efficiency through the use of Information and Communication Technologies (ICT).

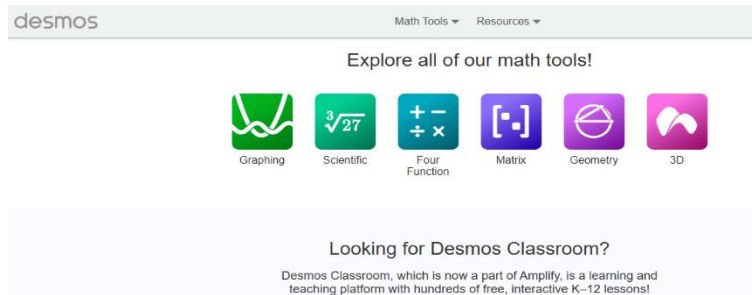
According to Maqoqa's research (2023:409), "technology gives extra chances for learners to see and interact with mathematical concepts" (Maqoqa, 2023:409). The study further reports that and that "improved technological availability for mathematics enables for a more tailored learning experience" (Maqoqa, 2023:409). It was noted that "incorporating technology into the mathematics classroom when available, enables learners to interact with others outside of the classroom to help broaden their understandings and perspectives about what they are studying" (Maqoqa, 2023:412). However, Maqoqa (2023:410) acknowledges that the "challenge rises with accessibility to tools and implementation of technology in classrooms, to teach mathematics". Despite the movement of technology use in the broader society, mathematics teachers do not always use digital tools and platforms to its full potential. The exploration of the available tools and platforms should become an easier way of enhancing mathematics concepts amongst teachers.

2.6 DIGITAL TOOLS USED IN THE TEACHING OF MATHEMATICS

Digital tools for teaching mathematics enhance engagement through visualisation, interactive practice, and personalised learning. Key tools include graphing calculators like Desmos and GeoGebra for dynamic geometry/algebra and AdvLearn and Khan Academy for personalised instruction.

2.6.1 Desmos

Desmos creates interactive, visual representations of abstract mathematical ideas. Figure 2.3 shows the Desmos online portal.



(Source:

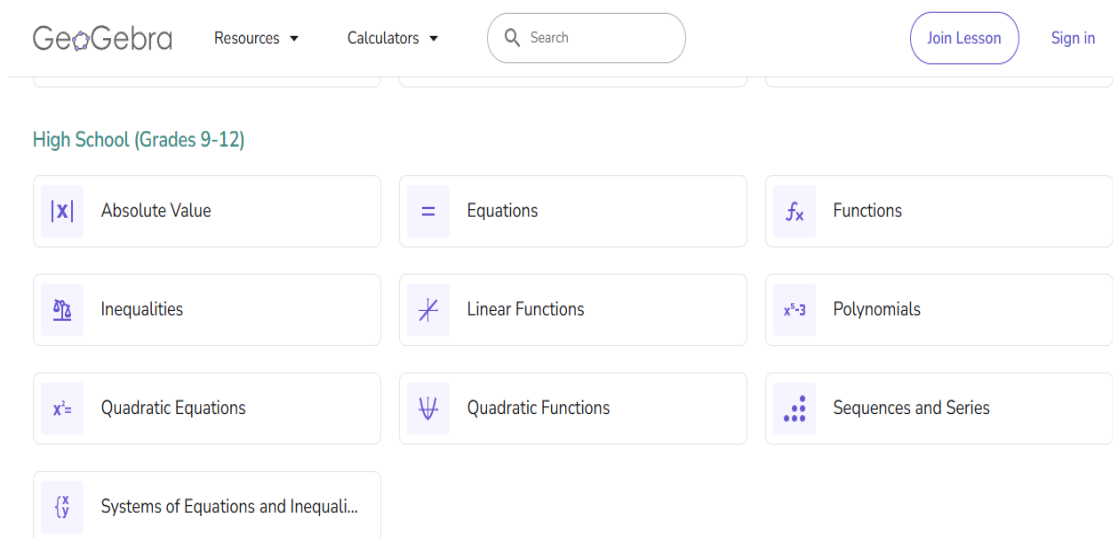
Kristanto, 2019:1)

Figure 2.3: Desmos online home page showing different mathematics topics

Desmos is an online tool designed to make math enjoyable and easier for pupils to learn (Kristanto, 2019). There are numerous free online mathematics exercises on Desmos that support learners' learning in various ways. Desmos offers a graphing calculator and an activity creation tool for math education. This platform is helpful, particularly for teaching and learning through online classes in the mathematics classroom.

2.6.2 GeoGebra

The GeoGebra portal shown in Figure 2.4, shows a variety of mathematical concepts with application activities under each tab. Questions can be created to real life situations in some instances.



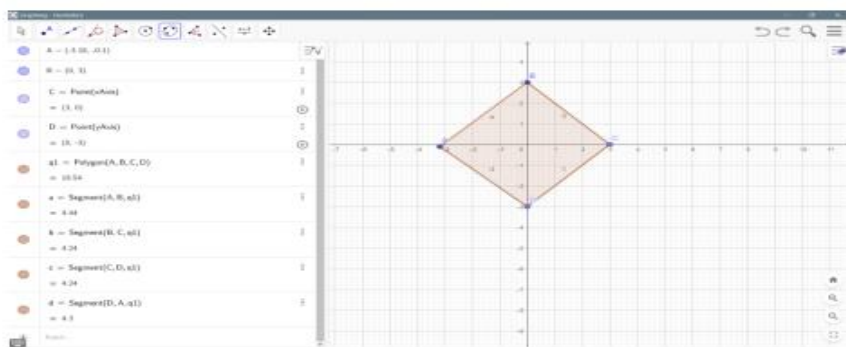
(Source: GeoGebra portal, Google, 2025:1)

Figure 2.4: GeoGebra illustration of the number concept on integers

2.6.3 GeoGebra Mobile

According to its official website (geogebra.org, 2020), millions of people use GeoGebra worldwide, indicating that its usage has increased quickly. Additionally, it is a top supplier of many mathematical applications that advance science, technology, engineering and global education technology and maths (STEM) education.

Figure 2.5 shows how GeoGebra may be used on devices, like cell phones or tablets to explore various algebraic functions easily. One may input various equations and explore the effects when variables change.

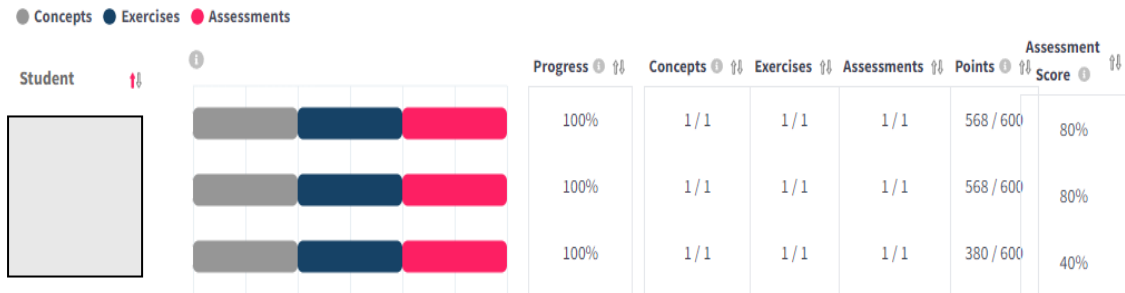


(Source: Widianti, 2023:3)

Figure 2.5: GeoGebra Mobile application

2.6.4 AdvLearn

ADvLEARN is a customised platform for ADvTECH schools that provides personalised learning paths in mathematics using adaptive technology to deliver data-driven insights and learning analytics. Learners are offered a unique learning experience while constantly improving their understanding in core areas. ADvTECH school division uses ADvLEARN to enhance learning in Mathematics (Grades 7 to 12), Physical Sciences (Grades 10 to 12), and Mathematical Literacy (Grades 10 to 12). The pedagogy applied in ADvLEARN seeks to find the mathematical and science gaps in learners' learning and then fill these gaps to ensure they improve their understanding in core areas. Through adaptive learning technology, the system supports both learners who want to progress faster as well as learners requiring reinforcement of key concepts (AdvTech, 2023).

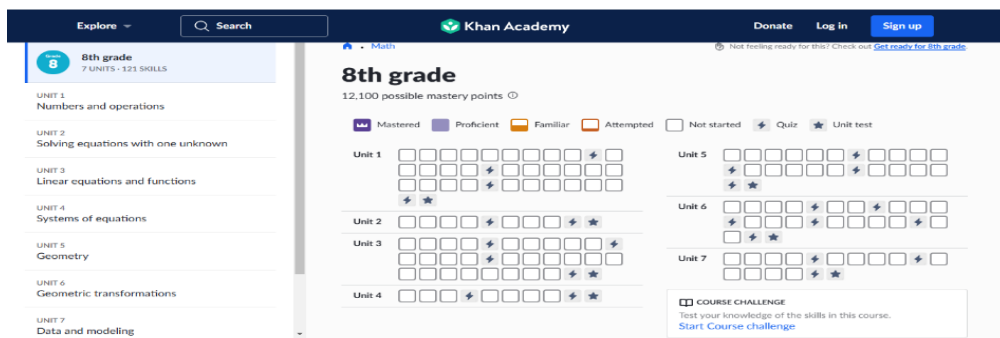


(Source: AdvLearn, 2024: 1)

Figure 2.6: AdvLearn portal

2.6.4 Khan Academy

Khan Academy is a famous mathematical digital tool that provides anyone with internet connection with a free online resource for self-directed learning. The resources provided in various fields are accessible to millions of people, encouraging self-control and lifelong learning. Khan Academy can be used for practice in class, as part of blended learning, or to flip learning, where learners learn more at home and then practice and get explanation in class (Khan Academy, n.d.).



(Source: Khan Academy, n.d.)

Figure 2.7: Khan Academy 8th grade resource page

2.7 THEORETICAL FRAMEWORK

Technology pioneer David Warlick (2020), an educator, author, and programmer, stated, “We need technology in every classroom and in every learner and teacher’s hand, because it is the pen and paper of our time, and it is the lens through which we experience much of our world.”

This section highlights the key theories that serve as the foundation of the research. As the starting point for critiquing scholarly work, the theoretical framework guides the

research process (Grant & Osanloo, 2014). Overall, the theoretical framework seeks to ensure that research findings are meaningful, widely accepted and applicable within broader theoretical structures (Dickson, Emad & Joe, 2018).

A theoretical framework is shaped by using established or emerging theories within a field with a significant historical foundation. It may include one or more interrelated theories that provide a reference point for predicting or explaining study outcomes. In this study two theories namely, educational technology theory and technological, pedagogical and content knowledge, commonly referred to as TPACK, were most appropriate. These two theories interlink and encompass digital technology allow for the aligned of this study with the history of the theories.

Nowadays, teaching mathematics does not only need a teacher and content knowledge but also pedagogical skills, which means knowing how to go about teaching mathematical concepts and familiarity with the best learning technologies (Nantschev et al., 2020). Educational technology focuses on the aspect of technology whilst TPACK relates to the interlinking of technology, pedagogy and knowledge of mathematics

2.7.1 Educational Technology Theory

Educational technology equips learners with the knowledge, skills, and competencies essential for success. The educational technology theory shows that by using ICTs, learners can access, create, and share information while enhancing their communication, creativity, problem-solving, and critical thinking abilities (Cirneanu & Moldoveanu, 2024). Furthermore, educational technology exposes learners to real-world challenges and opportunities, including computational thinking, physical computing, programming, and coding are key skills required across various industries and roles in the digital economy (Bressler & Bodzin, 2013).

Educational technology involves the systematic study and responsible application of theories, research findings and best practices using ICT and digital tools. Drom (2022) states that from the perspective of theory, it seems that technology is not so much a class of things or technical objects, but more a way of thinking about things in terms of how they work, as well as a way of acting on things to design them to work differently.

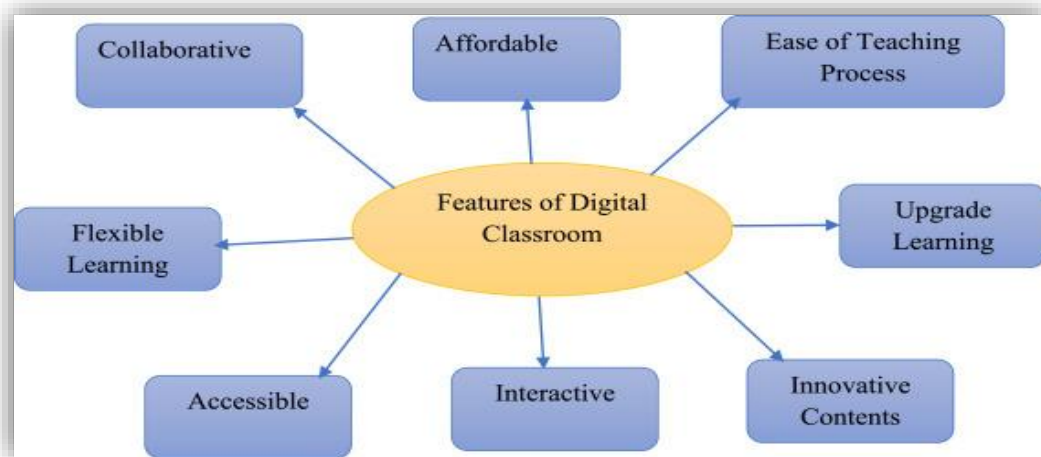
Applying the theory is evident within certain countries. Australian teachers focused on using technology in education such as using interactive digital tools in mathematics classrooms aligning this with the learning environment (Goos, 2020). Lee and Tomaszewski (2020) reported that in Australia, digital tools have been integrated into mathematics education to create interactive and learner-centred environments which facilitates better understanding through inter-active learning.

In Finland, Heikkilä and Lehtinen (2020) reported on digital tools being integrated into mathematics education which promoted learner-centred learning and allowed for collaboration among students. Encouraging learners to connect and solve problems with peers online as seen in schools in Finland, encourages collaborative learning and peer interaction in the teaching of mathematics (Siemens & Matheos, 2019).

Singaporean teachers use technology to enhance mathematics education, improving instruction and learner engagement via digital usage in their classes (Kaur, 2021). United Kingdom (UK) researchers Clark-Wilson, Robutti and Thomas (2020) analysed the role of digital tools in mathematics classrooms, looking at ways that collaborative platforms enhance learners' engagement and performance. In Japan and South Korea, Tanaka and Nakamura (2021) stated that the learning theory supported the implementation of digital tools in mathematics education. This was evident in the creation of digital assessment platforms which provide immediate feedback, allowing learners to pick up from their mistakes leading to achieving improved learning and results.

Digital tools and technology can bridge the equity gap in African schools when it comes to mathematics education in under-resourced schools (Rambe & Mlambo, 2020). The integration of digital tools in African secondary school mathematics classes showed both successes and challenges and teachers face while adopting digital tools (Khan & Ogundipe, 2020). Barriers to using and integrating educational technology in mathematics classrooms is evident in schools in Kenya (Mwenda & Thabo, 2021) where particularly with attempts to use mobile learning tools and digital textbooks.

Figure 2.8 highlights the features of a digital classroom, emphasising its flexible learning, affordability, accessibility, collaboration, interaction, innovative content, and ease of teaching processes, all of which align with key principles of Educational Technology Theory.



(Source: Kadya, 2024:1)

Figure 2.8: The features of a digital classroom

Educational Technology Theory promotes the use of digital tools to enhance learning environments, ensuring learners can engage meaningfully with content while fostering deeper understanding through technology integration.

Flexible and Accessible Learning: Features of digital platforms assist learners to learn at their own pace. Videos assist learners in areas that they find difficult while reviewing mathematics (Almekhlafi & Hiasat, 2021). Scores in metrics and questionnaires have been improved by adding features like video tutorials, quizzes and digital simulations.

Affordability: Cost wise, with regard to a single user perspective, technology-enhanced mathematics instruction proves to be a cheaper alternative as it minimises the dependency on physical resources such as textbooks and notebooks (Raza & Qazi, 2020). Free educational tools and platforms and open-access resources help in providing quality learning materials to resource constrained schools.

Collaborative Learning: Learners can engage in collaborative learning from any location through online tools whilst in a digital classroom setup that allows real-time interaction (Voogt et al., 2019). Peer instruction and group work which are essential in enhancing the learners' skills in solving problems in mathematics, are also encouraged with to utilize Google Classroom, a virtual classroom platform that allows educators to provide organised tools and resources for students.

Ease of Teaching Process: The use of instructional programs such as GeoGebra and Desmos makes it easier for the teachers to explain difficult mathematics topics

(Hodges et al., 2020). Various administrative processes are made easier through technology. For example, the creation of worksheets and assessments, the marking of scripts and the submission of assignments is made easier. South African teachers state that the use of digital technology serves two primary purposes because of its evolution: firstly, a support for the organisation of the teacher's work (generating worksheets, keeping grades), and secondly as a support for innovative approaches to mathematics (Sinclair & Robutti, 2020)

Innovative contents: Teachers have found that digital technology assists in creating innovative approaches to mathematics (Sinclair & Robutti, 2020) such as group learning and sharing of answers and activities for all students to see.

Interactive: of the teaching and learning of mathematics is more active and helps in problem-solving through offering interactivity in digital classrooms. Adding these digital features to the mathematical pedagogy, research shows that learners' interest and learning are enhanced using digital tools (Aydin, Saka & Dikmen, 2019).

Upgrade learning: Learning experiences become better when technology introduction, via digital tools are used as a method of instruction.

2.7.2 Technological, Pedagogical and Content Knowledge (TPACK) Model

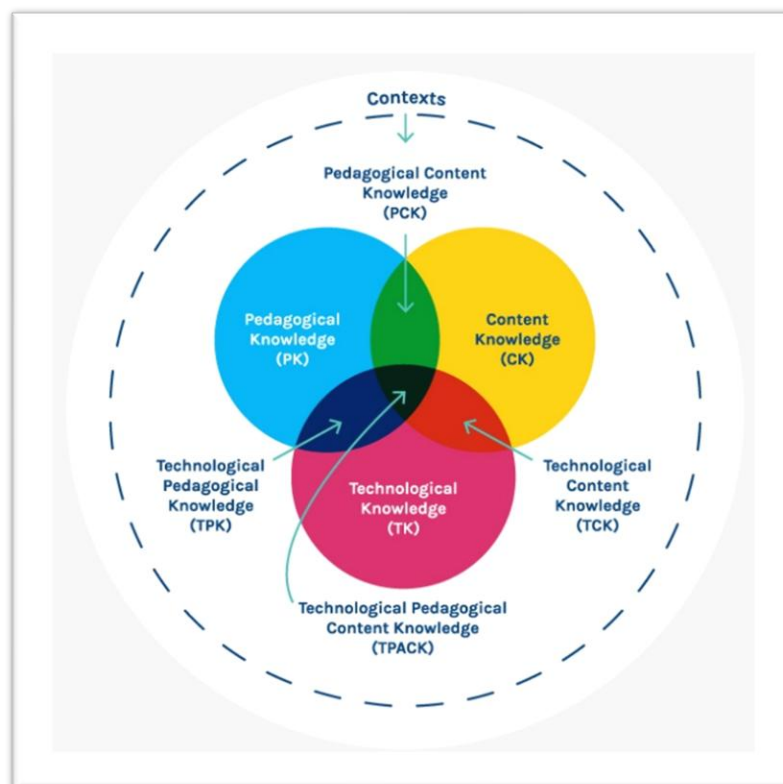
The technological, pedagogical and content knowledge (TPACK) model has been introduced as a conceptual framework to support teachers in using technology effectively together with their subject knowledge (Luo & Zou, 2022). TPACK is a model for teachers that identifies three core knowledge areas, Content (CK), Pedagogy (PK), and Technology (TK), and their complex interactions, guiding effective and meaningful integration of technology to enhance student learning by blending subject matter expertise, teaching strategies, and technological tools (Ning et al., 2024).

The TPACK model is relevant as a framework in investigating effective practices in the integration of technology in the teaching and learning environment. To answer research questions within this study, the TPACK model offers guidance for the practice of teachers in the integration of technology in the teaching environment. Effective technology integration requires teachers to develop knowledge in all three areas and understand their dynamic relationships, allowing them to design powerful learning experiences rather than just using technology for technology's sake. Gonzales and

Gonzales (2021), reported that while teachers are able to adapt to the digitalisation of learning activities, their pedagogical skills, particularly in developing learning objectives, tend to lag. It is sometimes difficult to distinguish pedagogical content knowledge from other types of teacher knowledge; it can refer to both content knowledge and primarily pedagogical skills, hence having a model like TPACK allows structure about teacher knowledge and skills as found in studies by Ball, Thames and Phelps (2008).

2.7.3 TPACK Model and its Components

Figure 2.9 below presents the TPACK model with its specific components.



