



**TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK):
INVESTIGATING SENIOR PRIMARY MATHEMATICS TEACHERS'
INTEGRATION OF TECHNOLOGY IN THE CLASSROOM
IN OKAHAO EDUCATIONAL CIRCUIT**

**A thesis submitted in fulfilment of the requirements for the degree Of
MASTER OF EDUCATION**

Information and Communication Technology Education

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By

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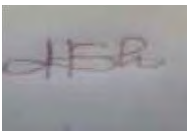
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January 2024

DECLARATION

I, Hilya Ndahambelela Shikesho, declare that this is my own independent work. It is submitted for the degree of Master of Education in ICT in Education at Rhodes University, Makhanda. It has not previously been submitted for academic examination towards any qualification. All the references that I have used have been indicated and acknowledged by means of complete references.

HILYA N SHIKESHO

A small, square image showing a handwritten signature in dark ink on a light-colored background. The signature appears to be 'HILYA N SHIKESHO' written in a cursive, stylized manner.

January 2024

ABSTRACT

The overwhelming advancement of ICT devices in the contemporary Namibian education system has led to their praise for supporting differentiated instruction, fostering collaboration, and engaging multiple intelligences in teaching and learning. Consequently, the compulsory incorporation of ICTs into the teaching and learning process becomes imperative across various fields of study, including Mathematics. However, the integration of technology-based teaching proves to be a complex and challenging issue, often considered a wicked problem. To explore this matter, a qualitative case study was conducted to investigate how Senior Primary Mathematics Teachers integrated technology to develop their TPACK. The study was conducted among the twenty-seven senior primary mathematics teachers in the Okahao educational circuit in the Omuasti region. The study utilized Vygotsky's (1978); Socio-cultural Theory, together with Mishra and Koehler (2006), and; the Technological Pedagogical Content Knowledge (TPACK) framework was used as a lens to analyse the data. The data were gathered through semi-structured questionnaires, semi-structured interviews, focus group interviews, and lesson observations. The study findings indicate that senior primary mathematics teachers utilize the available resources at their respective schools during their classroom instruction. The study further reveals that mathematics teachers exhibit a positive attitude toward the integration of technology. The study uncovers the intricate interplay between technological knowledge, pedagogical expertise, and content knowledge within the context of mathematics education. The findings reveal that while participants demonstrate a high level of proficiency in certain TPACK components such as CK, TK, PK, TPK, and PCK, they expressed a moderate level of expertise in TCK and TPCK. The study also identified challenges in TPACK development, particularly the need for subject specific technology training, lack of technological infrastructure, particularly advanced technology, as well as a deficiency in ICT knowledge. The importance of access to various technologies was emphasized, enabling teachers to seamlessly integrate technology into their practices and address diverse learning styles.

Key words: Integrating technology, ICT, Socio-cultural theory, mediation of learning, social interaction and TPACK

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DEDICATION

This thesis is dedicated :

To my late father Likius Shivute Katila Uunona Shikesho

To my momNdapanda Niipepa Simon Amadhila

To my daughter Diina Mwadhina Taapopi

LIST OF ACRONYMS AND MEANINGS

ACRONYMS	MEANING
CK	: Content Knowledge
CK	: Pedagogical Content Knowledge
FDS	: Finnish Development Support
FGI	: Focus Group Interview
ICT	: Information Communication Technology
MoE	: Ministry of Education
PK	: Pedagogical Knowledge
SPS	: Senior Primary School
SSI	: Semi-structured interviews
TCK	: Technological Content Knowledge
TK	: Technological Knowledge
TPK	: Technological Pedagogical Knowledge

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CHAPTER ONE: INTRODUCTION

1.1 	Introduction of the study
1.2 	Back ground of the study
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1.1 Introduction of the study

Teaching mathematics is perceived to be a challenging and often ill-structured process. As such, contemporary educational demand for the integration of information and communication technology (ICT) adds to the already existing difficulties of the process (Zulu, 2020). Hence, in many cases, technology-based teaching proves to be a wicked problem (Segal & Heath, 2020). However, effective utilization of technology in hard subjects such as mathematics is highly expected (Das, 2019), which adds another challenge to the process. Such a challenge can be solved effectively and in some cases, it requires mathematics teachers to be equipped with the necessary knowledge and experience about how to utilize technology in teaching (Retna, 2019). In recent years, many mathematics teachers have been adopting and adapting ICTs in their classrooms and thus trying to meet the needs of the 21st century's mathematics potential classroom competency development for all learners (Lu, 2017 ; Kgwefane, 2018 & Tan, 2021).