(Source: Mishra, Warr & Islam, 2023:1)

Figure 2.9: TPACK Model

To understand the role of TPACK in mathematics classrooms, it is essential to grasp the model's core concepts. According to Shulman (1999), the components include Technology knowledge (TK) which refers to human understanding of tools, materials, and systems; Pedagogical knowledge (PK), which involves the methods and practices of teaching and Content knowledge (CK), which encompasses both subject matter

and the pedagogy specific to that content, such as teaching elementary mathematical concepts like addition, subtraction, multiplication, division, measurement, or shape recognition. The TPACK model stems from Shulman's (1999) work, which explored the intersection of content and pedagogy.

Koehler et al. (2013) and Mishra and Koehler (2006) imply that a teacher's effectiveness depends on their ability to integrate all aspects of TPACK, Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK) seamlessly. These components are defined as follows:

Technological Knowledge (TK) refers to a teacher's ability to effectively integrate and use available digital technologies in the classroom. Recent studies highlight its significance in promoting innovative educational practices that keep pace with modern technological developments (Schmid, Brianza. & Petko, 2020).

Pedagogical Knowledge (PK) centres on a teacher's grasp of effective teaching strategies tailored to various subjects. Scherer et al. (2020) points out that PK encompasses classroom management, lesson planning and assessment techniques, enabling teachers to create learning environments that cater to diverse learner needs.

Content Knowledge (CK) involves a teacher's expertise in their subject area, which includes not just the core content but also its related components. De Aldama and Pozo (2020) contend that CK is essential for developing Pedagogical Content Knowledge (PCK) and Technological Content Knowledge (TCK), allowing teachers to present concepts clearly and draw connections between different aspects of the curriculum.

The relevance of TPACK in mathematics education extends beyond teachers to learners across various countries, as demonstrated by Koh, Chai and Natarajan (2018) in the context of developing nations. Shulman (1986) and his associates made a significant contribution by portraying content knowledge as a unique type of technical knowledge essential to the teaching profession, as noted by Ball, Thames, and Phelps (2008).

The move towards using technology raises an important concern regarding the suitability of the current TPACK framework for fulfilling the demands of teaching and professional development for educators as artificial intelligence (AI) becomes

increasingly integrated into educational activities (Ning et al., 2024). In modern mathematics instruction, educators must not only possess content knowledge (knowing what to teach) but also pedagogical expertise (understanding how to teach and address learner learning challenges) and proficiency with the most effective learning technologies (Nantschev et al., 2020)

TPACK, since its development has been used as a framework to guide teachers when designing technological-based mathematics learning activities (Yan, Chai & So, 2018). If the technology being referenced is digital technology, as noted by Za'ba et al. (2020), it is crucial for teacher education programmes to equip future educators with the necessary technological skills, along with pedagogical and content knowledge, to enable them to successfully integrate technology into their classrooms (Günbaşı, 2020; Ozudogru & Ozudogru, 2019).

Despite having access to the internet, teachers appear to be hesitant to use its resources to enhance their instruction (Taleb, Ahmadi & Musavi, 2015). Stols, Ono and Rogan (2015), found that teachers in South Africa were generally positive about the use of technology in the classroom. Although they acknowledged that technology may improve instruction and learning in their mathematics classes, they believed that their understanding of computers and software was insufficient to fully adopt new pedagogies and technologies (Stols et al., 2015). The importance of pedagogical content knowledge show findings that successful educators used metaphors, pictures, and explanations that were simultaneously sensitive to students' learning and the integrity of the subject matter together with digital tools, the Knowledge Growth in Teaching study illustrated important concepts (Ball, Thames & Phelps, 2008).

It is in instances such as this that it is vital that teachers integrate content and pedagogical knowledge with their developing technology knowledge to become more effective in their practice. Morris (2021) reported that Teacher A in his study, demonstrated how TPACK can help to develop mathematical proficiency in learners and help teachers teach mathematical proficiency in a Western Cape school. Teacher A acknowledge the role of technology in the mathematics classroom in creating a more productive disposition towards mathematics.

The TPACK model is integral to this study as it offers a method to map how teachers incorporate digital aspects into high school mathematics instruction across the various

knowledge components. Within this framework, TK focuses on the knowledge of tools, that are essential for effective teaching. The TPACK framework's incorporation of AI technology has the potential of transforming learning environments, teaching strategies, and other facets of education. As a result, creating an AI-infused TPACK model (AI-TPACK) introduces newer technology to classrooms as found in a study by Ning et al. (2024).

In conclusion, mathematics teachers believe their level of understanding TPACK and their acceptance of technology after the pandemic are adequate and fair (Patriarca, Lobo da Costa, & Fiori da Silva, 2019; Morales-López & Poveda-Vásquez, 2022; Rakes, 2022). Additionally, research findings indicate that teachers demonstrate a good level of readiness to integrate technology into mathematics instruction, as evidenced by their good TPACK understanding (Karakus, 2018; Başaran, 2020). However, increased computer usage correlates with improved perceptions of TPACK competency (Başaran, 2020) which then has an effect on the use of technology and digital tools in the teaching and learning process.

2.8 CHAPTER SUMMARY AND IMPLICATIONS FOR EMPIRICAL STUDY

This chapter explored the use of digital tools in the teaching of mathematics, drawing on international, African and South African literature. The review drew attention to the increasing use of technology in mathematics teaching, focusing on the way that digital resources, such as interactive whiteboards, educational apps, online platforms for learning and virtual manipulatives have remodelled teaching and learning experiences. Global advances toward technology-enriched learning environments were discussed in the chapter, demonstrating enhanced learner involvement and conceptual knowledge when digital tools are used in effective ways.

African countries, although incorporating ICT and technology, are faced with the challenges which points to the digital divide that exists in some regions. However, innovative practices have emerged, particularly in countries like Ghana and Nigeria. South African research underscores the dual challenges of technological access and teacher preparedness but reveals growing momentum in using digital tools to support curriculum goals and improve learner outcomes.

The utility of digital tools in mathematics education stands as a core theme of this chapter. The use of digital tools fosters collaboration, problem-solving and real-time feedback, thus deepening learners' mathematical understanding. Methods of teaching mathematics using digital tools enhance learner learning and engagement. However, the review also highlighted challenges such as poor infrastructure, teacher preparation deficits and the need for seamlessly integrated technology, as opposed to scattered use.

Educational Technology Theory and the Technological Pedagogical Content Knowledge (TPACK) model are used together. Educational Technology Theory offers an understanding of the ways in which technology may change teaching and learning, and how it may be used to improve education. It focuses on the teaching changes needed so that digital tools can be used in a meaningful way by learners. It proposes that teaching should be learner-focused and digital aids should be used in ways which enhance the development, even at the outset, of critical thinking and problem-solving.

The TPACK model also adds value to this understanding by stressing the combining of content knowledge, pedagogical knowledge and technological knowledge. The theory posits that educators require a thoughtful mixture of these three components to implement digital media appropriately in mathematics class. TPACK emphasises that teacher preparation, including career-long professional development, should acknowledge the need for technology not as a supplement but as an essential part of pedagogical practice, that is, something that improves learner learning.

The next chapter outlines the research design and methods that were used in conducting the research, focusing on data collection and analysis.

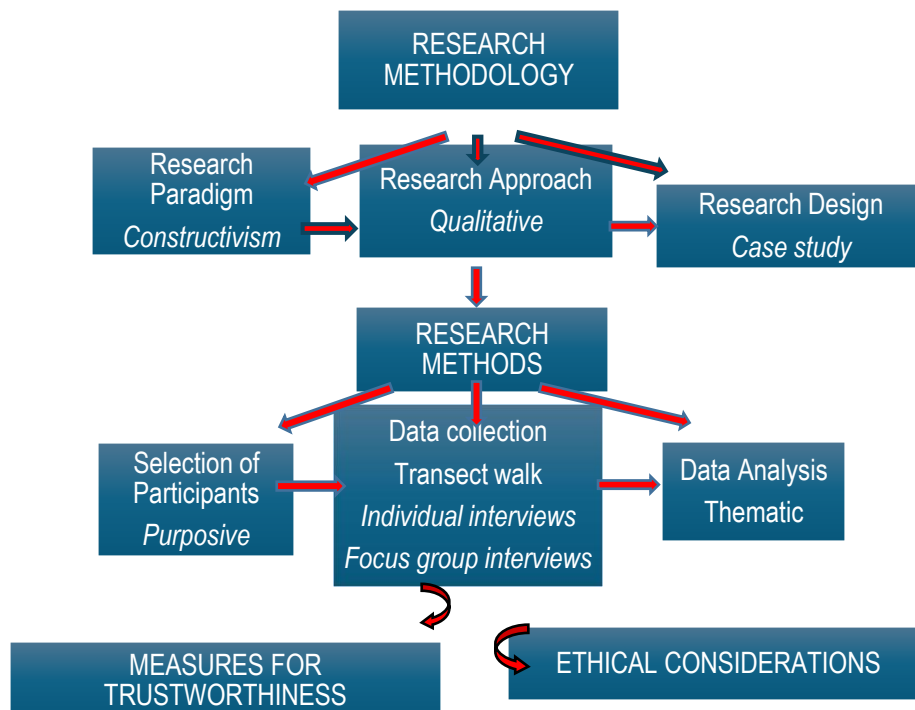
CHAPTER 3

RESEARCH METHODOLOGY AND DESIGN

3.1 INTRODUCTION

This chapter describes in detail the research methodology and design that guided the conducting this research to answer the research question: *How effective is the use of digital tools in the teaching of Grade 9 mathematics in the Ekurhuleni district?* This chapter presents the research paradigm which underpinned the research followed by the research approach and research design. Research methods include sampling, data collection and data analysis. Data collection included transect-walk interviews with open-ended questions to gain authentic insights into teachers' use of digital tools in their mathematics classrooms. Additionally, the chapter discussed measures to ensure trustworthiness and ethical considerations maintaining adherence to university regulations and research integrity data.

The figure below presents an outline of the research methodology discussion in this chapter.



(Author's own design)

Figure 3.1: Summary of methodology adopted for this study

3.2 RESEARCH METHODOLOGY

This section offers a description of the research methodology that guided this research. It includes the research paradigm, the research approach and the research design.

3.2.1 Research Paradigm

Guba and Lincoln (1994) claim that a paradigm is a general philosophy that reflects people's perceptions of the universe and the essence of the potential connections that might exist in that environment (Guba & Lincoln, 1994). Research paradigms that are primarily utilised in education include positivism, constructivism and interpretivism (Hatch, 2002; Turyahikayo, 2021). Positivists expect reality to be compartmentalised and assert that they are impartial in their pursuit of knowledge (Tsafe, 2020). Interpretivists hold that humans are presumed to have free will, in contrast to positivists. To obtain a relevant interpretation of their behaviour and the underlying characteristics, respondents should be active participants in the study process. But in terms of methodology, interpretivists employ techniques including content analysis, discourse analysis, interviews and unstructured observation (Ngulube, 2015; Mezmir, 2020; Reger & Kincaid, 2021). Essentially, the goal of interpretivist research is to get 'firsthand' knowledge from the participants.

These paradigms correspond to specific ontological, epistemological and methodological information, contingent on the study situation. According to Turyahikayo et al. (2021), these research paradigms are therefore helpful in explaining the identified problem to be investigated by the research from ontological, epistemological and methodological viewpoints. Additionally, it is beneficial to match the research with a specific philosophical perspective (Kivunja & Kuyini, 2017).

3.2.1.1 Ontology

Ontology relates to the reality of what is out there. The Open University (OU, 2025) explains that the philosophical study of being and existing is ontology and is shown as what is true or real. Referring to one's view of reality and to what extent it exists 'out there', allows one to build within the paradigm of constructivism (OU, 2025).

Taking this view, reality is created by each of the teachers based on previous experience and knowledge, attitudes and beliefs and this influences how they teach learners to 'construct' meaning and understanding in a specific context like mathematics. Hence the nature of reality is subjective as teachers face different realities during the teaching of mathematics to Grade 9 learners using digital tools.

Cleland and Durning (2023) agree on the approach of how knowledge is constructed by using the constructivist ontology. According to the constructivist perspective, learning happens when learners actively create meaning of new concepts. Cleland and Durning (2023) agree that knowledge of problem-solving and building knowledge allows the development of expertise and other aspects of learning based on the constructivist framework.

According to Fairus (2023), using the ontology of constructivism requires an awareness of the area of study and the process by which knowledge is created. The ontology of constructivism guided this study of examining the nature of teachers' realities, through their teaching of mathematics using digital tools (Zalukhu, 2023). A solid methodological basis for the advancement of mathematical knowledge is provided by the ontology of constructivism (Farid, 2022). Sadewo (2022) asserts that the ontological study of mathematics integrates ideas about the actual existence and actuality of mathematical concepts (Sadewo, 2022). The teaching and learning of mathematics should be integrated into the reality of life or real-life problems of everyday life (Fajri, 2022). This study will show the relevance of using digital tools to teach everyday mathematics, showing the effectiveness of the tools in grade 9 mathematics classrooms.

3.2.1.2 Epistemology

Epistemology relates to the philosophy of knowledge, defining how researchers determine what is true, valid and acceptable knowledge. Epistemology is essential to comprehending understanding and clarifying how one sees the world through different perspectives (Hasiram, 2023). The researcher explores his beliefs, prejudices and values as this influences what is studied and observed.

As teachers, learners and members of a knowledge society, we may all benefit from examining and debating how we perceive learning (Hasiram, 2023). Knowledge is

built from what we know. Constructivists agree that knowledge is constructed by the individual through his or her interactions in a particular environment (Springer, 2023).

A relationship is formed between the knower and the known but this is subjective and thus open to interpretation, which means that researchers need to separate themselves from the process or event to discover its true (Cleland & Duran, 2021).

The epistemology of constructivism allows learners to generate meaningful knowledge and think independently in a classroom (Boon, 2022). The constructivist teaching paradigm allows the construction of high-quality knowledge, development of valuable skills and shaping of personal attitudes and values amongst learners (Letena, 2022).

Constructing knowledge needs guidance within any environment, but in the teaching of mathematics, this depends on teachers' knowledge and learners' prior knowledge (Ignacio & Paras, 2024). Learners are more likely to develop a stronger understanding of mathematical ideas and use effective problem-solving techniques when learning through a constructivist approach (Tamba & Centrana, 2021). The constructivist approach therefore guides educators in the design and delivery of mathematics lessons and use of digital tools and resources (Ghazali, 2021). This study showed that constructing lessons and incorporating correct methods and tools become beneficial to learners in classroom.

3.2.1.3 Methodology

The research methodology outlines how the research should be conducted within the paradigm of constructivism. According to the University of California, San Diego (2021), the research technique should be accurate enough for any researcher to replicate the findings. Constructivist approaches to understanding are mainly qualitative, including questions such as why and how events and processes occur and how individuals and groups make meaning of them (Cleland & Durning, 2023).

The research methodology plays a vital role in structuring the research process and offers a well-defined framework for sampling, data collection and processing, and data analysis to achieve research aims (Irwansyah & Nandiyanto, 2024). Research information is vital to answer the research questions, so in this study, the focus is on gathering information from teachers (Susilawait et al., 2024), who use resources such as digital tools and techniques in the teaching of mathematics (Philippine Normal University, 2019). Interacting with each of the teachers allowed for developing an

understanding on how they construct knowledge based on their experiences in the use of digital tools in the teaching of Grade 9 mathematics in the Ekurhuleni district.

Qualitative research can be successfully conducted to gain quality data through trustworthy and traditional methods of data collection during interaction with participants, as these approaches serve their purpose while promoting inclusion and equality in research (Saarijarvi & Bratt, 2021).

3.2.1.4 Constructivism

The paradigm of constructivism grants individuals the freedom to learn and seek knowledge by identifying their needs and desires, with support from others. The constructivist paradigm promotes active learning, enabling individuals to develop their competencies, acquire knowledge, utilise technology and gain essential skills for growth (Kusuma, Rochmad, Isnarto & Hamidah, 2023). Vygotsky, Brunner and Dewey, are considered pioneers of constructivism (Naidoo & Mabaso, 2023). They believe that learners should actively create information rather than passively acquire it, and that cognition plays an active role in the organisation of the world they experience (Joseph, 2021). Constructivism stems from the word 'construct, which relates to knowledge being 'constructed' and not 'transferred', so knowledge is constructed within an environment conducive to learning and not just transferred from teacher to learner. This means that within constructivism, learners are actively involved and construct their knowledge by formulating meaning from learning experiences (Duffy & Jonassen, 2013; Akkoç & Ocak, 2019).

Social constructivism, developed by Vygotsky (2022) emphasises assisted-discovery learning (Ormord, 2007; Utami, 2016), which means that learning for children is carried out in interaction with the social and physical environment. Discovery in learning occurs in one's socio-cultural context (Poedjiadi, 1999; Utami, 2016). Yılmaz (2017) and Baran and Maskan (2021) explain that educators act as facilitators within the mathematics classrooms, assisting learners in understanding mathematical concepts by supporting exploration and problem-solving.

Using digital tools supports learners in building knowledge on their own. This formation of new knowledge emerges from integrating various learning experiences, like the use of digital tools in the mathematics classroom (Kusuma et. al., 2023).

Using the constructivist paradigm as a research paradigm in investigating how digital tools are used in the teaching of mathematics emphasises active engagement and collaboration, aligned well with the interactive nature of digital tools in education. Research done by Kim and Hannafin (2018) pointed out that constructivist theories used in learning environments motivate learners to engage in challenging thinking and problem-solving activities, which are important for meaningful learning experiences. Through constructivism, the focus shifts to understanding how learners actively construct their knowledge, enabling a deeper exploration of the processes and strategies they employ when using digital technology for mathematical learning. According to a study by Jonassen and Land (2018), constructivist theories employed in learning environments that allow integration of digital tools can significantly enhance learners' conceptual understanding and application of content in the broader world.

Adopting a constructivist approach, research methodology can incorporate qualitative methods such as interviews, observations and case studies, allowing for rich data collection and analysis that captures the complexities of digital technology usage in mathematics education. Smith and Greene (2018) found that case studies and interviews assist when engaging the need into how digital tools impact learner engagement and learning processes in mathematics classrooms. Similarly, Brown and Wilson (2019) pointed out that observational studies offer a structured view of the interactions between learners and digital technologies, showing the need and factors which influence the effectiveness of technology integration in educational settings.

3.2.2 Qualitative Research Approach

Qualitative research methods refer to techniques of a study that rely on non-statistical and non-numerical methods of data collection, analysis and evidence production. Qualitative research methods offer a perspective for understanding non-numerical phenomena including people's histories, cultures, languages and experiences (Bhangu, Provos & Caduff, 2023). Qualitative research explores the breadth and depth of context and voice in comprehending a phenomenon. This approach is beneficial, seeking to reveal the 'what', 'why', 'when', 'where', 'who' and 'how' (also known as the '5W1H') of the study question (Lim, 2023).

Qualitative research is useful when working in small environments, such as schools and classrooms. Creswell and Poth (2018) list several additional crucial aspects of

qualitative research. It offers a comprehensive explanation of the study in stating that it is context-dependent and is carried out in a natural environment. Corner, Murray and Brett (2019) explain that qualitative research collects participant perspectives, experiences and behaviour, and as mentioned above, these are the mathematics teachers, in order to investigate and offer deeper insights into real-world challenges and problems within digital usage in mathematics classrooms.

When using a qualitative research approach, the understanding and comprehension, together with the interpretation of the reality of the phenomena or circumstances, are under investigation. According to Soratto (2019), the framework of qualitative research is the employing of open-ended inquiries where responses are difficult to quantify with numerical values. One of the main advantages of qualitative research is its capacity to identify and explain the behaviour patterns and processes that are difficult to do in quantitative research (Moser & Korstjens, 2018).

Focusing on quality rather than quantity, Tscholl (2019) supports this by stating that rather than offering data or quantification, qualitative research offers knowledge on the human aspect of a problem. A qualitative research approach is successful in determining a variety of elements that enables the investigator to investigate and obtain profound understanding of the issue at hand by collecting participants' perspectives, experiences and actions (Corner et al., 2019).

In this research, a qualitative research approach was deemed appropriate to examine teachers' experiences and their perspectives of using digital tools in the teaching of mathematics. Using a qualitative approach to guide the research, gave teachers the opportunity to be authentic and explain why, how or what they were feeling, thinking and experiencing during teaching the subject. Moser and Korstjens (2018) explain that the teachers' attitudes, experiences and behaviours offer in-depth detail which contributes to the quality of data collection.

The core nature and use of qualitative research encompass several strengths, which make it a powerful tool for exploring phenomena within the real world. Research on the effectiveness of digital tools in mathematics has revealed the reality of learners using digital tools in mathematics and how digital tools are able to influence learners in the understanding of mathematics which then has a positive effect on their performance (Symonds & Gorard, 2010; Cohen, 2018; Wohlfart, 2020).

Mays and Pope (2020) suggest that a variety of questions as guiding principles assist in assessing the quality of a qualitative study. Good qualitative research should be well informed and thoroughly documented (Nassaji, 2020), which as the researcher, I attempted to ensure together with ethical considerations. I also acknowledged subjectivity and recognised the importance of personal experiences in making decisions about the research process by being the neutral party and unbiased as possible. Johnson and Christensen (2020) explain that this is especially true when a researcher is viewed as a research instrument and human ethics and values are considered.