Information and communication technology is defined by Tinio (2002) as an umbrella term that describes a diverse set of technological tools and resources used to communicate, create,

disseminate, store, and manage information. These technologies include computers, network hardware, software, mobile phones, faxes, and broadcasting technology such as radio, television and interactive whiteboards. Similarly, Toomey (2001) generally relates ICT to the technologies that are often used to access, gather, manipulate, present and communicate information in teaching and learning. In this study, the terms ICT and technology are used interchangeably meaning the same term.

Given the international agenda and inspiration toward quality education, many countries anticipate a paradigm shift from ICT in education (provision of ICT) into ICT for education (the use of ICT) (Henock, 2015). Many governments worldwide have invested a lot of resources in information and communication technology (ICT) development to enhance teaching and learning using technology in schools. Such integration is suggested among the general aims of the mathematics curriculum that teachers should use technology effectively in the teaching and learning process (Ministry of education Arts and Culture [MoEAC], 2015). To achieve this goal, some governments in developing and developed countries continue to introduce initiatives to train and support teachers to develop technological knowledge and adopt technology- based tools with the appropriate pedagogy to teach mathematics content (Sanus, Oyelere & Omidiora, 2022). Some of these initiatives include the millennium development goals project, which provides infrastructural facilities and training of teachers towards achieving the universal primary education goals (Nnokami & Suleii, 2017). Others include Finnish Development Support (SCOPE), SchoolNet SA, LOGO, mentor-based in-service training (DBE, 2004: 2015) and FAITH project (Merve, 2018). However, teachers' in particular those teaching mathematics, are not only expected to use their technology knowledge developed through such initiatives but also integrate technologies that facilitate and support students learning by taking into account students learning styles and individual differences (Cetin & Erdogan, 2018). But, for technology to become an integral component of learning, mathematics teachers must also develop an overarching conception of their subject matter concerning technology and what it means to teach with technology, according to Mishra & Koehler (2006).

Mishra & Koehler (2008) suggested that for teachers to be able to integrate technology in teaching subjects such as mathematics, it demands them to first be in sound possession of technological pedagogical content knowledge. Technological pedagogical

content knowledge refers to the form and constructs of knowledge that teachers should possess to effectively integrate technological tools into their teaching process (Koehler & Mishara, 2008). According to Niess (2005), teachers' technological pedagogical content knowledge is developed and shaped by a variety of contextual factors, such as school organizational structures, access to ICT devices, presence of ICT infrastructure. Thus, technological pedagogical content knowledge as it is applied in practice draws interdependent aspects of teachers' knowledge, making it a complex and highly situated educational construct that is not easily applied, learned or taught. Still, as professional knowledge, it can be developed over time. This study, therefore, intended to explore how mathematics teachers were developing or not developing technological pedagogical content knowledge as they integrated technologies in schools in a developing country context.

1.2 Background of the study

The current technological development is overwhelming in the contemporary Namibian education system (Simataa, 2015). Considering this, the compulsory employment of ICTs in the teaching and learning process becomes crucial and inevitable in multiple fields of study, and mathematics as a subject is no exemption. As such, the teaching and learning of mathematics within the basic education curriculum has now subsequently become emphasized as a major subject within it (Richter, Brunner & Richter, 2021). It is for this reason that mathematics is made a compulsory subject for all learners ranging from grade 0 to grade 12 (MoEAC, 2015). Yet researchers in mathematics education reported numerous cases where mathematics is taught by teachers using inadequate skills of integrating ICT, and these results in poor performance in mathematics across the country (Garofalo, Drier, Harper, Timmerman & Shockey, 2018; Spangenberg, & De Freitas, 2019; Hiebert, & Grouws, 2021). Since Namibia became independent, the need to incorporate ICT in education has been a preponderant concern in schools (Nuuyoma, 2018). The Ministry of Education in Namibia values ICT; hence the integration of ICT in curricula ascended the education agenda with the release of the ICT policy for Education in 2005 (Ministry of Education, 2005). The ICT policy for Education guided the Namibia government, through the Ministry of Education, to undertake several initiatives to equip schools with ICT tools, to empower teachers to integrate ICT in their teaching (MoE, 2005). For example, some schools received ICTs

such as computers, laptops, and installed internet, among others (Namibian education technology alliance [NETA], 2005). Even though the ministry of education has adopted the ICT policy in education, alongside the provision of the necessary ICT equipment, most teachers in Namibian are still proving clear insufficiency in integrating ICT into their teaching (NETA, 2005; Nngololo, 2010).