3.2.3 Research Design

The research design is a structured, strategic blueprint for a study and within a qualitative approach could be phenomenology, ethnography, grounded theory, narrative research, active research and case study. A case study provides a thorough account of one or more instances, as reported by Renjith et al. (2021). The unit of analysis is reduced to examining an event, programme, activity or sickness and defines the scope of the research, guiding data collection and analysis. Case studies are most suited for comprehending a case. Data are gathered through observations, one-on-one interviews, artifacts and documents. Themes and cross-case themes are derived from this (Handcock & Lim, 2021).

A case study, according to Yin (2018:45), is an “empirical investigation that thoroughly examines a current occurrence within its actual context”, particularly when it is difficult to distinguish between the two. Case studies are effective at providing answers to ‘how’ and ‘why’ research questions (Yin, 2018). The description and in-depth examination of the current study, which examines the efficacy and usage of digital tools by Grade 9 mathematics learners, are the main objectives of case study research.

A qualitative multiple case study was used as the research design (Baxter & Jack, 2008; Glette & Wiig, 2022). Using a multiple case study to explore the effectiveness of digital tools in the teaching of mathematics and its influence on learner performance revealed real-world information. This study included three types of schools, namely government, former Model C and private schools and at least two teachers from each school type were purposively sampled. Each school type represented a case resulting

in a multiple case study. The methodology of the study must subsequently be directed by the study's primary goal and inquiry (Baxter & Jack, 2008; Crowe, et al., 2011; Yin, 2018), which is exploring how each school uses digital tools in the teaching of mathematics. A multiple-case study in this study allowed me to look at different schools and each scenario according to the context and setting of the school.

3.3 RESEARCH METHODS

Research methods refer to the techniques and instruments a researcher uses in conducting the research to gather data for a study. In this qualitative study, research methods included identifying the population, sampling, data collection and analysis, to gain in-depth and detailed knowledge on how digital tools influence learner performance in Grade 9 mathematics.

3.3.1 Population and Sampling

The population includes the entire group of individuals that display the same characteristics. The population for this study was high school mathematics teachers in the East Rand of Johannesburg. Three high schools that adhere to the nation's general education systems to guarantee a representative sample, were identified. These schools represent the segmented tiers found in the South African education system. Selected schools included a private school, which is independent, non-government owned institution often characterised by smaller classes and higher fees, a former Model C institution, which is publicly funded schools with high levels of self-funding and a government school, which is fully state-funded and operated, often serving the majority of pupils, but sometimes under-resourced. These selected schools assisted in gaining varied perspectives.

Sampling is a technique used for selecting participants for a study. Prandner and Weichbold (2019) point out that using a 'sampling frame' to determine the selection of participants who are important to the study. Non-probability sampling is a research technique where samples are selected based on non-random criteria based on the researchers' criteria. One method is purposive sampling that recognises that researchers select participants based on their expertise and the information they can offer based on specific criteria. The criteria that were considered were that participants had to be Grade 9 mathematics teachers in each of the selected schools (Thomas,

2022) to ensure that the sampled teachers from each school (Friday & Leah, 2024) would be able to offer rich data on the phenomenon under study. Three teachers from each school were chosen.

Researchers (Creswell (1998); Morse (2000); Baker and Edwards (2012); Kindsiko and Poltimae (2019); Sim, Saunders, Waterfield and Kingstone (2018) and Vasileious, Barnet, Thorpe and Young (2018)) suggest that five to thirty could be a numerical guideline in determining the sample size for their qualitative study. However, Friday and Leah (2024) state that the specific number of participants should be manageable. In this study, nine participants formed the sample.

3.3.2 Data Collection

Techniques or approaches that investigators employ to gather data are known as data collection (Rahayu & Taufiq, 2020). Data collection takes the research into the field to answer the research questions posed in the study and information gathered through qualitative approaches is communicated through language (Shod, 2022).

The researcher can use one or more methods to collect data depending on the research problem. Methods (rules or techniques) are abstract terms that exist only via the use of surveys, case studies, observations, inquiries, in-depth interviews, documentation, focus groups and other methods rather than being present in physical items, as noted by Kabir (2016) and Taherdoost (2021). Data are gathered in order to produce the research findings required to meet the goals of the study. Data collection methods need to be planned and strategised. Lester, Cho and Lochmiller (2020) state that employing data collection methods requires reflection in addition to the importance of participant viewpoints and the researcher as an instrument and Shodh (2022) suggests that analysing concepts, ideas and recollections is a major technique to improve data collecting.

In order for collected data to be valid, the researcher needs to know how to collect data during the research, so that the data strengthens research questions answers (Sukmawati & Salmia, 2023). Jalinus and Risfendra (2020) add that more than one method should be used so that the data collection process goes well, and data are more accurate and valid.

The focus of this research was on mathematics teachers within specific schools to gain information about the use of digital tools in the teaching of mathematics, Data were collected through transect walks, observations and a focus group discussion.

3.3.2.1 *Transect Walks*

Transect walks, developed by Chambers (1997), are practical method for gathering information from teachers in the school environment. A transect walk in a practice to draw from personal experiences (Geduld (2021). Pitikoe and Morojele (2017) used transect walks to probe a community's perspective on the historical background of local resources in Lesotho, how the resources are used and distributed, and how they foresee the future of their land use. This relates to Chambers (1997), who acknowledged that using the knowledge that already exists within a community is vital in research.

Using transect walks has the potential to empower participants, teachers in this situation, which allows them to talk about realities and the learners they educate by stepping beyond their comfort zones and discovering who they are while interacting constructively, creatively and critically (Jensen, 2019). According to Sathorar (2018), education must provide chances for teachers to support culture and should work to give their pupils a platform to communicate real-life experiences, allowing digital tools into their space.

The nature of transect walks allowed me to conduct informal interviews with mathematics teachers relating to their teaching of mathematics via digital tools (Geduld, 2021). Informal Interviews during the walk were conducted to ensure coherence and highlighted pedagogical practices encompassing digitalisation in mathematics based on each individual teacher's experience (Geduld, 2021). Appendix F shows the guided questions that were used as prompts to the conversation to ensure consistency of the study.

During the transect walk, participants spoke about the teaching of mathematics, the use of digital tools, challenges and other study-related items. Their responses to the questions with added information and narratives gathered during the transect walk were valuable, as suggested by Geduld, Sathorar and Mdzanga (2021). Using the transect walks, the classroom environment was noted together with the digital aspects

used to teach mathematics or certain topics of mathematics. Transect walks with the participants gave insight into personal experiences and provided valuable information about their teaching and use of digital tools (Siebert, 2023).

The transect walks took place at each school, walking around the classroom and outside the classroom. This participant being the teachers were then able to point out the digital tools that they use to teach their mathematics classes. Each transect walk was about 30 -45 minutes, discussing insightful and valuable information. This took place during term three of 2025, during the school day when the teacher did not have a class.

3.3.2.2 Observations

Observation, a scientific tool used for data collection by the researcher, is planned and recorded and is subjected to checks and controls on validity and reliability (Mazhar Anjum, Anwar & Khan, 2021). Qualitative observations are a means of data collection comprised of viewing and documenting what people do in their environment with the goal of understanding behaviour in context (Mazhar et al., 2021), Observing and recording people's actions in their surroundings with the aim of comprehending behaviour in context is known as qualitative observation.

Routine behaviour carried out by participants, like teachers in routine settings, offers important contextual information that might not be recognised in a simulated scenario (Horwitz, 2018) or might have advantages not picked up by techniques like interviews. Teachers in mathematics classes normally engage in routine tasks and activities that can be observed.

Findings pertaining to the objectives of the study can be developed using observational data for qualitative research. According to Lauren, Weston, Krein and Harrod (2021), this can also be analysed in conjunction with other kinds of data, such as data that has been either more organised techniques (like surveys), self-report techniques (like focus groups and interviews), or additional observational techniques (like shadowing).

Teachers were observed teaching Grade 9 learners where they used digital tools during the lessons. Guided by the observation schedule (Appendix G), it gave an

opportunity to ascertain how the digital tools are used in the classroom environment and whether they were effective in developing understanding.

One grade 9 mathematics lesson, about an hour long, was observed at each of the chosen schools, completing three observed lessons across the schools. This was important to the study as I physically wanted to be in the classroom space while the teachers used digital tools to teach mathematics. Observing the different lessons gained me an important perspective of how teachers used digital tools at schools in the East Rand of Johannesburg.

3.3.2.3 Focus Group Discussion

Focus group discussions have grown in popularity in academic and applied research domains over the last few decades, particularly in the social sciences, health, management and education. This is supported by Gundumogula and Hatlevik (2020), who claims that a focus group approach is a qualitative method that collects information on a selected topic. Focus group discussions are very useful for rapidly providing precise information when combined with other data collection methods (Gundumogula & Hatlevik, 2020).

Richard et al. (2021) in his recent study, compared in-person and on-line focus groups which worked well as a data collection method. Namey (2019) found that in-person focus groups allow the person to say more but agrees that both types of focus groups are beneficial and unique Full stop.

An online focus group discussion was created as the mathematics teachers teach at three different schools across Gauteng. It was important to create a comfortable online environment in which participants were able to connect, interact and discuss the use of digital tools in the teaching of mathematics (Richard et al., 2021).

The focus group took place towards the end of my study and at the end of term 3 in 2025. This brought a few of the participants together from different schools. It played an important part in teachers showing agreement and disagreements in the usage of digital tools in the grade 9 mathematics space. The online discussion lasted a fruitful one hour, and teachers were very willing to share their expertise.

3.3.3 Data Analysis

In qualitative research, data analysis can be done either through deductive or inductive reasoning, with an emphasis on content or interpretive themes. According to Lester, Cho and Lochmiller (2020), certain methods of analysing data may be necessary for some data. Using the qualitative collection methods and thematic analysis, data were analysed to ascertain how these tools are used by teachers. Aspers and Corte (2019) also point out that one of the unique characteristics of qualitative analysis is that it promotes the development of new ideas and the understanding of the connections between ideas. It is important ensure comparison, contrast and classification processes, which are crucial in the majority of quantitative analysis.

3.3.2.1 Thematic Analysis

Thematic analysis uncovers trends, themes and insights from the data gathered. Nowell et al. (2019) and Braun and Clarke (2019) state that thematic analysis in educational settings identifies significant trends and experiences. In addition, Clarke et al. (2020) emphasise its adaptability and appropriateness for qualitative data analysis. Because of this, theme analysis is a crucial technique for investigating how digital tools affect math classroom learning processes (Hayfield, Terry, Clarke & Braun, 2019).

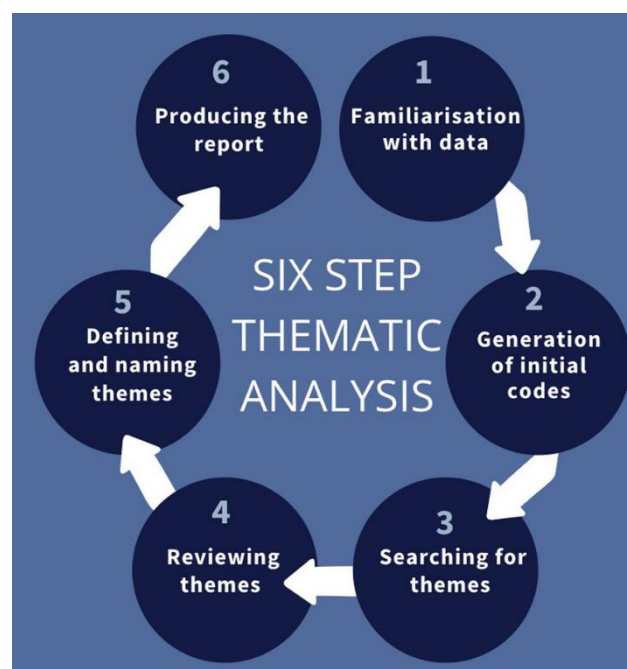
Thematic analysis has been said to be accurate and useful in educational research. The benefits of this analytical approach include an interactive data interpretation process, an approachable type of analysis, a certain degree of flexibility, resulting in the development of theories and results (Boyatzis, 1998; Sigurvinsdottir, 2016; Neuendorf, 2018; Braun & Clarke, 2019). The use of this analysis has increased in various disciplines, such as psychology and education, hence being beneficial to this research (Andriotis & Paraskevaidis, 2022)

Researchers frequently use the terms 'thematic analysis' and 'qualitative thematic analysis'. Although the term 'analysis' is frequently used to refer to content analysis, which can be qualitative, quantitative, or a combination of the two (Braun & Clarke, 2021), the qualitative application of thematic analysis was used in this research. By using this approach, comprehension on how learners use digital technology was facilitated by methodically identifying and interpreting important data points.

3.3.2.2 The six-step data analysis process

In order to assist the researcher in recognising and addressing the key elements of theme analysis, Braun and Clarke (2012, 2013, 2014, 2020) have created a six-phase process for data analysis. Analysis of themes can be a lengthy procedure that enables the researcher to progress through the various stages (Braun & Clarke, 2020). The six-phase method, considered the perfect analysis technique for researchers, should be viewed as a series of guidelines rather than rules that should be implemented, as this may result in new interpretations of the data (Braun & Clarke 2013, 2020); however, the six steps allow for flexibility as well as accuracy and validity.

There are many ways to define and categorise themes, sub-themes, topics, categories, and codes, as suggested by Vaismoradi et al. (2016) and Braun and Clarke (2020). Useful outline distinctions between codes and topics, tend to be detailed, descriptive and aligned with relevant content and themes, which become more interpretive to actual experiences (Braun et al., 2021). More recently, Braun and Clarke (2019a, 2019b, 2021) have expanded and refined their methodology to show differences explicitly in constructivist approaches to those who use different methods of the thematic coding processes. The six-step process is presented in Figure 3.2 and described below:



(Source: McInerney, Seedhouse, Pettit, Roberts & Druva, 2022:63)

Figure 3.2: Thematic analysis

Step 1: Become familiar with the data (Get to Know Your Data) – The first step is to analyse the data by reading and re-reading transcripts, making rough notes along the way. I read all the information sheets that were have written on and gathered via transect walks, observations, as well as when conducting the focus group discussion. This stage is all about immersion, getting familiar with the details and nuances of what's been collected (Braun, & Clarke, 2021). This step allowed me to summarise and streamline the collected data.

Step 2: Generate initial codes (Identify Key Patterns-Coding) – Next, the researcher starts organising the data by highlighting important elements and giving them short, meaningful labels or codes. Assigning codes to chunks of data assist in making sense of the data by identifying recurring ideas. Once coding is done, all related pieces of information are grouped together for deeper analysis (Braun, & Clarke, 2021). These codes were used to streamline and group similar ideas or thoughts.

Step 3: Search for themes (Find Themes) – This step is about making connections and shaping meaningful categories that help tell a bigger story (Braun & Clarke, 2021). I looked for broader patterns by grouping similar codes together looking at how the teachers incorporate digital tools into their mathematics lessons.

Step 4: Review themes (Refine and Adjust Themes) – Not all themes are perfect at first. Some may need to be merged, separated or even removed if they do not quite fit. I streamlined the data collected according to what was relevant to digital usage in mathematics. This was fine-tuning the themes to ensure they worked well together and reflected the data collected; while also making sure they aligned with the research questions (Braun, & Clarke, 2021).

Step 5: Define and Name Themes – This stage requires a clear, compelling narrative for each theme by giving it a name that is both informative and engaging (Braun & Clarke, 2021). This is where the themes really took shape. Each one was carefully refined and analysed to capture its core message. Once I had reviewed the themes, I was able to categorise these and define each theme under the effects of digital tools.

Step 6: Write-up (Tell the Story) – This step involves linking findings to existing literature on digital mathematics and using real examples from the data to create a persuasive and insightful discussion (Braun & Clarke, 2021). I combined everything into a well-structured analysis, integrating themes into the larger research report. I was thus able to complete a full analysis of the data, examining the effectiveness of the use of digital tools across the three schools. The findings are presented in Chapter 5.

3.4 MEASURES FOR TRUSTWORTHINESS

Trustworthiness is the primary factor of qualitative research investigations (Amankwaa, 2016; Eryilmaz, 2022). One of the most widely used and widely recognised standards for evaluating the reliability of qualitative research was first provided by Lincoln and Guba (1985), and it has since been modified and applied through the years. Lincoln and Guba (1985) developed a widely accepted model and strategies to ensure the trustworthiness and generalisability of qualitative research. He highlighted four key ideas to improve trustworthiness: credibility, transferability, dependability and confirmability (Riazi & Ghanbar, 2023).

Kakar (2023) built on Guba’s (1985) trustworthiness model and states that credibility is like internal validity in quantitative analysis and provides the actual data about the phenomenon.

Figure 3.3 below shows the norms discussed in terms of this study’s trustworthiness.



(Source: Adapted from Kocaman, 2025:9)

Figure 3.3: Criteria and strategies for ensuring trustworthiness

3.4.1 Credibility

Ensuring credibility of data is vital for accurate results. “The importance of credibility is important to any study, it is explained that credibility shows the truth of data and participants’ views and their interpretation” (Enworo, 2023:1017). Credibility shows the truth of data collected and the views of teachers who responded as well as the interpretation by the researcher (Hanson, 2019).

Credibility was ensured by using a more flexible approach which allowed participants to feel comfortable and put forward their own views and opinions. Participants were granted the opportunity to review and verify the information they had provided before it was used in the research, this practice is known as member checking, which further enhances credibility (Korstjens & Moser, 2018). More than one data collection technique was used in this research and this allowed for triangulation.

A credible study must relate to reality. Rasheed (2023) agrees that the study's findings should be like human experiences and commonly accepted within the classroom. The other aspect of credibility is the researcher’s experiences in the field of research, which will be within the schooling environment (Rasheed, 2023).

3.4.2 Transferability

The standard by which external validity is evaluated is transferability. It is well acknowledged that the research findings should allow readers to assess the relevance of the findings to their own situations (Riazi & Ghanbar, 2023). Transferability is like generalisability in quantitative research, but Korstjens and Moser (2018) state that it focuses on the applicability of findings to similar contexts or individuals rather than broader contexts. The findings of a qualitative study are deemed applicable if readers or others who were not involved in the study can relate them to their personal experiences, which should be other teachers teaching mathematics. Lincoln and Guba's (1985) recommendations on the applicability of research data were considered in numerous contexts (Riazi & Ghanbar, 2023).

Participants were encouraged to answer according to their personal experiences while adhering to the research guidelines, as this ensures a rich and full understanding of the research problem (Creswell & Poth, 2018). Ensuring this meant that teachers must

answer truthfully to what they do within their classrooms with the use of digital tools in mathematics.

I ensured that the questions were not limited to specific situations but were open-ended allowing for the development of a thick description of the research context and research process. This allowed for broader applicability and transferability to other contexts with similar characteristics. This approach, according to Patton (2019), aligns with the principles of qualitative inquiry, which point out the importance of flexibility and context-specific understanding.

3.4.3 Dependability

Dependability in qualitative research is like reliability in quantitative studies. It can be achieved through rigorous and well-documented data collection techniques and analysis procedures. The research findings are referred to as dependable, which relates to how stable and consistent the findings are (Riazi & Ghanbar, 2023). Kakar (2023) argue that it is relevant and reliable to the research findings' consistency over time, which is used to assess the reliability of findings. Consistency or dependability of data is an important criterion of trustworthiness explain that dependability is data consistency over similar contexts (Enworo, 2023; Sandelowski, 1986).

Lincoln and Guba (2020) also refer to an inquiry audit, conducted by an external reviewer, as a technique commonly employed to ensure dependability. This process involves meticulously tracking and documenting all parts of the research to provide a clear audit trail, enhancing the credibility and trustworthiness of the findings (Shenton, 2021). Conducting peer debriefing means that I called upon peers to assist in analysing the data and was to open to their opinions on the data collected to identify the findings around the research topic

3.4.4 Confirmability

Confirmability is the core that ensures that findings are impartial and objective, guaranteeing that the results are unaffected by the researchers' biases or preferences (Kakar et al., 2023). The unbiased nature of the researcher results in findings from the participant's responses being objective. Confirmability relates to the conclusion, interpretation, and findings being derived directly from data (Riazi & Ghanbar, 2023).

This is to ensure neutrality in that the research data are of greater significance than the researcher's viewpoint.

Data should be systematically checked and rechecked during both data collection and analysis, aiming to establish that findings could potentially be replicated by others (Patton, 2019).

I ensured that I remained as neutral and unbiased as was possible, by verifying accurate participant selection and checking and also being the neutral party by having a neutral outlook of viewing and accepting their responses from an unbiased viewpoint. Confirmability in qualitative research involves addressing personal biases, often achieved through methods such as bracketing interviews or reflexivity as noted by Creswell and Poth (2018).