A study conducted by Nuuyoma (2018) in Omusati region rural primary schools, revealed that teachers in Omusati rural schools faced common challenges. Some of the challenges were attributed to a lack of support to use technologies, a lack of appropriate technological skills and competencies, a lack of continuous support both at the school level and at the regional level, and a lack of training. Even though most schools were beneficiaries of the deployment of ICTs, teachers were still unable to utilize the resources made available to them. However, teachers expressed their appreciation for the ICT integration initiative, citing that it motivated them and their learners and made them part of the global village. Moreover, the Okahao Educational Circuit in the Omusati Region is one of the circuits characterized by poor performance in Grade 4-7 Mathematics Namibia national standardized achievement test (NSAT) level as opposed to other circuits within the region (NIED,2020). The circuit has less than 25 primary schools, and all schools are in rural areas. As part of the government agenda of the National Education Standard that seeks to ensure equitable distribution of resources to education across the country , Okahao Circuit and its schools also fell part of recipients of this agenda beneficitation. Subsequently, the government has ever since sustained the provision of ICT infrastructures such as computers, laptops, tablets, whiteboards, computer laboratories, and software for teaching mathematics and science subjects to all circuit schools (MoE, 2005;Shambare & Simuja,2022). Many schools are supplied with electricity conventionally or alternatively via solar panel installation. This was primarily done with the purpose of extending the efficient use and power of technologies.

Following the supply of the afore-stated ICT equipment, it was shortly thereafter discovered that these equipment merely lay unutilized in some of the schools within the circuit (Farrelll & Isaacs, 2007). It was consequent to these teachers' ICT insufficiency that by 2018 government shouldered the obligation to provide ICT training via occasional workshops to the teachers, with some specific training for the mathematics and science teachers in the

circuit. Such training was thus occasionally facilitated through the aid of Regional Education Officers, tertiary education institutions and non-governmental institutions. Mathematics teachers, therefore, attended these ICT training sessions at the circuit, regional and national levels (MoEAC, 2018). The training included basic skills and knowledge of using Microsoft Word, Microsoft Excel, Microsoft Access, and Microsoft PowerPoint, as well as designing lessons and assessments with applications such as Geogebra, Kahoot, Scilab, Math Solver and other educational-related technologies. More than these training sessions, the teachers were encouraged to integrate these technologies into their teaching. (Nuuyoma, 2012).

Although there is a clearly proven governmental will towards the provision of ICT equipment and training workshops, particularly, for mathematics teachers across the circuit, it is less known how mathematics teachers are developing new domains of knowledge as they negotiate the integration of technologies in their classroom. Nevertheless, most mathematics teachers seem to be integrating some technologies in their lessons from time to time and at their discretion and effort (Nuuyoma, 2012). This underscores the fact that at some stage, some mathematics teachers have somehow developed or are developing, unknowingly and without guidelines, some technological pedagogical content knowledge (Koehler & Mishra, 2016; Conger et al., 2017). However, little is known about how and when they constructed and developed this specialised and situated knowledge type (Salas-Rueda, 2018). Therefore, this evokes deep crucial questions about how teachers who are integrating technology integration in mathematics teaching could possibly develop an understanding of the dynamic, complex, and transactional relationships of content, pedagogy, and technology.

1.3 Statement of the problem

In Namibia, the national curriculum, in consideration of the ICT policy in education, is in favor of integrating technology in teaching and learning. However, both the curriculum as the guiding pilot document and the ICTs policy have only given the essential importance of integrating ICTs in teaching and learning, but they have not prescribed clear implementational guidelines on how technology should be integrated in the teaching and learning of Mathematics or to say in a specific subject. However, as technology availability increases, in senior primary schools in Namibia, most mathematics teachers in Okahao find themselves in front of technology-oriented

learners in technology-infused classrooms. As a senior primary school mathematics teacher in Okahao Education Circuit, I observed that such context is, in many ways, not the one most of us were initially trained to practice. Most mathematics teachers in the circuit have not received formal technology integration training and consequently have a technological knowledge gap. To address this gap, the Ministry of Education has continued to roll out different technologies to schools in the Okahao circuit and a plethora of professional teacher development workshops on various hardware and software packages to equip the teachers with the skills needed to teach with technology. Some mathematics teachers in senior primary schools in Okahao schools may or may not have attended these workshops. While the technology training workshops are essential, this approach to teacher development suggests that teachers should merely be trained to use the technologies (Barab et al., 2000; Koehler & Mishra, 2009; Spangenberg & De Freitas, 2019). The anticipation, however, is that by demonstrating technology skills to use the various hardware and software, the teachers will then be able to integrate technologies into their teaching effectively.