3.5 ETHICAL CONSIDERATIONS

Engaging with people in research necessitates adherence to ethical guidelines to safeguard their rights and prevent harm. Resnik (2019) emphasises the importance of informed consent and confidentiality in upholding ethical standards. Ethical research practices include securing informed consent, maintaining confidentiality and reducing potential risks to participants. Additionally, researchers must be transparent about the study's purpose and how the collected data will be used. Babbie (2020) further highlights transparency and the minimisation of harm as fundamental principles of ethical research conduct.

Transparency and accountability, two crucial ideas that apply to teachers in the education sector, are situated between ethical considerations. Only when these are implemented will education's transformative potential be fully realised. Considering (Zahid & Irfan 2021), in the educational system, ensuring accountability and transparency eliminates the possibility of bias and advances equity (Davis, 2020). Scientific ethical values are communicated through research ethics. The Principles of Research Ethics, which are founded on societal morality, outline the fundamental principles and values of the research community (The Norwegian National Research Ethics Committees, 2019).

The mannerism and behaviour of researchers is governed by research ethics. Ethical principles are essential to protect the dignity and rights of research participants. The

ethical committee should review all studies involving human subjects to ensure that adequate ethical standards are being followed. Concerns include the authors' potential impact on respondents and vice versa, as well as confidentiality and anonymity (Oswaldo, 2021). Resnik (2020) points out that moral and social values, such as corporate responsibility, human dignity and rights, and legal compliance are promoted by many research moral codes. These were considered when engaging with Grade 9 mathematics teachers in their schools and classrooms.

Ethical Clearance was obtained from the University of South Africa's College of Education board to conduct the research, maintaining the integrity of the University and myself (see Appendix A: Ethical Clearance Reference Number 8733). In addition to ethical clearing, permission was obtained from the Gauteng Department of Education (GDE) to conduct the research in their schools (see Appendix B). An information letter was prepared for teacher participants detailing the research and participant's role (Appendix C). Participants signed a consent when agreeing to participate in the research (Appendix D). An information letter was also prepared for parents detailing the research and their children's role (Appendix E). Parent signed a consent form and learners an assent form agreeing to participate in the research (Appendix E).

Safety of the participants was ensured, particularly confidentiality of information. There was no personal involvement other than professionally interacting with the teachers and observation of the lesson after the consent/assent of participants was granted to the researcher. Anonymity was ensured by assigning each participant a pseudonym.

In qualitative research, ensuring the questions are not overly specific but open-ended enhances their applicability across contexts with similar characteristics (Patton, 2019). Participants were encouraged to provide responses based on personal experiences within the framework of the research guidelines, promoting a nuanced understanding of the research issue (Creswell & Poth, 2018).

As the researcher, I abided by the university rules on ethics according to its policies. The research data were considered accurate and fair, using measures of trustworthiness through the research. The research design and sampling techniques, data collection method, data collection tools, materials, data analysis were ethically

conducted (Knottnerus & Tugwell, 2018). This ensured my study was carried out ethically in accordance with the university standards.

3.6 CHAPTER SUMMARY

Chapter 3 provided a detailed description of the research after ethical clearance was granted. This chapter gave in-depth details on the research methodology and design used to gather data and analyse evidence for this study. A constructivist paradigm was adopted, enabling the researcher to explore personal experiences of teachers in mathematics classrooms. This framework allowed for an investigation into the use of digital tools in the teaching of mathematics at Grade 9 level.

Additionally, the chapter outlined the methodology for data collection using transect walks, observations and a focus group discussion in collecting data. The chapter also described the thematic data analysis procedure which involved the six-step process. Measures of trustworthiness and ethical considerations were discussed to ensure the researcher adhered to the university guidelines and values. These aspects are essential in maintaining research integrity and aligning with university guidelines and regulations.

The following chapter presents the findings emerging from data collected from mathematics teachers at the selected schools in Gauteng.

CHAPTER 4

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 INTRODUCTION

This chapter presents the findings emerging from the analyses of qualitative data, generated from classroom interviews through transect walks, observations as well as focus groups in three selected schools in the District of Ekurhuleni. The aim of this research was to explore the effectiveness of digital tools in the teaching of Grade 9 mathematics.

The analytical lens adopted in this chapter was based on the TPACK (Technological Pedagogical Content Knowledge framework) and Educational Technology theory as well as on the literature reviewed in Chapter 2. TPACK provides an analysis of the process by which teachers can incorporate technology (TK), pedagogy (PK) and mathematical content knowledge (CK). This framework shows differences in the use of digital tools, teacher decisions regarding instruction and the extent to which technology supports mathematics learning in meaningful ways.

The table below gives the biographical data of all participants in this study.

Table 4.1: Participant details

Teacher	School	Years of experience
Mike	Private	4
Tari	Private	20
Taka	Private	3
Odena	former Model C	15
Kerbs	former Model C	3
Kuhle	former Model C	2
Roko	Government	10
Van Merwe	Government	7
Tim	Government	6

4.2 RESEARCH SETTING

The three schools that were selected to be part of this research represent the segmented tiers found in the South African education system comprising a private school, a former Model C school and a government school, all located in the Ekurhuleni district of Gauteng.

The private school, which has a functional physical environment, caters for students with class sizes ranging from 20-25. The school is well-resourced, as evident in the well-organised classrooms. It seems that the mathematics department is also well-resourced with technology access for learners and teachers being evident. The school had a culturally diverse range of range of staff and students.

The Model C school was formerly an Afrikaans instruction school which was changed to a dual-medium school. This school has a high enrolment with over 1000 learners and class sizes ranging from 30-35. Most classrooms depict the typical traditional classroom setting. Resources are not as easily available compared to the private school, with some technology seen in certain classrooms. This school had a majority of African and white staff and students.

The government school also had a massive enrolment and seemed to have outgrown its original buildings resulting in prefab classrooms to cater for the increased enrolment. Class sizes ranged from 35-40 which resulted in overcrowding in the classrooms and not much room for student movement. Limited resources were available to the mathematics department for teachers to use. This school consisted of a culturally diverse range of staff and students.

4.3 THEMES AND SUB-THEMES

The research findings were categorised into themes and then sub-themes for deeper insight into the study of how effective digital tools were as well as the challenges that was experienced when using digital tools as seen in Table 4.2 below.

Table 4.2: Themes, sub-themes and codes

Theme	Sub-theme	Codes
1. Introduction of New Digital Tools in Grade 9 Mathematics teaching		<ul style="list-style-type: none"> ✓ New educational technologies ✓ Support for technology adoption ✓ Usefulness of new digital tools ✓ Accessibility
2. Integration of Digital Tools into Grade 9 Mathematics teaching	a. Types of digital tools used in instruction	<ul style="list-style-type: none"> ✓ Whiteboards, tablets and laptops ✓ Learning management systems (LMS) ✓ Online tools ✓ Assessment and feedback tools
3. Effects of Digital Tools on Learner Performance	a. Increased engagement and motivation a. Improvements in test and examination performance	<ul style="list-style-type: none"> ✓ Learner participation ✓ Enjoyment ✓ Confidence ✓ Positive attitudes ✓ Self-directed learning ✓ Problem-solving skills ✓ Assessment scores ✓ Examination performance
4. Equity and Inclusion in Digital Mathematics Learning		<ul style="list-style-type: none"> ✓ Equal access ✓ Diverse learning ✓ Inclusive instruction ✓ Differentiated instruction
5. Challenges Experienced by Teachers When Integrating Digital Tools in the Classroom	a. Accessibility of digital tools and internet connectivity b. Inadequate teacher training in digital pedagogy c. Learner distraction when using digital tools d. Pedagogical shifts resulting from digital integration	<ul style="list-style-type: none"> ✓ Limited access ✓ Inconsistent internet ✓ Insufficient digital resources ✓ Infrastructure challenges ✓ Teacher confidence in technology use ✓ Classroom management ✓ Facilitation ✓ Collaborative learning ✓ Real-world contexts

4.3.1 Theme 1: Introduction of New Digital Tools in Mathematics Teaching

The first theme focuses on teachers' views regarding the implementation of new digital tools and platforms in Grade 9 Mathematics classrooms. Data from this theme emerged from transect walks and informal interviews, observations and a focus group discussion. With educational systems globally responding to how to prepare learners for the challenges of 4IR, teachers are emerging as 'vital actors' in the shaping and deployment of digital innovation. It is underscored in literature that the teacher, as the leader in the teaching and learning space, has a significant influence on whether or how digital reform takes place at a school (Collie et al., 2018; Hicks, 2011). Teachers' work is not confined to the classroom, and their use of digital tools shapes not only the delivery of instruction but also how learners are positioned as they draw on mathematical resources.

Data for this theme emerged from the transect walks and informal interviews:

- What digital tools do you use when teaching grade 9 mathematics?
- What effects does the digital tool/s have on students grasping of mathematical concepts?

Throughout the three schools in the study, teachers demonstrated a positive attitude for adopting new digital tools. At the private school, Teacher Mike described the significant technological changes that were to be implemented:

"The introduction and rolling out of Moodle in 2026 will occur at my school. This will become a tool for every learner and teacher to use, making life much easier. I will be able to load resources and preset work for learners, making planning a breeze for me. So, introducing new digital platforms and tools is something we are implementing."
(Teacher Mike)

Figure 4.1 below shows an online Moodle platform with sections of mathematics.

Documentation

Search MoodleDocs 🔍

5.1 docs ▾ Main Page Page Comments View source View history

Docs overview ▸ Moodle Docs 5.1

<p>Get started</p> <ul style="list-style-type: none"> • Browse features • Teacher quick guide • Admin quick guide • Installation quick guide <p>More quick guides →</p>	<p>Manage your course</p> <ul style="list-style-type: none"> • Set up your course • Add students • Track progress • Upload files <p>More for teachers →</p>	<p>Add activities</p> <ul style="list-style-type: none"> • Use assignments to assess • Discuss in forums • Test students with a quiz • Peer-assess with a workshop <p>More activities →</p>
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(Source: Moodle portal, Google 2025:1)

Figure 4.1: Moodle online platform

Teacher Taka at the same school also spoke positively about introducing the new learning management system (LMS) which learners will then need to learn to use. They will use their digital skills to access Moodle, an open-source LMS designed to help educators create, manage, and deliver online courses and training.

Using Moodle in South Africa has shown success as Brijlall and Ally (2020). Found that classrooms that offer chances for procedure development, conceptual understanding, problem-solving abilities advancement, reasoning and justification reinforcement, and motivation enhancement. Showing Moodle as a testing platform positively and enhancing marks according to Brijlall and Ally (2020).

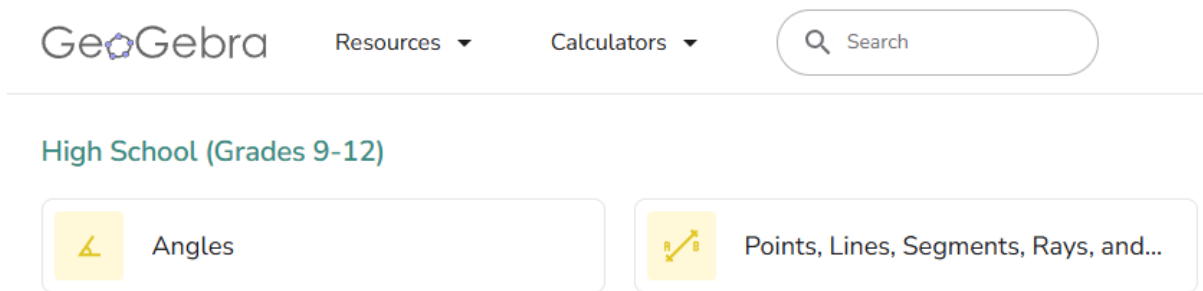
Teacher Tari also teaching at the same as Teacher Taka school explained:

“My learners will be able to work with new digital tools effectively, as they are of that age where they are digitally inclined.”

At the former Model C school, teachers use digital platforms and tools as well and say that they would like to use digital aspects more interactively in their classrooms.

“Using GeoGebra in my classroom for geometry will be more evident from next year, as I have seen learners take to this. Moving away from the board drawings which aren’t always to scale, now gives me the chance to be accurate.” (Teacher Odena)

Figure 4.2 below shows the GeoGebra online platform.



(Source: GeoGebra portal, Google 2025:2)

Figure 4.2: GeoGebra online platform

Teacher Odena as well as Teacher Kerbs will have access to GeoGebra in the future will mean that it could be used more often in class, as seen in the figure above. It will facilitate the teaching of geometry to Grade 9 learners as the platform offers interactive visualisation of 2D/3D geometry, algebra, spreadsheets, and calculus. The constructivist perspective, which encourages students to take charge of their education, is supported by all diagnostic tests on moodle showing positive increases in group averages for the second and third attempts (Brijlall & Ally, 2020).

“Using new digital tools isn’t always easy but I will introduce new tools, especially when I teach Geometry, I have seen the engagement with learners and have become more open to this. I will gladly be using digital teaching tools, as this will advantage me as a teacher.” (Teacher Kerbs)

Teacher Kulhe has not been able to fully use digital tools in her teaching; she hopes to incorporate digital tools more regularly from the new year. She has now seen how other teachers use digital tools in the teaching of Grade 9 mathematics and wants to use these, especially in the teaching of geometry.

Government schools have also introduced basic digital tools for teachers to use, and some schools allow learners to use devices. At a government school, Teacher Van Merwe mentioned that smart boards will be available in certain classrooms the following year, which will be a major advantage for teachers to use. Teacher Roko and Teacher Tim agreed that the smartboards across the school will assist in teaching.

“Replacing the traditional boards with something interactive will make the lessons more engaging for me to teach.” (Teacher Roko)

As indicated by Teacher Roko, whiteboards, particularly interactive ones, enhance teaching by increasing student engagement, fostering collaboration and supporting diverse learning styles through multimedia.

Teachers at the various school levels appeared positive and open minded to integrating new digital tools especially those that improve visualisation, accuracy, effectiveness and learner engagement. Integrating tools such as Moodle and GeoGebra, in classrooms with access to smart boards, also reflects a more general trend towards increased reliance on technology-supported learner-centred mathematical pedagogy being observed around the globe.

A study by Brijlall and Ally (2020) reported on identifying these basic mathematical deficiencies, fixing and strengthening these arithmetic abilities through diagnostic quiz assessments, via the Moodle platform showed the positive use as mentioned in this study. The impact and degree to which the online diagnostic tests affected students' acquisition of fundamental mathematical information includes the ensuing enhancement in the application and utilisation of this knowledge in the first-year pre-calculus examined in this research.

The findings revealed how open teachers are to bring digital tools into learning. Teacher Thole was very interested when speaking to her class about using digital devices moving forward, whilst Teacher Taka had been using digital more often and creates positivity around the use of tools.

The addition of new technologies to teaching is greatly influenced by the comfort, satisfaction and perceived levels of achievement that teachers feel when using computing tools. Teachers are more likely to sustainably adopt digital technologies if, and only if, they have positive experiences and support while implementing technology (Chigona 2018). Digital devices also appear to have the potential to facilitate more interactive, learner-centred methods of implementing and improving learning outcomes (Chandra & Mills, 2014; Fransson et al., 2018). With the increasing shift in schools toward 21st century pedagogies, teachers are being enticed if not mandated to incorporate digital tools that may enhance efficiency, help ensure accuracy and engage learners during mathematics instruction (Abukhattala, 2016).

The findings of this study show that the research indicates that digital tools might be an opportunity for creative instructional approach, better learner involvement and academic achievement. Educators' acceptance of innovative tools bodes well for the digital revolution in Grade 9 Mathematics in different schooling contexts. Cevikbas and Kaiser (2020), Lo and Hew (2017) and Muir (2017) showed that different aspects of learner engagement brought positive results when new tools were introduced in digital mathematics classrooms. Literature by Bond (2020) and Lo and Hew (2017) indicate that future studies should focus on digital learning, especially in secondary schools.

4.3.2 Theme 2: Integration of Digital Tools into Grade 9 Mathematics Teaching

Digital tools were integrated in varying degrees in the teaching of mathematics across schools. Teachers in private schools demonstrated use of advanced platforms such as Polypad, Moodle and Siyavula, while government schools primarily relied on projectors, e-books and visualisers. Teachers indicated that digitisation improved lesson delivery, visual clarity, and access to resources, enabling more efficient coverage of the mathematics curriculum.

4.3.1.1 Sub-Theme A: Types of Digital Tools Used in Instruction

This sub-theme focuses on the specific digital tools teachers reported using in their Grade 9 Mathematics classrooms, and how these tools support teaching and learning. The variety of tools used across the three schools reflects differences in resource availability, teacher confidence and school-level digital infrastructure. Data for this sub-theme emerged from the transect walks and informal interviews:

- What digital tools do you use when teaching Grade 9 Mathematics?
- Have you introduced any digital aspects into your classroom?
- How do these tools support your teaching of mathematical concepts?

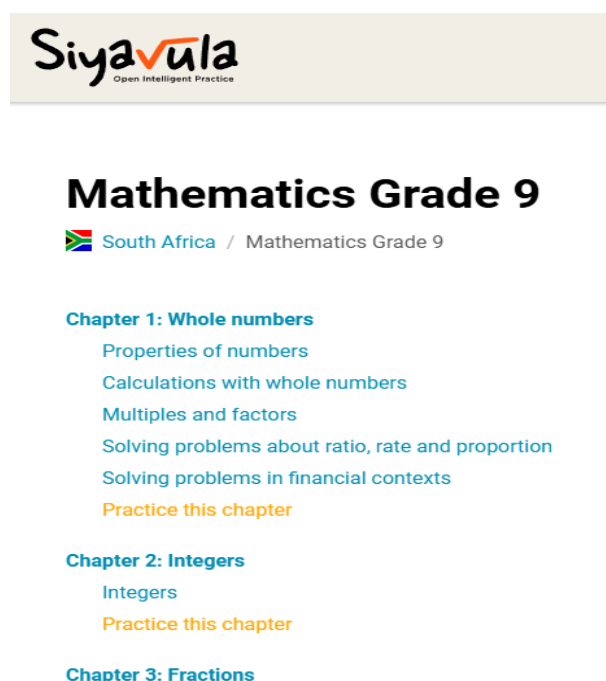
These questions allowed teachers to describe the digital resources they use, ranging from basic projection tools to specialised mathematical software.

At the private school, teachers demonstrated extensive use of advanced tools.

“I started using digital tools and resources when I started teaching at the current private school.” (Teacher Taka)

He mentioned that due to the resources being available, he is now able to use the data projector, PowerPoint and other digital materials when teaching Grade 9 mathematics. Siyavula, an African-based educational technology company and online learning platform providing free, curriculum-aligned, and adaptive mathematics and science practice for learners, is commonly used. Moodle is being launched in 2026 as a learning tool. The digital version of the mathematics textbooks together with the videos and teacher guides.

Figure 4.3 shows the Siyavula online platform for Grade 9 mathematics.



(Source: Siyavula portal)

Figure 4.3: Siyavula online platform for Grade 9 Mathematics

Teacher Mike at the same private school uses a digital writing tool, called a polypad and a digital projector, as well as the digital version of the textbook together with online platforms like Siyavula. He also mentioned that Moodle will become a vital platform in their school setting soon. Teacher Mike uses Polypad, a free, browser-based, interactive mathematical playground featuring virtual manipulatives for K-12 students, especially useful when teaching geometrical concepts. Whilst observing one of his mathematics lessons, it was interesting to see how technology and digitisation made it convenient for him to draw the shapes on a digital cartesian plane. He taught a lesson on transformation geometry. Prior to having white digital boards or data projectors, teachers needed to make more of an effort to ensure accuracy when

drawing shapes on chalkboards. The Polypad creates an advantage for the teacher and saves time as it is user-friendly. The colour brought about when drawing different shapes due to digital tools also made the lesson more interesting. The software that Teacher Mike used was able to save his notes and drawings that he digital compiled whilst teaching. This is then sent to the learners as a reference tool. This is convenient for both the teacher and learner, and saves paper, considering the environment.

Figure 4.4 shows the Siyavula online platform with each chapter of topics.

Chapter 11: Construction of geometric figures

Construction of geometric figures

Practice this chapter

Chapter 12: Geometry of 2d shapes

Geometry of 2d shapes

Practice this chapter

Chapter 13: Geometry of straight lines

Angle relationships

Identify and name angles

Solving problems

Practice this chapter

Chapter 14: Pythagoras' theorem

Pythagoras' theorem

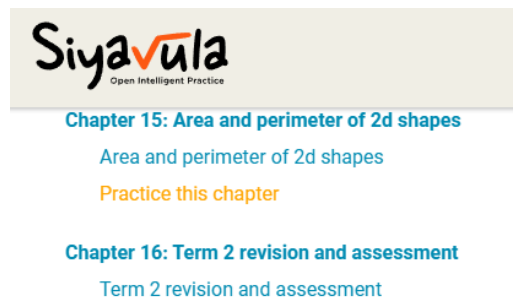
(Source: Siyavula portal, Google)

Figure 4.4: Siyavula chapter breakdown

Teachers like Teacher Mike, Teacher Odena and Teacher Van de Merwe incorporate Siyavula when teaching geometry as it assists learners in developing a good level of understanding of the concepts.

“Using Siyavula as an online platform supplements my teaching as an extension to what was taught in my classroom. Teaching geometry can be challenging as visuals and diagrams are the core of understanding angles.” (Teacher Van de Merwe)

Figure 4.5 shows the Siyavula chapter breakdown as well as revision and assessment section.



(Source: Siyavula platform, Google)

Figure 4.5: Siyavula online platform

“Siyavula has become so useful when teaching Grade 9 learners as the structure of the online platform is so user friendly for learners in mathematics. Each topic is separated into chapters following with a practice of the chapter, this gives learners more experience and exposure in preparation for tests and examinations. The revision of the term is also included.” (Teacher Odena)

Figures 4.4 and 4.5 show how orderly the chapters have been sorted out for learners to use. Chapter 16 shows how the term revision and assessment is structured as well, as mentioned by teachers.

Figure 4.6 below shows a Polypad that teachers use in the teaching of geometry.



(Source: Authors own image)

Figure 4.6: Polypad image

Teacher Tari, a more senior teacher with two decades of teaching experience teaches at the same private school. He is also completing his PhD and is knowledgeable. He shares the same sentiments as Teacher Mike as they have the same resources available at the schools:

“I use the digital tools a lot at school, it becomes interesting to have the textbook projected as compared to writing everything like before in a “chalk and talk” environment”. (Teacher Tari)

Teacher Tari also stated that the Polypad becomes convenient and a time saver in the classroom.

“Projecting memorandums also helps learners see how we mark and where we allocate marks as per the marking guideline.” (Teacher Tari))

The use of memorandums assists learners with answers to problematic questions and helps on how to answer which then becomes part of the test and examination preparation.

Figure 4.7 below shows part of a mathematics textbook.

Example 8
The sum of three consecutive even numbers is equal to 42. Determine the three numbers.

Solution
Let the numbers be $2x$; $2x+2$ and $2x+4$
 $\therefore 2x + (2x+2) + (2x+4) = 42$
 $\therefore 6x + 6 = 42$
 $\therefore 6x = 36$
 $\therefore x = 6$
The three consecutive even numbers are:
 $2x = 2(6) = 12$
 $2x + 2 = 2(6) + 2 = 14$
 $2x + 4 = 2(6) + 4 = 16$
Check: $12 + 14 + 16 = 42$ which is true.

(Source: Mind action series, pg:124)

Figure 4.7: Digital page of Grade 9 MAS Mathematics textbook

Teacher Tari referred to something like what is shown in Figure 4.7, where digital textbooks are available to teach concepts, projecting the information and thus saving time in class.

At another school, former Model C, I observed Teacher Thole’s geometry lesson, focusing on similar and congruent triangles. She used a digital projector and a visualiser, which turns information into a visible, graphical format, to have the textbook

projected whilst she worked through the exercises in the book. This made it easier for her as the teacher to show the learners how to work in their books and focused on accuracy as compared to redrawing on the board and not having a scaled drawing.

“Grade 9’s as you see me draw from point to point, you will follow this method into your books. Let us prove by measuring the sides and angles, work with me and see my hand movements as I demonstrate this in my book, as you will into your book, let us go step by step.” (Teacher Thole)

Learners become engaged in the lesson as the teacher was drawing on the paper as they would, it was relatable and easier to grasp. The real-time modelling gave the teacher the opportunity to demonstrate to the learners which aided in explaining complex tasks.

Teacher Kerbs, at the same school, mentioned that using the visualiser to project textbook content is a timesaver, and learners directly see what is required thus improving engagement and learning. Teacher Kerbs described the digital tools he used in his teaching:

“I use Teams and Google classroom for my extra support lessons for Grade 9 mathematics. This helps the shy learners who are afraid to ask questions to open up, so even though it isn’t a digital tool used within the classroom, the digital platform has created a comfort zone for my learners.” (Teacher Kerbs)

Teacher Odena, head of mathematics with over 15 years of teaching mathematics, at the same school as Teachers Herbst and Sithole, shared her use of digital tools.

“I use WhatsApp as a digital tool for the digital worksheets and PowerPoints so learners have access to these even after I teach it in class. With digital tools and the internet available I am able to extend myself instead of being restricted to worksheets and textbooks like before.” (Teacher Odena)

Teacher Odena also mentioned: *“Having digital platforms to send homework answers and memorandums really help when it comes to marking. Learners are then allowed to use their devices for this, since it being available in English and Afrikaans, this platform is usable to all learners at the school.”*

At a government school, Teacher Van Merwe spoke positively about introducing digital tools in her Grade 9 mathematics classrooms.

“I really think that digital tools are good if learners use these tools appropriately. The digital tool that I use like my projector, helps for example, when teaching aspects that require the cartesian plane. I can plot points and draw graphs accurately due to digital projection.” (Teacher Van Merwe)

She also mentioned that laptops and tablets are used in her classroom, which most learners have for their e-books. This has made the learners lives easier as well, instead of carrying thick textbooks.

“The appropriate use of the digital tools in the mathematics classrooms create an advantage and save time, as there is so much content to cover. Having access to digital aspects become more exciting as well, not just drawing or writing with chalk and erasing, I am able to save my slides and lessons and use it repeatedly, which makes my life easier”. (Teacher Van Merwe)

Teacher Tim at the same school explained that he has become digitally inclined as the world is moving towards digital aspects in most sectors on society.

“PowerPoint is used in my classroom a lot. I also use the clicking system which is digital and engages learners. I can interact with my class while teaching, standing away from my laptop” (Teacher Tim)

Figure 4.8 presents an example of PowerPoint slides on transformation geometry. This application allows teachers to click slides instead of being stationed at their table or laptop, which allows for more classroom visibility and interaction. The use of this application also helps when teaching multiple classes and being restricted to one white board or chalkboard. Teachers Tari like many other teachers, share the slide presentation with learners for references after lessons.



(Source: Author's own design)

Figure 4.8: PowerPoint presentation

Teacher Smit, who has been teaching Grade 9 mathematics for 6 years, commented that it has become normal for him to use the projector and laptop as part of his lessons. as compared to writing as much, he says that he has been and to gain the attention of the learner, the digital route does have an advantage.

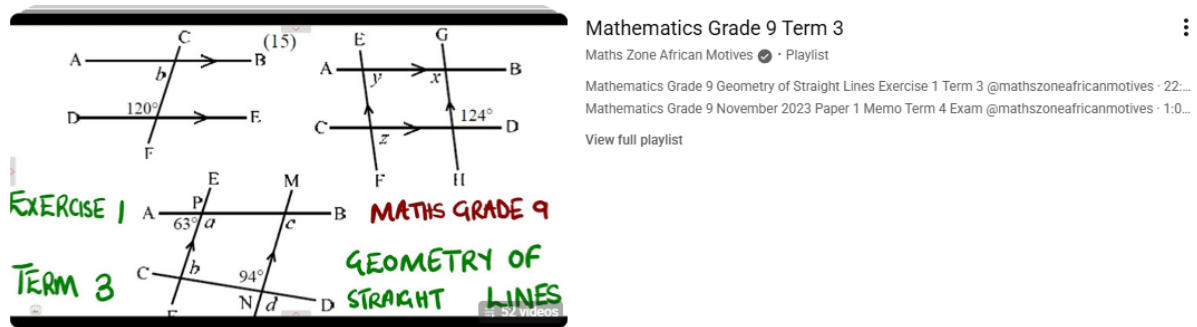
Teacher Roko is the head of mathematics at the same school as Teacher Smit and Vande Merwe. Teacher Soko in her 10 years of teaching mathematics shared some valuable insights when it comes to us digital tools in the classroom.

“Teaching Grade 9 learners being teenagers can be difficult but as teachers, we need to find a way around our learners and digital tools in a digital era has become important.” (Teacher Soko)

As Grade 9 learners are usually digitally literate, using digital tools in the classroom creates an engagement and interaction whilst teaching.

“Using YouTube videos to teach concepts and having the privilege of projecting this for the learners in class helps. Teaching concepts via digital tools saves time as a teacher. E-books are more available, and learners are used to being on devices, I am not taking away that learners need practice in mathematics, having digitisation is an added advantage.” (Teacher Soko)

Figure 4.9 gives an example of a YouTube video explaining a geometry concept.



(Source: YouTube videos online, 2025:1)

Figure 4.9: YouTube video - Geometry of straight lines

Amongst the three schools, teachers used a variety of educational technologies, from simple projection tools to specialised mathematics platforms, including Polypad and Siyavula. The range and complexity of tools related to the available resources and levels of institutional support. Consistent with research done elsewhere in the world (Haleem et al., 2022), teachers reported that digital tools made it possible for learners to better visualise concepts and process, explain their reasoning, learn at different paces and participate meaningfully in lessons.

Influenced by TPACK, teachers' selection of digital tools is guided by their TK; however, the tools' effectiveness in teaching depends on the extent to which they are congruent with pedagogical strategies (PK) and mathematical learning goals (CK). Variability across schools suggests diversity in TPACK growth. For example, teachers using Polypad or GeoGebra, applications directly underpin mathematical visualisation reveal high levels of TCK.

Nanbam et al. (2018) found that digital technology and ICTs in South African schools have been appraised as a powerful tool in the educational sector, which brings about change as they are a combination of technologies which can be feasible and flexible, as discussed in Chapter 2. The private school particularly demonstrated effective use of digital tools which can change teaching and learning in the classroom.

In provinces such as the Western Cape, the WCED has led multiple projects since 2019 to integrate digital technology across schools, including the development of 'Smart Classrooms' and expanding access to e-learning resources in core subjects like mathematics. Digital tools aimed at enhancing mathematics instruction, such as

interactive applications, virtual simulations, and digital assessments, which have helped increase learner engagement and improve learning outcomes in mathematics across the province in Western Cape showed positive feedback (WCED, 2019). Other provinces, such as Gauteng guided by the GDE, are also focused on implementing more technology in schools, as indicated in then findings reported above.

AI in mathematics has become common in mathematics teaching. According to Serhan Alam (2022), digital tools and ICT enable teachers to create their own content, affording them greater control over course materials than traditional classroom environments allow.

Schools in parts of Kwa-Zulu Natal have been able to use digitisation in the teaching and learning process. However, many teachers lack strong content knowledge to effectively utilise traditional methods to teach mathematics in a productive manner (Aliustaoglu & Tuna 2021).

The integration of ICT in the classroom within the Gauteng province, promotes learner-centred approaches, such as project-based learning, as noted in the focus group interview. Allowing learners to tackle real-world mathematical problems using diverse technologies, as learners build confidence in using ICT, they are better equipped to apply and share their knowledge effectively with new tools (Bhattacharjee & Deb, 2016a). Training in Gauteng was provided to mathematics teachers on GeoGebra, which is used by a few sampled teachers GeoGebra is a software tool that facilitates interactive lessons across various mathematical domains, including geometry, algebra, calculus, and statistics. This software is also compatible with Smart Notebook, enhancing its usability in teaching contexts (Kheswa, 2020).

According to its official website (geogebra.org, 2020), millions of people use GeoGebra worldwide, indicating that its usage has increased quickly. Additionally, it is a top supplier of many mathematical applications that advance Science, Technology, Engineering, Mathematics (STEM) education. The teachers were observed making use of these in their classrooms, especially at the private school.

4.3.3 Theme 3: Effects of Digital Tools on Learner Performance

Digital literacy skills assist learners with using technology as a tool in the learning process, for instance e-books, instructional videos, simulations and online leaning

platforms (Deja, 2021). When used well, these tools can increase participation, deepen understanding and facilitate collaborative engagement in ways that traditional approaches rarely do. Learners with a high level of digital literacy are inclined to get involved in the group discussions and networked collaboration, that helps promotion of better understanding by interacting with peers. Digital literacy provides learners with the knowledge and skills to critically evaluate the information available online, differentiate between reliable and unreliable information and through the meaningful use of technology, significantly improve student learning outcomes (Wang et al., 2023). These skills are also essential for learners to transition into the advances and demands of technology in a school setting as well as in life.

4.3.3.1 Sub-Theme A: Increased Engagement and Motivation

This sub-theme investigates how the use of digital tools influences learner engagement and motivation in Grade 9 mathematics classes. Among the most frequently cited reasons for this was that digital technologies engage and maintain attention and motivate learners to participate, where conventional chalk-and-talk styles of teaching often did not. The conclusions in this section emerged from the transect walks and informal interviews.

- How do learners respond when digital tools are used during mathematics lessons?
- What effects do digital tools have on learners' understanding of mathematical concepts?
- Do you see positive behavioural changes, such as increased attention or motivation, when using digital tools?

Teachers' responses revealed a clear pattern: digital tools promote interaction, curiosity, and sustained effort among Grade 9 learners.

At the private school, teachers frequently described heightened engagement when learners use devices such as tablets, laptops, or mobile phones for mathematics learning.

“When teaching the grade 9s, they tend to enjoy using their devices and it also enhances their attention to some extent, and this has to be controlled.” (Teacher Mike)

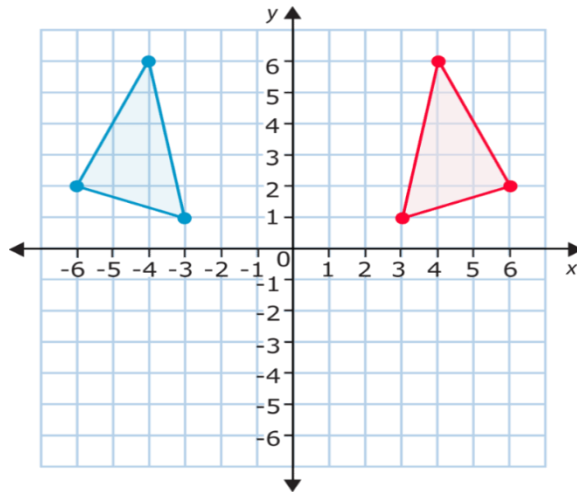
Teacher Mike during his geometry lesson, used different colours when drawing shapes when teaching transformation geometry (see Figure 4.10 below). The learners were more engaged whilst he taught and showed the different shapes from original to translated, using notes in colour as he did the translation on the cartesian plane. He did this using his Polypad which is the digital aspect that allowed him to be creative in the lesson and catch the attention of learners. His lesson became interactive visualisations and was automatically being saved onto his laptop, which also helped learners who were not in attendance in class to have access to his resources.



(Source: Author's own image)

Figure 4.10: Teacher Mike using digital tools to teach geometry

Figure 4.11 below shows what Teacher Mike was demonstrating using digital tools when teaching transformation geometry to his grade 9 class. Colour becomes important, showing the original shape and then the reflective image of the shape. Using colour allows learners to see the accuracy of flipping the image to create a reflection on the cartesian plane.



(Source: Google)

Figure 4.11: Cartesian plane showing reflective images

Teacher Tari at the same school stated that he had access to digital materials on difficult concepts together with memos, which could be shared with learners.

“Having the memorandums and exam papers available directly shows learners what is required and when concepts are taught, how are examiners going to test these” (Teacher Tari).

Access to technology assists in the teaching of specific mathematical concepts particularly offering learners a range of practice questions online which trains them to apply the knowledge taught by the teacher into tests and examinations.

Learners become familiar with using digital tools and are forced to engage in homework activities as they know it is monitored.

“Having online platforms like Siyavula, allows us to even monitor the homework that needs to be done when learners are at home. This keeps them going and they are urged to complete all work per concept that was taught in the mathematics classroom.” (Teacher Taka)

Teacher Taka explains that learners are able to use the available platforms to better understand concepts that they do not immediately grasp. With the help of AI and online digital resources, mathematical concepts can be learnt via many methods, including online games.

Grasping the different mathematical concepts at the Grade 9 level can also be a lot for learners, says Teacher Kerbs from another school. The curriculum is vast, and time is limited amongst other distractions and interruptions during the school year. However, with the increasing access to online resources, learners can engage with these to facilitate the understanding of mathematical concepts.

“The learners then engage and grasp concepts when they are part of lessons and are able to work with their friends, the engagement between their peers also creates an excitement while getting conceptual learning done in a proactive way”. (Teacher Kerbs)

“Creating a visual in mathematics for the age group of learners in Grade 9, becomes interesting and curiosity flows in their minds. Time saver is a big factor for the syllabus coverage and we as teachers need to teach concrete concepts as we prepare these Grade 9s for the FET phase of schooling, bringing digital tools to the classroom and our teaching methods, learners become engaged and are willing to learn through these methods. Being an old schoolteacher, I encourage my learners to construct and use their motor skills, which are important for development. Yet, I also like them to engage in activities which are online and where they can check with friends if they are correct.” (Teacher Odena)

Grade 9 learners today are digitally inclined and when digital platforms are used in the teaching of mathematics, learners are more interested, engage in lessons which facilitates understanding of mathematical concepts Figure 4.12 below shows a digital projector and screen set up in a classroom.



(Source: Author's own image)

Figure 4.12: Projector and visualiser set up in a classroom

During a lesson on parallelograms at a government school, Teacher Van Merwe's presented the different properties in colour and was able to enlarge each aspect during the explanation. This captured learner interest and ensure that learners were able to see and understand the properties. This understanding led to them knowing how to apply this when answering questions.

"There are advantages and disadvantages when it comes to digital tools and learner engagement amongst Grade 9 learners. The highflyers in my class keep themselves occupied and are curious to always do more using digital tools, while the other learners might not be as active." (Teacher Van Merwe)

Teacher Van Merwe noted that while engagement levels vary, digital tools could provide struggling learners with opportunities to revisit foundational concepts independently, which would then improve learner understanding and ultimately, learner performance.

Whilst observing her transformation geometry lesson, Teacher Van De Merwe used the overhead projector to project a cartesian plane onto the whiteboard and trace the x and y axis onto the board with a marker. This illustrated accuracy on the cartesian plane. This simple method of using a digital tool assisted learners in better understanding transformation of 2D shapes.

Teacher Mike, at the private school, used a polypad and lots of colour to illustrate methods of translations and reflections in geometry. Using digital tools effectively in the teaching process facilitated learning as learners were able to use GeoGebra on their digital devices to transform shapes, transitioning conceptual knowledge into actually drawings and transforming shapes on the cartesian plane. Even though learners' motor skills were not used in physical drawing, it helped them understand the need for accuracy via digital means.

The findings emerging from data at all three schools revealed that digital tools were widely perceived to significantly enhance learner engagement and motivation. The findings are aligned closely with those of the TPACK framework where Technological Knowledge (TK), Pedagogical Knowledge (PK) and Content Knowledge (CK) as well as the Educational Technology Theory indicate that all types of knowledge are vital for the effective teaching of mathematics with digital tools.

Digital simulations and interactive tools indicate high Technology Content Knowledge (TCK) which afford learners the ability to 'see' mathematical ideas in a new way. Bretscher (2022) conducted a case study and found that the key constructs of TPACK through various teacher strategies, including the use of transitions in and out of dynamic geometry environments to teach geometry better. This study via observations reported noticeable differences with learner performance. In planned tasks and directed activities when educators integrate digital resources to help plan, demonstrate and rehearse instruction they exhibit TPK. When TK and PK are in sync, lessons are more interactive ensuring that learners become curious about maths. In modern mathematics instruction, educators must not only possess content knowledge (knowing what to teach) but also pedagogical expertise (understanding how to teach and address learner learning challenges) and proficiency with the most effective learning technologies (Nantschev et al., 2020)

The findings of this study are in line with other studies that have demonstrated the positive impact of well-integrated digital tools on attention, motivation and conceptual understanding in mathematics classrooms, as found by Vidergor and Ben-Amram, (2020). While level of learner engagement is not uniform, technology environments in general are more engaging instructional settings, particularly for those topics that have high visual demands, such as geometry. Effective use of digital tools therefore

depends on teachers' TPACK competence, which determines how meaningfully technology strengthens understanding and supports mathematics learning.

4.3.3.2 Sub-Theme B: Improvements in Test and Examination Performance

Teachers in all three schools stated that the use of digital resources, particularly visualisation software, online practice systems and digital teaching materials yield improved performance in tests and examinations. The findings emerged from the transect walks and informal interview questions:

- What effects do digital tools have on learners' grasping of mathematical concepts?
- Do you see positive effects of using digital tools reflected in learners' test or exam results?
- In what ways do digital tools help learners prepare for assessments?

The responses indicated that digital content assisted with concept understanding, repeated practice and efficient explanation of lessons which have had an impact on learner performance and assessment results.

Research supports these observations. Vidergor and Ben-Amram (2020) discovered that digitally enhanced classroom situations promote learners' enthusiasm for mathematics, and their enthusiasm significantly impacts achievement. Similarly, Noreen et al. (2019) explain that the way mathematics is presented can greatly influence learning, and O'Meara and Prendergast (2019) note that instructional time made efficient through digital provision underpins mathematics performance.

"The improvement is seen amongst the class, when I use a Polypad and the digital aspects to teach measurement, like area and perimeter. I use colour and grids that are digitally projected and easier for learners to see. The learners are able to remember these abstract methods and apply this in their assessments." (Teacher Mike)

This method used digital tools which enhanced the concept being taught, so when this topic was assessed, learners were able to relate and apply the knowledge in answering the questions.

Teacher Tari at the same school also reported on the positive effects of using digital tools.

“When teaching using digital tools, it saves us time as teachers and allows us more time on concepts that are difficult, indirectly this translates into the learners results, because me as a teacher, I have more time to push difficult questions and prepare the learners for the tasks ahead.” (Teacher Tari)

He also stated that when learners complete mathematical tasks online, he can monitor and measure their progress per concept and they are able to redo tasks online, giving them opportunities to improve their results.

“We are able to use online tasks and tests to prepare learners for exams. Being able to monitor learner results and analyse this, assists us to bridge the gaps they have, especially with the lower end learners. It does not work with every group yet, overall learners are aware that we track their progress, pushing them to apply their skills in their written examination and tests.” (Teacher Taka)

Teacher Kerbs at a former Model C school, advocates that positive influence is visible amongst Grade 9 learners who have access to digital tools and resources as a learning platform. When the teacher uses the digital aspects in class to teach, it enhances the learning of mathematics concepts.

“With the available resources online, the tools we bring into the classroom, it does have an effect, even if it is slight. The learners are used to having a screen in front of them and being able to watch videos, like social media platforms. The teaching aspect and learning enhance and excite learners to continue working within the subject matter. This then has a ripple effect when they answer questions in tests and exams and the quality of work that they produce as well.” (Teacher Kerbs)

PowerPoints that Teacher Kerbs: creates for lessons are useful particularly as they are accessible online and do not need to be printed out.

“I have the freedom of putting together questions and activities that learners are able to work with from home, as practice or when they study. These help them and obviously push the results of the learners up as they work through the past papers and test that are also added onto my PowerPoints”. (Teacher Odena)

Teacher Van De Merwe reported an increase of 20% in learner results amongst learners due to the use of digital tools. Teacher Tim shared the same sentiment.

“Learners tend to find anything outside of the textbook interesting, like visual projectors, especially at a government school where exposure to technology and digital tools is limited. Using this as a positive, I teach using the available tools in my class, enhancing the learner conceptual understanding. When they sit to write a test and exam, they remember the ‘extra-ordinary’ parts of the lesson and answer well. This is how the improvement of results sprung up to 20% with most learners. Each group is different but for the most part, I see digital introduction in Grade 9 classrooms filtering into the results of formal tasks through the year” (Teacher Tim)

Head of Mathematics, Teacher Roko, acknowledged that teachers use different teaching methods.

“Getting teachers to change methods of teaching isn’t always easy and each Grade 9 class differs, I see the difference slightly but do not always use the digitisation in my teaching, but I do agree that it helps with results.” (Teacher Roko)

The findings revealed that certain teachers like Teacher Van de Merwe and Teacher Roko found a 20% increase in learner results when digital tools and platforms were used in the teaching process. Lo and Hew (2017) and Muir (2017) highlight that different aspects of learner engagement in digital mathematics classrooms have been insufficiently examined. This study revealed a gradually change in technology use even though there is room for improvement. Recent studies by Bond (2020) and Lo and Hew (2017) indicate that future studies should focus on digital learning, especially in secondary school education. Recent studies on TPACK highlight its significance in promoting innovative educational practices that keep pace with modern technological developments when using digital aspects in classrooms (Schmid et al., 2020); this ties in with teacher comments during the transect walks, particularly in the private school.

When using digital tools, it is important to build strong learner engagement in the technological environment as it is critical for the delivery of effective teaching. Learner engagement is a prerequisite for successful learning, as stated by Lam et al. (2018). Educational technology theory shows that by using ICTs, learners can access, create and share information while enhancing their communication, creativity, problem-solving and critical thinking abilities, when used in mathematics education (Cirneanu & Moldoveanu, 2024). It was evident at the private school that learners become engaged and interactive when using digital tools in the learning process. Ryan and

Deci (2020) recently suggested that research should focus on the design of learning via digital tools. Teachers who are more willing to use digital tools, as seen in this research, gain more from the learners and in turn, this improves learner performance in tests and examinations.

The findings indicate that digital tools make a significant difference to learner achievement in mathematical assessments by providing greater conceptual clarity, more opportunities for practice and increased learner engagement with mathematics content. Drom (2022) says that the perspective of educational technology theory indicates that it is not so much a class of things or technical objects, but more a way of thinking about things in terms of how they work as well as a way of acting on things to design them to work differently. Such results are strongly consistent with models of learning. Although the findings are not consistent across all schools or learners, in general evidence, they point to the fact that digital integration leads to enhanced performance in Grade 9 Mathematics.

4.3.4 Theme 4: Equity and Inclusion in Digital Mathematics Learning

Digital technologies improve efficiency and connectivity and in the case of the teaching of mathematics, offers access to high quality educational materials; however, in the school situation, inequalities may be seen where access to devices, internet connectivity, digital skills or language-appropriate digital platforms is uneven. It was mentioned by a teacher that some platforms only come in a standard language, English which isn't all learners' home language. This study shows a need for inclusion with this one basic factors of inclusion and equity. Teachers in all three schools noted that digital integration does not serve all learners to the same extent, particularly in contexts of social inequities, multi-lingualism and diverse levels of digital experience. These concerns have immediate implications for the extent to which learners can effectively engage in digital mathematics tasks and emphasise the importance of teachers' TPACK in mediating equitable learning opportunities.

The following theme emerged from the transect walks and informal interviews:

- Are all learners able to use digital tools positively in your mathematics classroom?
- Do learners face challenges when digital tools are used for homework or classwork?

- How do differences in learner background affect how they engage with digital tools?

These questions uncovered the ways in which digital integration enabled and constrained learning according to learners' situations in the selection schools in the Ekurhuleni district.

Across the three types of schools, differences were observed with respect to learners' opportunities for accessing digital mathematics platforms. Language proved to be an issue in the dual-medium former Model C school.

"When the platform is only in English, some of my Afrikaans-speaking Grade 9s struggle to follow the steps. It slows them down and they lose confidence." (Teacher Odena)

This highlights issues in CK and TK: without digital tools which provide multilingual scaffolding, the integration of CK is not accessible for some learners. Teachers' strong TPK is needed to choose, redesign or create additional resources with language support that they include to ensure that the digital task is inclusive.

The impact of linguistic accessibility on learner engagement was also raised.

"If the instructions are not in their home language, the weaker learners tend to switch off. The stronger learners manage, but others feel lost before they even start the task." (Teacher Thole)

Her experience highlights the importance of TPACK-sensitive lesson design, in which teachers either select digital tools that minimise language demands or adapt existing digital tools to ensure mathematics learning is not eclipsed by language. Equity considerations were most closely related to socio-economic situations and device access at the government school. Under the watchful eye of Teacher Van Merwe, learners in possession of their own devices were seen to interact with digitally rendered mathematics content.

"The highflyers keep themselves curious with the digital tools... but my weaker learners fall behind because they don't always have access to the same tools at home." (Teacher Van Merwe)

This divide is indicative of variations in the development of learners' TK. Some learners are able to develop more digital fluency and familiarity with mathematics platforms by using their own devices, while others only have access within the school. Their lack of consistent exposure limits their opportunities to develop a deep understanding of the connections between the technology and mathematical content increasing the TPACK gap for learners.

Teachers also noted safety and budgetary concerns.

“Many of our learners walk long distances or use public transport. They can't risk bringing tablets or phones every day, it's not safe.” (Teacher Roko)

Such circumstances limit equitable classroom participation when digital engagement depends on personal devices. Teacher Tim added that homework-based digital platforms are not equally accessible:

“Google Classroom works well, but only for the learners who have Wi-Fi at home. The others can't always complete the online activities.” (Teacher Tim)

This finding illustrates how homework is not completed because of access to digital tools, which may inadvertently exacerbate learning disparities between more and less resourced learners. This is an example of how digital homework can inadvertently perpetuate inequalities where access to WiFi is restricted. Learners without access to home internet cannot complete homework using the digital tools which hinders the development of TCK. Such an effect of technology integration is also likely to result in an unintended advantage to learners in higher-resourced homes.

The findings of this study are consistent with global evidence indicating that unequal access to devices and connectivity compounds pre-existing educational inequalities (OECD, 2021; UNESCO, 2020) amongst other issues. In contrast, learners from digitally privileged backgrounds, as seen in this study, amongst the different types of schools, are more likely to acquire the necessary TK for successfully navigating mathematics platforms and make good use of the interplay between TK, PK and CK. On the other hand, learners who experience little digital exposure are less likely to have developed TPACK-related skills, like working on software for mathematics pattern recognition tasks, interpret digitised representations or use online tools for exercises and revision. Gauteng has been one of those provinces adapting to

digitisation in subjects like mathematics. This signifies the onset of a revolution that is transforming lives digitally (Schwab, 2016).

It becomes crucial though for teacher education programmes to equip future educators with the necessary technological skills, along with pedagogical and content knowledge, to enable them to successfully integrate technology in their classrooms (Günbaşı, 2020; Ozudogru & Ozudogru, 2019), this then filters into the use of TPACK in classrooms.

In multilingual classroom environments, the lack of language adequate digital content dilutes the relationship between CK and TK. The former Model C school raised this point, a point to focus on when integrating digital tools in class. A teacher in the Western Cape showed that to improve Grade 9 Mathematics teachers' TPACKs, the right context is needed to do so (Morris, 2021). Without translation assistance, visual scaffolds or user-friendly interfaces, learners are unable to understand online prompts and mathematical justifications. This then places limits on the teacher's capacity to combine pedagogy, content and technology that enable inclusive learning. Mehta (2022) revealed that schools in India are also challenged with significant infrastructural limitations which limit the access and use of digital tools in mathematics education.

In order to support an equitable digital mathematics learning experience, schools need to invest in strategies that enhance learners' access to TPACK-aligned opportunities. Using digital tools in the learning process encourages learner interaction, promotes collaboration with peers to solve problems with peers online as revealed in Finland (Siemens & Matheos, 2019). Various aspects need to be considered such a multilingual digital support, safe device storage strategies and vast classroom-based digital tasks which do not solely rely on home access or personal technologies. Without these interventions, digital integration in the teaching of mathematics will be challenged.

4.3.5 Theme 5: Challenges Experienced When Integrating Digital Tools

Participants from the three schools all identified structural, pedagogical and learner-related challenges hindering effective digital integration. These issues are driven by socio-economic disparities among school types, as reported by Chen (2015) on schools in developing countries being affected by the digital divide. From a TPACK point of view, the irregular availability of digital equipment, as well as unstable Internet

access, constrains teachers' inclusion of TK into their PK and CK. Where technology is not available, teachers do not have the opportunity of shaping a lesson that effectively integrates these three domains. As a consequence, the development of teachers' TPACK continues to be restricted across contexts, resulting in inequitable learning opportunities.

4.3.5.1 Sub-Theme A: Accessibility of Digital Tools and Internet Connectivity

Access is at the root of successful digital integration, as learners must have in-class and out-of-school access to devices and connectivity to meaningfully engage with digital mathematics learning. Variations in socio-economic status, level of resourcing in schools, and family circumstances are some of the factors that lead to differing levels of access across schools.

Data for this sub-theme emerged from the transect walks and informal interviews:

- Have you introduced any digital aspects into your classroom?
- What digital tools do you use when teaching Grade 9 mathematics?
- Are the learners able to use digital tools positively in your classroom for mathematics?
- Do the learners comment or complain about using digital tools for learning?

In keeping with the literature regarding the digital divide in a developing environment (Chen, 2015), teachers reported that availability of devices and internet connection had significant variation between different schools. Teacher Mike, who comes from a well-resourced private school indicated how socio-economic privilege works to his advantage.

“Learners are able to afford devices of their own and have internet access at home as well as school.” (Teacher Mike)

This is indicative of a space where digital learning is not limited by access and teachers can more confidently implement digital platforms in their teaching. Teachers in the former Model C school reported varying access. While richer in resources, not all learners had the devices at their disposal.

“Digital devices or tools aren’t always allowed due to safety, and also learners might not have their own personal devices. This creates a challenge when allocating digital mathematics resources.” (Teacher Odena)

on the issue of the economic diversity within her learner population was raised

“Our learners come from different economic backgrounds, and it might be out of their reach to have personal access to digital tools and the internet.” (Teacher Odena)

Not all learners have access to their own digital devices, teachers are restricted to using digital tools during face-to-face time, which limits learners’ access to digital home practice or revision of mathematics. The state school was the most problematic. Teacher Van Merwe had nearly 40 learners in her Grade 9 Mathematics class, many of whom lived a distance from school and relied on public transport or had to walk to school, which posed a significant safety and affordability risk.

“Many of my learners walk to school or take public transport, so if they do have devices, it is unsafe for them to bring it to school regularly.” (Teacher Van Merwe)

Thus, for instance if learners have access to digital devices, there is the risk of safety.

- **Accessibility of Digital Tools and Internet Connectivity**

The above findings indicate that socio-economic differences influence digital access in South African schools. Learners attending a variety of types of schools, private, government, as well as former Model C, have different access to digital tools, due to affordability. Despite having access to the internet, educators appear to be hesitant to use their own resources and digital devices to enhance their instruction (Taleb, Ahmadi & Musavi, 2015). Poor device usage and unreliable access to internet limit the possible gains of digital learning, particularly in relation to mathematics. According to Stols et al. (2015), mathematics teachers in South Africa responded positively to the notion of using technology in the classroom, but they felt it increased the workload and had an effect on general class management.

The finding of the study revealed that most learners had access to digital tools at school but many did not have access at home. Although they acknowledged that technology may improve instruction and learning in their mathematics teaching, some teachers believed that their understanding of computers and software was inadequate

to fully adopt new pedagogies and technologies (Stols et al., 2015), which encompass TPACK. Without consistent access to such digital tools, the methods become ineffective, pose as unreliable for long-term dependency, are inconvenient to a student's learning environment due to the students' usage of this technology for inconsistent periods of time. Thus, without consistent access to such digital tools, content is unable to be reinforced effectively which is likely to undermine digital technology being considered a vital tool in the teaching of mathematics. Van Dyk and White (2019) acknowledge that high poverty levels restrict access to the financial and material resources needed for digital remote teaching and learning in all subjects. These factors affect mathematical learning through digital platforms as well as teacher development in these digital areas of teaching.

4.3.5.2 Sub-Theme B: Inadequate Teacher Training in Digital Pedagogy

The quality of teachers features prominently as an influencing factor on how digital materials are adopted, modified and used during instruction. The integration of digital tools is not equitable in all schools; however, there is a move towards sustainable, long-term and inclusive digital integration in the teaching of mathematics. National studies found that the majority of South African teachers do not possess sufficient digital skills for technology integration (Nyathi & Joseph, 2024), an issue that needs to be addressed.

This sub-theme was supported by the transect walks and informal interviews that sought background information about teachers' digital teaching experiences:

- Have you introduced any digital aspects into your classroom?
- What digital tools do you use when teaching Grade 9 mathematics?
- Do you feel adequately skilled or trained to use these tools effectively?

Government schoolteachers mentioned insufficient training opportunities, although financial implications of professional development were raised:

“There are not enough funds available to train teachers who teach mathematics. The platforms are available, but teachers cannot afford to train themselves as this is expensive and the school or department does not allocate funds for these trainings.”

(Teacher Roko)

This supports the view that, regardless of the existence of technology, lack of training leads to an inability for teachers to use it effectively. In many cases, teachers had to rely on their own resources to develop their digital competence:

“The reason I am digitally advanced is because I grew up with devices and the internet; not all teachers have had that access.” (Teacher Van Merwe)

“I have become digitally orientated due to personal need, yet other colleagues do not always come with the required training and skills.” (Teacher Tim)

Less exposure to digital tools and limited use among staff leads to lack of competency in using digitalisation in the teaching of mathematics.

The use of digital tools in the teaching of mathematics varies from one teacher to another. This seems to be because of limited availability and utilisation of digital resources and lack of training in developing digital literacy.

However, at the private school, teachers are required to be digitally literate:

“The hiring process allows us to state the requirement for teachers to be digitally versed and knowledgeable when they are employed.” (Teacher Mike)

Creating a more consistent baseline level of digital utilisation enables digital infusion in classroom settings.

- **Inadequate Teacher Training in Digital Pedagogy:**

Many educators lack the confidence or competence to effectively integrate technology into their lesson plans, focusing more on technical skills rather than pedagogical strategies. Teachers are of the drivers of digital integration. This study has revealed that not every teacher is confidently equipped to use digital tools. Ertmer’s research (2019), that discusses the resistance that teachers have towards adopting ICT in mathematics education in the USA, shows a correlation to South African schools; there is resistance, as found by this study. Adegoke and Akinola (2021a) in a study in Nigerian schools, report on inadequate infrastructure, limited teacher training and a divide which causes issues in integrating digital tools in such settings, even though the attempt was made. This is a problem across Africa and not unique in South African schools. A major issue is teacher training and professional development of teachers, as revealed in the government, former Model C and private schools.

Some teachers lack TPK, the ability to choose or manage technologies in ways that support instructional goals. Nelson (2019) used the TPACK framework to explore factors influencing technology integration among teachers, highlighting that technological knowledge and institutional support play a significant role in fostering TPACK development. Digital tools are not always integrated into task design, meaning they become add-ons rather than structured learning activities. Without strong PK, classrooms become difficult to manage when digital tools compete with non-academic content. Without strong TK, teachers cannot configure tools or platforms (for example, restricted modes, guided navigation). The purpose and implementation of TPACK has been important in education to ensure that learning through technology is meaningful (Brantley-Dias & Ertmer, 2013; Pradana et al., 2020).

While prospective teachers can quickly adapt to the digitalisation of learning activities, their pedagogical skills, particularly in developing learning objectives, tend to lag (Gonzales & Gonzales, 2021). In the absence of TK, PK and CK, use of technology is at classroom level, focusing on presentation tools rather than enriching conceptual understanding. Hence, digital access by itself is not effective in mathematics classrooms and in the absence of specific TPACK development training, teachers cannot effectively use digital resources for improving Grade 9 learning of mathematics.

4.3.5.3 Sub-Theme C: Learner Distraction When Using Digital Tools

Learner distraction was a recurring issue at all three schools. Teachers identified digital devices including social media, entertainment 'apps' and instant messaging applications as being beneficial for teaching; however, these provided learners with conflicting stimuli, and teachers reported that learners found great difficulty remaining on task.

The findings on classroom behaviour emerged from interview questions, both focus group and transect-walk informal interviews:

- Are learners able to use digital tools positively in your classroom for mathematics?
- Do the learners comment or complain about using digital tools for learning?
- What challenges do you face when learners use digital tools during lessons?

Concerns about behaviour were raised by teachers from participating schools, government, former Model C and private are similar.

“It sometimes can be challenging teaching the younger teenage group, such as Grade 9 mathematics learners. It is still their early high school years and they easily get distracted.” (Teacher Taka)

His thoughts focus on the 9th grade pupils' developmental skills, as well as their inability to focus when engaged in activities using digital tools.

Likewise, Teacher Tari, who has 20 years' experience, claimed that online materials particularly affected the learners' attention:

“The focus depends on the learner and the class... Grade 9 learners know more because of social media platforms and what's available on the internet.” (Teacher Tari)

He further explained that the large number of learners in the classroom are more challenging to manage with a class size of 40 or 45. Overcrowding creates additional challenges for behaviour, causes distractions and lack of focus when working on activities using digital tools.

Distractions at the former Model C schools was also seen as a result of poor mediating qualities, lack of digital literacy and language differences.

“Learners do not always learn quickly from digital tools, and when left on their own, the responses differ. With digital platforms only in English at times, the language becomes a challenge.” (Teacher Odena)

This shows that 'distraction' is not only behavioural, but it may be connected to learners experiencing difficulty finding their way around new or language-inaccessible platforms.

Teacher Khule brought in another perspective when he said that over dependency on technology could also erode the core mathematical processing:

“Grade 9 learners become reliant on the technology at hand, as compared to working out problems mentally. This has shown slower processing when answering mathematics questions.” (Teacher Khule)

This reliance aligns with findings that when not scaffolded, technology may lower cognitive load and, in doing so, lead to superficial learning rather than meaningful involvement.

- **Learner Distraction When Using Digital Tools**

The findings of this study revealed that the use of digital tools, if not managed effectively, could result in distractions in the classroom. The TPACK framework explains the issue as a breakdown in technological-pedagogical alignment, as using these tools can be effective as well as distracting when large numbers are in classes. Using digital tools in the teaching of mathematics creates a learner-centred approach where learners become more active in the learning process which helps in problem-solving. Research shows that adding digital features to mathematical pedagogy, means that learner interest and learning is enhanced using digital tools (Aydın, Saka, & Dikmen, 2019).

This study revealed that larger numbers of learners in classrooms, particularly at government schools, are challenging to manage. With the added interest of digital tools, learners become distracted with social media rather than using digital tools for learning. However, distracted by social media rather than using digital tools for learning may occur at any of the school types. Learners sometimes lack focus and engagement in the mathematics classrooms as they tend to be more drawn to social media. This was noted across the private, former Model C and government schools.

Learner distraction is not merely a behavioural issue, but an instructional challenge linked to limitations in teachers' TPACK development. When teachers have stronger TPACK knowledge, they design digital activities that guide learners' attention, support mathematical content, and reduce opportunities for off-task engagement. It is shown that there are gaps in terms of conceptual and methodological considerations related to engagement in these learning settings (Bredow et al., 2021).

4.3.5.4 Sub-Theme D: Pedagogical Shifts Resulting from Digital Integration

This issue investigates how the embedding of digital technologies has transformed teaching practices in Grade 9 Mathematics classrooms. Teachers from all three schools described transformations in their lesson plans, the ways they present mathematics and their relationships with learners. These transitions are aligned with

worldwide studies demonstrating that digitisation leads to the conversion of the conventional 'chalk-and-talk' method of teaching into multimodal, blended and interactive learning spaces (Kafyulilo, 2022; Voogt et al., 2020). Teachers, utilising online tools to teach, are increasingly agentive, busy and varied in what they do in their work requiring more advancing competence and complex support on the use of technologies, lesson design, assessment and classroom management.

In both the private and former Model C schools, teachers explained how the use of digital technologies had altered their teaching practice and enhanced their teaching.

“When I project the memo or the worked example, learners see exactly how a solution should develop step by step. It saves time and allows me to focus more on difficult topics instead of rewriting everything on the board.” (Teacher Tari)

This represents a move in TPK where technology enables the efficiency of instruction and allows teachers to spend more time in conceptual engagement and development of deep understanding of concepts.

“Using the Polypad allows me to show every transformation clearly, rotation, reflection, translation. The learners follow the colours and movement, and it becomes easier for them to reproduce the steps in their books.” (Teacher Mike)

His case illustrates a successful combination of CK with TK, which led to dynamically representing transformations, which help learners reason visually and appropriately in terms of procedures. Teachers at the former Model C school also spoke of pedagogical changes that mirrored those experienced by the teachers in the private school.

“Before, I had to draw everything by hand, and learners struggled when diagrams were not to scale. Now, when I use the visualiser, they copy exactly what I’m doing in the book. It’s clearer and they make fewer mistakes.” (Teacher Thole)

This demonstrates technology's role in fluency, as TCK elevates accuracy and efficiency of mathematical representations.

Digital shifts also prompt more interaction and questioning:

“Once learners see me solving a problem on the screen, they ask more questions. The lesson becomes less teacher-centred and more of a conversation.” (Teacher Kerbs)

This movement shows a progression toward greater levels of TPK, where technology enables dialogic approaches to teaching and facilitates more participative learning experiences, enhancing the quality of teaching and interaction by learners.

“With the smartboard, I won’t have to erase and rewrite all the time. I can keep the examples on the screen, move between pages, and build a lesson more logically. That structure really helps my weaker learners.” (Teacher Van Merwe)

The capacity to save, revisit, and sequence digital content constitutes the pedagogical promise of TK–PK alignment; it enables more coordinated lesson flow as well as better scaffolding for those who need further support.

- **Pedagogical Shifts Resulting from Digital Integration:**

Through this study, it can be concluded that digital integration is leading to major pedagogical transformations at schools, whether government, former Model C or private schools as per the data collected. Research has demonstrated that digital technologies can facilitate multimodal instruction incorporating visual, auditory and interactive elements that improve learning comprehension and retention (Haleem et al., 2022). Through enhanced modelling, lesson pacing and visualisation, digital tools have the potential to increase access to mathematics content and ensure that instruction is responsive to the needs of all learners. Participants from the selected schools have acknowledged improvement in Grade 9 mathematics performance and results. The changes seem to indicate that digital integration is not just putting tools in the classroom, but shifting how mathematics is being taught, learned and experienced through rich development of teachers’ TPACK.

TPACK has been used as a framework to guide teachers when designing technologically-based mathematics learning activities (Yan, Chai & So, 2018). If the technology being referenced is digital technology, as noted by Za'ba et al. (2020), it is more appropriate to focus on prospective teachers. Therefore, it is crucial for teacher education programmes to equip future educators with the necessary technological skills, along with pedagogical and content knowledge, to enable them to successfully integrate technology into their classrooms (Günbaşı, 2020; Ozudogru & Ozudogru, 2019). More advanced technology, including projectors, visualisers, the Polypad and GeoGebra, as seen in the classroom across the different schools, provided clearer explanation of how these tools are being used to teach mathematics. Teachers can

teach with a visual model (TK) along steps in an instructional sequence (PK), demonstrating content specific methods (CK). TPACK can help to both develop mathematical proficiency in learners and help teachers teach mathematical proficiency. Technological Pedagogical Knowledge (TPK) is where teachers modified their practices so that technology matches instructional demands, and Technological Content Knowledge (TCK), in which digital tools advance learner insight into mathematical ideas (Morris, 2021).

4.4 CHAPTER SUMMARY

This chapter presented the findings emerging from the thematic analysis of data collected by transect walks and informal interviews, observations and a focus group discussion with teachers from the private, former Model-C and government schools to develop a deeper view of how digital tools are being used by teachers to teach mathematics at the Grade 9 level.

Common themes emerged from analysis of data, and these have been listed above under the sub-themes. The analysis tied into the research questions to solidify findings and achieve the aim and objectives. Discussions under each theme brought in relevant theoretical theories in which this study was based on, namely TPACK and the Educational technology theory. Through data collection, analysis and discussion of the findings it has been clearly noted how teachers feel about digital tools as well as the usage across these schools in the Ekurhuleni district in Gauteng.

Chapter 5 presents a summary of findings derived from this study on the utilisation of digital tools in the teaching of mathematics at Grade 9 level, focusing specifically on the mathematics context.

CHAPTER 5

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

Chapter 5 presents a comprehensive summary of findings to answer the research question: *How effective is the use of digital tools in the teaching of Grade 9 mathematics in the Ekurhuleni district?* in conjunction with the aims and objectives of the research.

The findings present the outcomes of using digital tools, highlighting their effectiveness and impact on the teaching and learning process. Through an analysis of collected data, this section draws meaningful conclusions regarding the benefits and challenges associated with digital tool integration in the teaching of mathematics.

Additionally, Chapter 5 presents concluding remarks that underscore the significance of the study's findings. It emphasises the contributions of the research in advancing pedagogical practices in mathematics education, particularly in leveraging digital tools for enhanced learning outcomes. Overall, the chapter serves as a pivotal component in synthesising the study's insights and shaping future directions for leveraging technology in mathematics education.

Recommendations and suggestions for further study are also included in the chapter, taking into consideration the limitations and delimitations of the study as well as drawing a conclusion.

5.2 RESEARCH FINDINGS

Data collection was done via school visits, which allowed for the collection data via transect walks and informal interviews, classroom observations and a focus group discussion amongst teachers in different schools. This chapter presents a summary of the findings of the study to answer the research questions and achieve the aim and objectives of the study.

5.2.1 RQ1: How do Teachers Integrate Digital Tools in their Teaching Practice?

Teachers indicated that including digital tools improved lesson delivery, visual clarity and access to a wide range of resources, which engaged learners more effectively in the teaching and learning process. Teachers use different digital teaching tools, such as Polypad, Moodle and Siyavula, to enhance their practice in the teaching of mathematics.

Polypad, a free, interactive virtual manipulative platform, transforms the teaching of geometry apart from assisting the teacher with accurate diagrams and the application of different colours teaching the concept of transformation geometry on a cartesian plane, learners can explore, visualise and manipulate 2D shapes and 3D solids. The importance of technology in effective teaching and learning is also illustrated by the studies conducted by Vásquez et al. (2017) who found that the use of technology usage in classrooms ensured that learners were effectively engaged in the teaching and learning process during mathematics lessons which show that in this study it was effective as well. Effective teaching was done via digital tools which motivate and encourage students to learn using their passion for technology and digital tools (Elmahdi et al., 2018) as seen in this study when teaching grade 9 mathematics.

PowerPoint was also seen as a successful digital platform together with a remote clicker, where the teacher was able to walk around the classroom, interacting with the learners while they responded to questions about the mathematics content. The use of digital tools created a more interactive environment in the classroom with the concept of transformation geometry being supported with via the slides. Mavhunga and Naidoo (2020) investigated the impact of digital tools, interactive software and online resources used in the teaching of mathematics and found that it boosted learner participation and understanding, also shown in this study whilst visiting the schools in Gauteng.

Some schools, that were not as equipped with up-to-date technology, made more use of overhead projectors, e-books and visualisers. E-books are commonly used, as in this study, certain teachers preferred using digital textbooks, showing examples and answers of what learners have in their textbooks. A digital version of the textbook and memos streamlined the teaching process as these versions offer portability as seen in

this study, lower costs, search functionality and interactive features in contrast to writing continuously on the board, if hard copy textbooks were in short supply in the classroom (Miller & Thomas, 2015).

Williams (2020) found that the 4IR era is defined by the convergence of digital, physical, and biological systems, driven by innovations like artificial intelligence (AI), cloud computing, robotics, 3D printing, the Internet of Things (IoT), and high-speed wireless networks, bringing the relevance of digital tools to light as seen through this study. Teachers are part of the 4IR as they use digital tools in the teaching of mathematics. This research found that ICT integration improves learner understanding, which agrees with boosting interest in mathematics and enhances classroom engagement in previous studies (Bhattacharjee & Deb, 2016b; Netsianda & Ramaila, 2021; Nihuka & Bussu, 2015). Teachers have shown a positive attitude to the use of a range of digital tools in the teaching of mathematics at Grade 9 level resulting in developing a more interesting learning environment.

Even though the majority of teachers were confident in the use of digital tools and platforms as a learning tool, they are open to introducing new digital tools, particularly with advancements in technology. Nguyen and Lee (2021) in their studies on the role of digital learning tools in teaching geometry to high school learners in Australia, found that digital resources significantly enhanced learner understanding of geometric concepts, which showed that when teachers use visual aids to teach geometry in this study it worked effectively.

GeoGebra, a free, open-source dynamic mathematics software suite that combines geometry, algebra, spreadsheets, graphing, statistics, and calculus into a single, user-friendly interface, was used by some participants. One teacher used GeoGebra to teach transformation geometry, as diagrams are easily available, and it was seen as effective as compared traditional drawing methods.

It was found that integrating tools such as Moodle and GeoGebra, in classrooms with access to smart boards, also reflects a more general trend amongst mathematics teachers. Das (2019) indicated that rapidly evolving tools that embrace digital technology such as computers, Smartboards, handheld calculators, overhead projectors, smartphones, and cloud computing, along with applications like simulators,

spreadsheets, virtual environments and video conferencing are advancements in mathematics education. This study agrees and showed that these advancements are beneficial in mathematics.

The introduction of new digital tools also in the teaching of mathematics posed a positive challenge for the study participants and motivated them to upskill and find creative methods to keep up with trends and advancements. Teachers were open to incorporating new digital tools in their practice and adapting their teaching methods. There is a growing need for teachers to introduce new tools and to positively adapt to technological changes in classrooms as this was seen in this study as well (Flavell et al., 2019), being supported through ongoing professional development, conversations with peers and focus-group collaborations.

5.2.2 RQ2: What Are the Benefits When Integrating Digital Tools in the Classroom?

This use of digital tools and platforms in the teaching of mathematics at Grade 9 level has resulted in major benefits for both teachers and learners. Teachers have access to a vast range of resources that they can incorporate in their lessons which offer diverse multimedia materials, worksheets, interactive games, and assessment tasks. Teachers do not need to only rely on textbooks, of which many are outdated, for teaching content. Rapanta (2021) supports this in previous studies by showing that capability and creativity are essential qualities for ensuring high-quality teaching and learning with digital tools in mathematics. Serhan and Alam (2022) found that digital tools and ICT enable teachers to create their own content, which was also found in this study, affording them greater control over course materials than traditional classroom environments allow. Teachers in this study concluded that the use of digital tools created a better understanding of concepts which motivated learners to be involved, interactive and take control of their learning.

The use of digital tools resulted in an increase in learner engagement and motivation when certain tasks were digitally assigned to them. Learners were diligently involved when using digital resources and engaged in completing the learning activities

Modern teenagers tend to be 'tech-savvy' with high proficiency, knowledge and confidence in using modern technology. This means that in the teaching and learning environment there should be a new era of digital engagement. The use of digital tools

in the teaching of mathematics motivates learners, increasing their interest and participation. Creating a more engaging class as well as an interactive class keeps learners motivated throughout the lesson. Incorporating interactive visualisations in the lesson, makes complex topics easier to understand. In addition, digital tools and activities enable learners to work together on projects and share strategies, fostering a collaborative learning environment. Ngai et al. (2018) agree that by using digital tools, it brings about different experiences and ideas among learners, promoting teamwork, improving academic competence, enhancing self-efficacy and building social and cognitive skills, teachers in this study agreed about the experiences when digital tools were used.

Hazaymeh (2021) supports this study by indicating that the competence, effective and efficient use of new technologies enhances learners' abilities to apply and transfer knowledge, which was shown in this study, thereby increasing their confidence in the learning process in core subjects like mathematics.

5.3.3 RQ3: How do Digital Tools Influence Learner Performance in the Classroom?

This use of digital tools and platforms in the teaching of mathematics at Grade 9 level have a major influence on learner performance and results. As the world is moving towards a more digitally inclined society, incorporating digital tools in the teaching of mathematics has shown good relevance to the real world, tying in with the learner improvement in understanding and performance as well as assessment and examination results.

Educational technology theory exposes learners to real-world challenges and opportunities, including computational thinking, physical computing, programming and coding key skills required across various industries and roles in the digital economy (Bressler & Bodzin, 2013), depicted in this research as well showing an agreement to previous studies. Learners at Grade 9 level are also very interested in career choices which lead to subject choices. As a result, learners need to ensure good mathematics results which could influence subject choice for the Further Education and Training (FET) Phase. Teachers found that using this as a motivation with the use of digital tools and platforms, allowed learners develop a better mathematical conceptual understanding.

When digital platforms are added to mathematical pedagogy, learner interest and learning is enhanced resulting in positive improvement of understanding and thus performance (Aydın et al., 2019) as mentioned by teachers in this study. In addition, learners can better prepare for assessment and examinations with access to digital resources such as Siyavula, the Khan Academy and Advlearn, which would then improve their performance and achievement results.

It was found that teachers who used digital tools as part of teaching a mathematical concept in this study, were able to track learner improvement after tests. In addition, the feedback, allowed learners to identify mistakes and correct understanding. Lo and Hew (2017) and Muir (2017) agree with this and stated that learners should be sufficiently examined once digital tools have been used to teach and take notice of the difference in performance and achievement. Recent studies by Bond (2020) and Lo and Hew (2017) also agree and indicate that future studies should focus on digital learning, with tests and examination especially in secondary school education.

Research conducted in Indonesia by Miftachurohmah, Nasruddin and Palobo (2025) found that technology-enhanced learning has a positive effect on student performance, tying in with this current study. The results suggest that effective incorporation of ICT tools, such as GeoGebra, Desmos and various online learning platforms, are able to strengthen students' conceptual understanding, promote deeper engagement and facilitate more interactive learning experiences (Miftachurohmah et al., 2025). These researchers reported that ICT usage can account for approximately 23% of the variance in mathematics achievement scores (Miftachurohmah et al., 2025).

5.2.4 RQ4: What Challenges Do Teachers Experience When Integrating Digital Tools in the Classroom?

Teachers face many challenges when integrating digital tools in the teaching of mathematics. The access to digital resources and internet connectivity in schools is characterised by a significant digital divide, with well-resourced schools possessing advanced technology while rural and township schools often lacking basic connectivity and devices. Socio-economic differences affect the affordability of digital devices, as not all parents are able to buy cellphones, tablets or laptops for their children. Van Dyk and White (2019) noted that high poverty levels have limited access to the financial

and material resources needed for digital remote teaching and learning in all subjects, which showed in the government schools as compared to more privileged schools in this study.

Adegoke and Akinola (2021) in a study in African schools, found that there is inadequate infrastructure showing the digital divide which causes issues in integrating digital tools in such settings, where learners do not have full internet access. Most private school learners possess their own devices, while many of the former Model C and government school learners do not have their own devices or sufficient internet access. Hansson (2018) found that insufficient resources, like internet connectivity contribute to the negative aspect of digital usage in some South African classrooms.

Across the continent of Africa, the issue of devices and access to the internet is well known. Despite the advantages of incorporating digital tools, some teachers show limited interest in using technology in their mathematics classrooms (Daher et al., 2018), also mentioned by teachers during this study. A major challenge faced by teachers in Zimbabwe was covering internet costs from their limited salaries while using personal devices to manage hundreds of assignments (Matimaire, 2020; Vurayai, 2022). This indicates that many parts of African countries have limited or no access to the internet.

With advancements in technology, teachers are not confident in using digital tools when teaching. Not every teacher has been trained to implement and introduce digital tools in their teaching practice. Research found that mathematics teachers in India faced inadequate training and lack of support which resulted in lack of confidence in using digital tools in their practice (Kumar & Singh, 2020), some teachers also experience this as spoken by mathematics heads in this study. Although teachers may be computer literate and aware of digital teaching methods, as in this study, not every teacher has developed the knowledge and skills to use digital tools to enhance the teaching of mathematics. Many teachers are accustomed to using a traditional approach in the teaching of mathematics, which entails using an ink marker to display problems and formulas on a whiteboard or using chalk on a chalkboard (Fuentes-Cabrera et al., 2020). Davis and Nguyen (2021) reported that in Australia, mathematics teachers resist using digital and ICT tools as they tend to use traditional methods of teaching within the classroom.

Teachers need to develop the knowledge and skills required to incorporate technology in their practice. TPK (Technological Pedagogical Knowledge) is the ability to choose or manage technologies in ways that support instructional goals. Nelson (2019) stated that the TPACK framework to explore factors influencing technology integration among teachers, highlights that technological knowledge and institutional support play a significant role in fostering TPACK development. This study showed the lack of the theory being put into practice by certain teachers.

Research has indicated that rapidly evolving tools that embrace digital technology such as computers, smartboards, handheld calculators, overhead projectors, smartphones and cloud computing, along with applications like simulators, spreadsheets, virtual environments and video conferencing are advancements in learning. These contribute to a more dynamic and interactive mathematical learning process even though the distraction is evident with some learners (Abbas, 2013; Alazam, Bakar & Asmiran, 2008; Buabeng-Andoh, 2012; Das, 2019; Dube, Nhamo & Magonde, 2018; Jatileni & Jatileni, 2018; Niyibizi et al., 2023; Volman, Eck, Heemskerck & Kuiper, 2005). In addition, teachers identified digital devices social media apps such as entertainment apps and instant messaging as beneficial in teaching; however, these prove to have a negative effect on learners who find difficulty in staying on task and tend to become distracted with non-academic apps and digital material, which would then have an effect on their engagement with the learning material.

5.3 ADDRESSING THE STUDY GAP

In answering the main research question: *How effective is the use of digital tools in the teaching of Grade 9 mathematics in the Ekurhuleni district?* this study is significant in that it shows that digital tools are effective in the teaching of mathematics in the private, former Model-C and government schools in the Ekurhuleni district. However, even though the participants reported positive effects on mathematics pedagogy, there was limited use of digital tools. Muhazir and Retnawat (2022) stated that using technology to teach and learn mathematics increases students' motivation, interests, and achievement. However, just 19.22% of junior high school students and only 16.23% of senior high school students use technology to learn mathematics to address the difficulties of the digital age (Muhazir & Retnawat, 2022). This study highlights the gap between digital tools and how teachers use them in the classroom.

Digital tools used to teach in classrooms have been seen as a positive in this study; however, not all teachers use digital tools effectively in the teaching of mathematics, creating a gap in the learning environment. The South African government has spent over 15.3 billion rands on educational technology and other instructional supplies as Minister Malusi Gigiba, mentioned in his budget address in 2018, yet many schools are faced with issues and challenges with access to resources. However, according to Xiang (2018), many mathematics teachers are still unaware of the ways that educational technology might improve instruction and learning.

Therefore, it becomes important in South African classrooms to ensure that teachers are aware of digital resources and tools that are accessible to bridge the gap between traditional learning and digital learning. In mathematics, technology and digital tools must be integrated into the classroom to support the teaching-learning process so that students can develop their knowledge of mathematical concepts and procedures until they are able to do it without the aid of technology (Muhazir & Retnawat, 2022). Anything that improves classroom learning through the use of blended, in-person or online learning, is considered educational technology. All digital devices, including computers, laptops, tablets, smartphones, the internet, audio-visual resources and computer software, are included in the definition of instructional technology (Saal & Graham, 2023). A comparison between administrator and teacher perspectives on the usage of educational technology and the obstacles to its integration indicate the need to pursue digital tools (Saal & Graham, 2023).

5.4 RECOMMENDATIONS

The recommendations are derived from the findings of this study:

- Teachers need to be trained to implement digital tools as part of their teaching and learning. One out of the nine teachers use digital tools confidently and are self-taught. It was mentioned that the cost of training and courses cannot be afforded by all teachers teaching mathematics at schools.
- The cost of digital tools can be high, the GDE together with School Governing Body (SGB) members need to invest in school devices for long-term learning. This will bring about uniformity across classrooms and maybe uniformity of tools across different schools in South Africa. It was seen that private school learners

are equipped with digital devices and this made learning easier as compared to non-private schools.

- Subject advisors, specifically mathematics subject advisors and Heads of Department should also include digital teaching methods in their workshops and planning. This would allow teachers to be trained in using digital tools creating opportunities for teachers to be creative and willing to introduce digital tools effectively.
- Collaboration should occur amongst teachers teaching the same grade across schools, even in the same district. This creates a platform for teachers to meet with each other and ensure teaching standards are on par, once digital tools and platforms are introduced more frequently in classrooms.
- Pre- service teachers are the new generation of teachers and should be encouraged to use digital tools in their teaching practice lessons. The university should encourage collaboration with the mentor teacher during teaching practice.

5.5 SUGGESTIONS FOR FUTHER RESEARCH

This study focused on using digital tools effectively in the teaching of mathematics at Grade 9 level. This was, however, limited to three schools and nine teachers in the Ekurhuleni district in Gauteng, limiting the grade and area of study in mathematics. Future research should focus on

- the broader areas and include rural as well as affluent urban areas to identify the digital divide and digital progress across the country.
- the most used digital tool by teachers and learners, which is also more effective if used across a province and the country.
- Including mathematics teachers with more experience as well will benefit future study.

5.6 LIMITATIONS AND DELIMITATIONS

5.6.1 Limitations

Certain limitations were experienced in conducting this research. These limitations stem from factors such as limited access to certain digital tools or platforms, as well

as variations in technological infrastructure across different educational settings. However, these constraints provided a perspective on the feasibility and practicality of implementing digital tools in mathematics instruction at the Grade 9 level.

The digital tools did not always work, due to technical issues or the internet; therefore, it is important to have more than one tool in the setting. Access to the internet in the schools to use the digital tools was not always possible.

Data collection instruments were written in English, which were participants' additional language and could have been a challenge in understanding. A tape recorder was used to record interviews. The time that teachers could commit to the research was limited, so it was important to remain in contact with teachers online to maximise the information they provided.

5.6.2 Delimitations

Delimitations are the boundaries set by the researcher to narrow the scope of a study, helping to define its focus and enhance manageability. These boundaries are intentional and often include factors such as the number of schools, geographical location, sample size and specific research methods. Setting delimitations allows researchers to concentrate on aspects of a phenomenon while acknowledging the limitations inherent in their study. According to Creswell and Creswell (2020), clearly stating delimitations helps to clarify the study's aims and ensures a more focused approach. Roberts and Hyatt (2021) agree and point out that delimitations are important in distinguishing between what the study will and will not address, aiding in the study's overall coherence and feasibility.

This study was confined to the province of Gauteng, South Africa, specifically the Ekurhuleni district, and to three schools only, and focused solely on six teachers involved in mathematics education for Grade 9 learners.

5.7 CONCLUSIONS

This study's findings have shown that integrating digital tools into the teaching of mathematics at Grade 9 level have revealed the effective use of digital tools in the teaching and learning process. Digital tools are effective as they increase learner engagement, interest and motivation. The use of digital tools creates a more engaging

interactive class particularly when incorporating interactive visualisations which make complex topics easier to understand. Learner performance and achievement results were said to increase, which developed a positive attitude in learners.

However, various factors were seen as barriers to successful implementation of digital tools in the teaching of mathematics. Teacher knowledge and lack of experience with using digital tools effectively and implementing relevant digital tools due to lack of access and training were identified factors.

The theories of educational technology and the TPACK model tied in well with this study. The TPACK model identified the knowledge teachers need to integrate technology effectively in the teaching and learning process. Rather than treating technology in isolation, teachers must understand the complex, synergistic intersection of technology (TK), pedagogy (PK), and content (CK) (Mishra & Koehler, 2006) to ensure quality teaching in mathematics education at Grade 9 level.

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APPENDICES

Appendix A: University of South Africa Ethical Clearance



College of Education _ERC

Date: 27/08/2025

Dear: Mr Ishaan Baschoo

Decision: Ethics Approval from 27/08/2025 to 26/08/2028

NHREC Registration # : (if applicable)

Ref # : 0733

Name: Mr Ishaan Baschoo

Student # : 58241159

Staff # :

Researcher: Mr Ishaan Baschoo

7 Maria Road

Gauteng

58241159@mylife.unisa.ac.za 084 925 8919

Supervisor: Prof Safura Meeran meeran@unisa.ac.za

Co-Supervisor:

Co-Researcher(s):

Email address:

The effectiveness of using digital tools to teach grade 9 mathematics in the Ekurhuleni district

Qualification: MEd

Thank you for the application for research ethics approval by the College of Education _ERC for the above-mentioned research study. Ethics approval is granted for **three years** .

The **negligible risk application** was **reviewed** by the College of Education _ERC in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising during the undertaking of the research study that may affect the ethical integrity of the study, including those involving research participants, third parties, or juristic persons, must be reported in writing to the College of Education _ERC without delay.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that may affect study-related risks to research participants, juristic or third persons, must be reported in writing to the College of Education _ERC, accompanied by a progress report.

5. The researcher will ensure that the research study complies with all applicable national legislation, professional codes of conduct, institutional guidelines, and scientific standards relevant to the specific field of study. Where applicable, adherence to the following South African legislation is essential: the Protection of Personal Information Act (No. 4 of 2013), the Children's Act (No. 38 of 2005), and the National Health Act (No. 61 of 2003)
6. Future use of this research data is permitted only in de-identified form and only for secondary research with objectives similar to those of the original study. Any secondary use involving identifiable human data will require additional ethics clearance.
7. No fieldwork activities may continue beyond the stated expiry date (26/08/2026). A completed Research Ethics Progress Report must be submitted as an application for renewal and is subject to approval by the Research Ethics Committee. A Close-Out Report must be submitted upon completion of the research study.
8. The College of Education _ERC may require the submission of regular progress reports on an **annual** basis, in alignment with Section 7.2 of the Unisa Policy on Research Ethics (2024).

Additional Conditions

1. Disclosure of data to third parties is prohibited without explicit consent from the research participants and Unisa.
2. Research data must be stored in compliance with the university's research data management policy for a period of up to 15 years.
3. When publishing the results, the researcher must take appropriate precautions to safeguard the confidentiality and privacy of the research participants, juristic persons, third parties, and the university, in accordance with institutional policies and ethical standards.
4. Adherence to the National Statement on Ethical Research and Publication Practices, specifically Principle 7 on Social Awareness, must be ensured. This principle states: 'Researchers and institutions must be sensitive to the potential impact of their research on society, marginal groups, or individuals, and must consider these when weighing the benefits of the research against any harmful effects, with a view to minimising or avoiding the latter where possible.' The University of South Africa (Unisa) accepts no liability for any failure to comply with this principle.

Note

The reference number 8733 should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.

Kind regards,



Prof. Justin Dewin August
Chair of College of Education _ERC
E-mail: augusjo@unisa.ac.za

Appendix B: GDE Approval Letter



GAUTENG PROVINCE

Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	11 June 2025
Validity of Research Approval:	08 February 2025– 30 September 2025 2025/158
Name of Researcher:	Bauchoo I
Address of Researcher:	Greenpark Lifestyle Estate Boksburg/Gauteng
Telephone Number:	084 025 8919
Email address:	ibauchoo@gmail.com
Research Topic:	The effectiveness of using digital tools to teach grade 9 mathematics in the Ekurhuleni District.
Name of University:	UNISA
Type of qualification	Masters
Number and type of schools:	3 Secondary Schools
District/s/HO	Ekurhuleni North, Ekurhuleni South

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

Making education a societal priority

Office of the Director: Education Research and Knowledge Management

7th Floor, 17 Simmonds Street, Johannesburg, 2001

Tel: (011) 366 0488

Email: Faith.Tshabalala@gauteng.gov.za

Website: www.education.gpg.gov.za

1. Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.
2. The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.
3. Because of the relaxation of COVID 19 regulations researchers can collect data online, telephonically, physically access schools or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate.
4. The Researchers are advised to wear a mask at all times, Social distance at all times, Provide a vaccination certificate or negative COVID-19 test, not older than 72 hours, and Sanitise frequently.
5. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.
6. A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.
7. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalized in any way.
8. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.
9. Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.
10. Items 5 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.
11. It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.
12. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, fares and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
13. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.
14. On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.
15. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.
16. Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards



.....
Mr. David Bapela
CES: Education Research and Knowledge Management

DATE: 18/07/2025

2

Making education a societal priority

Office of the Director: Education Research and Knowledge Management

7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabelala@gauteng.gov.za
Website: www.education.gpp.gov.za

Appendix C: Participant Information Sheet



Date: 20 June 2025

Title : **The effectiveness of using digital tools to teach grade 9 mathematics in the Ekurhuleni district.**

DEAR PROSPECTIVE PARTICIPANT

My name is Ishaan Bauchoo, I am doing research under the supervision Prof. S Meeran a professor in the Department of Curriculum and Instructional Studies towards a Masters Degree at the University of South Africa. We are inviting you to participate in a study entitled: **The effectiveness of using digital tools to teach grade 9 mathematics in the Ekurhuleni district.**

In case you need further information about the study contact my supervisor on the following contact details: Telephone; 012 429 6039, email; meeras@unisa.ac.za.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of my study is to look at digitisation within the mathematics classroom. My focus will be on grade 9 mathematics classrooms as these age group of learners are interested in devices or digital tools. I would like to see if these digital tools are effectiveness on learners mathematics results.

WHY AM I BEING INVITED TO PARTICIPATE?

You are invited because you are a grade 9 mathematics teacher. You will be able to share your teaching practices and methods with me. More importantly you will be able to share how you use digital tools or devices in your classroom.

I obtained your contact details from your HOD/Principal who recommended you as the relevant teacher who can provide reliable information for this research study. You are among the nine teachers who are sampled for this research. Confidentiality of your personal information is guaranteed.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

The study involves the use of transect walks, observations and interviews to collect information for the study. Firstly the participant will complete a transect walk about their experiences and challenges when using digital tools, secondly I will observe classroom activity when you teach a grade 9 class. Thirdly there will be a focus group discussion on the use of digital tools. Open ended questions will be asked because the study is about your personal use of digital tools in your classroom.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and

be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

Your involvement in the study will assist us to bridge the mathematical gaps by using digital tools. It will be seen as a positive contribution to the education sector in South Africa. The focus on mathematics and using digital tools to enhance learning will benefit teachers like yourself.

ARE THERE ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

There are no risks and dangers attached to the research. Data collection will be done at your school participants will be in their own safe and calming environments when this study is conducted. The participant will only need to have data and create time for meetings and the completion of the interview. Identities of selected participants will be kept private.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

You have the right to insist that your name will not be recorded anywhere and that no one, apart from the researcher and identified members of the research team, will know about your involvement in this research. Your name will not be recorded anywhere and no one will be able to connect you to the answers you give. Your answers will be given a code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings.

Your answers may be reviewed by people responsible for making sure that research is done properly, including the transcriber, external coder and members of the Research Ethics Review Committee. Otherwise, your records will be available only to people working on the study, unless you give permission for other people to see the records.

The information you provide may be reviewed by the university's Research Ethics committee, the transcribers and the external coder to make sure processes of research are done properly for journals and in other articles that might be issued for public consumption, however the information will be kept confidential to other parties unless through your consent.

Note that the information you provide may be used for research reports, journal articles and conference proceedings and even if a copy is submitted for publication, you will not be identified in such a report. Confidentiality and anonymity is guaranteed in this.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

Hard copies of your answers will be stored by the researcher for a period of five years in a locked cupboard/filing cabinet for future research or academic purposes; electronic information will be stored on a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. Indicate how information will be destroyed if necessary. If necessary, hard copies will be shredded and electronic copies will be permanently deleted from the hard drive of the computer through the use of a relevant software programme.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

Participation is voluntary and there no incentives and payments that will be given to the participants for their involvement in the study.

HAS THE STUDY RECEIVED ETHICS APPROVAL

This study has received written approval from the Research Ethics Review Committee of the College of Education, Unisa. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact Ishaan Bauchoo on 084 025 8919 or email 58241159@mylife.unisa.ac.za. The findings are accessible for a period not exceeding five years.

Should you have concerns about the way in which the research has been conducted, you may contact Prof. S. Meeran on 012 429 6093, email; meeras@unisa.ac.za

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.



Ishaan Bauchoo

Appendix D: Consent/Assent Form



I, _____ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the _____

I have received a signed copy of the informed consent agreement.

Participant Name & Surname (please print) _____

Participant Signature

Date

Researcher's Name & Surname (please print): **Ishaan Bauchoo**

A handwritten signature in black ink, appearing to be "Ishaan Bauchoo".

Researcher's signature

Date: **20/06/2025**

Appendix E: Information Letter for Parents and Consent/Assent Form



Dear Parent

Your child is invited to participate in a study entitled **the effectiveness of using digital tools to teach grade 9 mathematics**

As part of my Master's research through UNISA, I am conducting a study titled "*The Effectiveness of Using Digital Tools in the Grade 9 Classroom to Teach Mathematics.*" The purpose of this study is to explore how digital tools can enhance learner learning and understanding in mathematics. Your child's participation would involve being observed during normal classroom activities where digital tools are integrated into the teaching and learning process.

Please note that no additional tasks will be required from your child beyond their regular classwork, and participation is entirely voluntary. All information collected will remain confidential, and no individual learner will be identified in any reports or publications. I kindly request your permission to include your child in these classroom observations as part of this research study.

If you allow your child to participate, I shall request him/her to:

- Be observed during Mathematics lessons.
- Use his/her assessments to gauge progress.

Any information that is obtained in connection with this study and can be identified with your child will remain confidential and will only be disclosed with your permission. His/her responses will not be linked to his/her name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only.

There are no foreseeable risks to your child by participating in the study. Your child will receive no direct benefit from participating in the study; however, the possible benefit to education is the improvement in performance in Mathematics. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect

him/her in any way. Similarly, you can agree to allow your child to be in the study now and change your mind later without any penalty.

The study will take place during regular classroom activities with the prior approval of the school and your child's teacher.

In addition to your permission, your child must agree to participate in the study and you and your child will also be asked to sign the assent form which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password locked computer in my locked office for five years after the study. Thereafter, records will be erased.


The benefits of this study are improvement in Mathematics performance and providing relevant and authentic activities that the learner is familiar with and can use to benefit him in learning. There are no potential risks to your child if she or he participates in the study. There will be no reimbursement or any incentives for participation in the research.

If you have questions about this study please ask me, Mr. I Bauchoo, a teacher at a high school in Gauteng and also a learner of the Department of Curriculum and Instructional Studies, College of Education, University of South Africa. My contact number is 084 025 8919 and my e-mail is ibauchoo@mylife.unisa.ac.za. Permission for the study has already been given by the Department of Basic Education (DBE) and the Ethics Committee of the College of Education, UNISA.

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child:

Sincerely

_____	_____	_____
Parent/guardian's name (print)	Parent/guardian's signature:	Date:
Ishaan Bauchoo		20/06/2025
Researcher's name (print)	Researcher's signature	Date:

Dear learner

Date _____

My name is Mr I Bauchoo. I am doing a research study for my Master’s degree to find out how using digital tools can help learners learn Mathematics better. As part of this study, I would like to observe one of your normal Mathematics lessons where digital tools will be used. You will not need to do anything extra, just take part in the lesson as you usually would.



Your participation in this observation is voluntary, and all information will be kept private. You will not be identified in any reports or results from the study. If you are happy to be part of this research, please sign the form. You can also choose not to participate, and that is completely okay.

If you do not want to take part, it will also be fine with me. Remember, you can say ‘yes’ or you can say ‘no’ and no one will be upset if you don’t want to take part or even if you change your mind later and want to stop. You can ask any questions that you have now. If you have a question later that you didn’t think of now, ask me next time I visit your school. You can also contact me on 58241159@mylife.unisa.ac.za.

Please speak to mommy or daddy about taking part before you sign this letter. Signing your name at the bottom means that you agree to be in this study. A copy of this letter will be given to your parents.

Regards

Mr I Bauchoo

Your Name	Yes I will take part 	No I don’t want to take part 
Name of the researcher		
Date		
Witness		

I _____ grant consent/assent that the information I share during the focus group may be used by Mr. I Bauchoo for research purposes. I am aware that the group discussions will be observed and grant consent/assent for these, provided that my privacy will be protected. I undertake not to divulge any information that is shared in the group discussions to any person outside the group in order to maintain confidentiality.

Participant's Name (Please print): _____

Participant Signature: _____

Researcher's Name: (Please print): _____

Researcher's Signature: _____

Date: _____

If you are and adult who gives permission you **consent** then delete assent

If you are a learner who gives permission you **assent** and then delete consent

Appendix F: Transect Walk Schedule

Questions

- How many years have you been teaching grade 9 mathematics?
- How has your experience been teaching grade 9 mathematical concepts?
- Have you introduced any digital aspects into your classroom?
- What digital tools do you use when teaching grade 9 mathematics?
- Are the learners able to use digital tools positively in your classroom for mathematics?
- Do the learners comment or complain about using digital tools for learning?
- What effects does the digital tool/s have on learners grasping of mathematical concepts?
- Do you see the positive effects of using digital aspects to teach in learners results? How do you see this?
- Would you introduce any new digital tools and platforms to your learners? Why or why not? – Concepts to work for
- Why do you think it is important for grade 9 learners to make use of digital tools while learning?

Appendix G: Observation Schedule

School name: _____

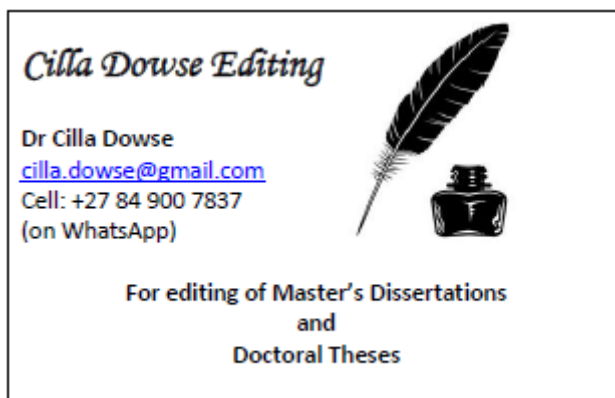
Observe the teacher whilst teaching.	
Observe the use of teaching tools	
Look out for any digital aspects/tools being used in the lesson.	
Observe learners using digital tools during the lesson.	
Observe the learner and teacher interaction while using digital tools.	

Appendix H: Focus Group Discussion

Focus group questions:

1. How often do you integrate digital tools into your Grade 9 mathematics lessons, and for what purposes (e.g., demonstration, practice, assessment)?
2. Which specific digital tools have you found most effective in helping learners grasp challenging Grade 9 mathematics concepts, and why?
3. How do your learners generally respond to the use of digital tools in the classroom? Do you notice any change in their engagement or understanding?
4. What strategies do you use to incorporate digital tools into your daily or weekly lesson planning?
5. Are there any topics or sections of the Grade 9 mathematics curriculum where digital tools are particularly beneficial or, conversely, less effective? Please elaborate.
6. How do you evaluate whether learners are using the digital tools meaningfully and not just as a form of passive engagement?
7. Do you encourage or assign the use of digital tools outside the classroom (e.g., for homework, revision, or project-based learning)? If yes, how do you follow up on this usage?
8. What challenges have you encountered when using digital tools in your teaching (e.g., access issues, technical problems, learner misuse), and how have you addressed them?
9. In your opinion, what professional development or training is needed to help teachers more effectively use digital tools in mathematics education?
10. Overall, do you believe digital tools have a positive impact on the teaching and learning of mathematics in Grade 9? Why or why not?

Appendix I: Proof of Editing



This letter serves to confirm that editing and proofreading were done for:

ISHAAN BAUCHOO

Master's in Education

Curriculum Studies

University of South Africa

THE EFFECTIVENESS OF USING DIGITAL TOOLS TO TEACH GRADE 9

MATHEMATICS IN THE EKURHULENI DISTRICT

Cilla Dowse
23 February 2026

Cilla Dowse
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Disclaimer: The editor takes no responsibility for any changes or revision to the document after the final round of editing has been completed and the proof of editing certificate issued.

Appendix J: Turnitin Report

Similarity Report	
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