However, as Koehler & Mishra (2006) have argued, this focus on technology skills is fundamentally flawed in developing the deep understanding to enable teachers to develop technological pedagogical content knowledge mainly because the approach is context-neutral. Yet, technology integration in teaching is not context-free and depends on factors such as the grade, subject, learner background, types of available technologies including individual teacher attributes such as their philosophy, teaching style and experience (Koh & Chai, 2011; Koehler & Mishra, 2006; Spangenberg & De Freitas, 2019). My contention is not that technology training workshops are not helpful. However, despite their valuable contribution, such context-free methods are likely to fail because they focus more on technology skills without developing technological pedagogical and content knowledge (Abrami et al., 2016; Koehler & Mishra, 2006). In other words, merely knowing how to use technology is not the same as knowing how to teach with it.

Therefore, consistent with other researchers in this area (Barab et al., 2000; Hanshaw et al., 2022; Neiss, 2011), This study assumed that most or some senior primary school mathematics teachers in Okahao were integrating various educational technologies to

meet their learners' needs. However, the teachers could most likely unknowingly, and without any guidelines develop technological pedagogical content knowledge. There seems to be a dearth of empirical research in Namibia that has articulated such a perspective, and as alluded to earlier hereof, most of the studies conducted in Namibia focus on understanding the benefit of using technology in teaching (Ngololo 2010; Nuuyoma, 2012; Rejoice 2014; Malakia & Cloneria 2018; Waiganjo, 2021). Whereas simultaneously others have unearthed some of the challenges potentially hindering the integration of technology in the teachers' teachings (Iipinge 2010; Etuna 2014; Simataa & Nyathi, 2016; Ngeama, 2018). Yet a few other studies have presented the evaluation of implementing the ICT policy in education. An instance of the latter is Ngololo (2010), whose study focused merely on the evaluation of the implementation of the ICT Policy for Education in Namibian rural schools. There are deeper and more intractable issues than just what technology training can offer. Thus, the interest of this exploratory case study is to understand how senior primary school mathematics teachers develop technological pedagogical content knowledge as they integrate technologies in their classrooms in Okahao Education circuit

1.4 Significant of the study

This study aimed to investigate senior primary mathematics teachers concerning the integration of technology in teaching mathematics and their development of technological pedagogical content knowledge (TPACK). The findings from the study may provide insight into the benefits, barriers and measures encountered by senior primary teachers to address technology integration and developing TPACK in teaching mathematics. The findings from the study might be of interest to mathematics teachers in Namibia and may contribute to knowledge on the adoption of technological-based classroom teaching. The research study may also be used as a guide for policy-makers, decision-makers, educational investors, and other stakeholders to make well informed decisions about ICT policies. This, in turn, may facilitate all educational stakeholders' decision-making over-investment in technology facilities and infrastructures.

The study may also informatively supplement the existing literature on the use of technology to facilitate teaching processes in primary school and the development of TPACK. Finally, the study findings may add literature to the limited research on

technology use and integration in Namibia and provide a more holistic understanding of the subject matter by providing necessary adjustments on how senior primary teachers should be trained to integrate technologies as well as develop TPACK during teaching.

1.5 Research purpose

In this study, the background and significance of investigating teachers' integration of technology in teaching mathematics are presented in the section above. The research question plays a crucial role in guiding the entire research process (Phair & Shaeffe, 2022), focusing on a particular area of study within the broader topic of interest (Creswell, 2014). Furthermore, Nägel, Bleck, & Lipowsky (2023) assert that these questions are formulated to explore or clarify the purpose of a research study.

1.5.1 Purpose and objectives

The purpose of this exploratory investigative study was to comprehend how senior primary mathematics teachers integrated technology and developed their TPACK within the Okahao Education Circuit.

Objective 1:

To investigate how senior primary school mathematics teachers describe their ways of integrating technology in the classroom in Okahao education circuit.

Objective 2:

To investigate how senior primary school mathematics teachers in Okahao education circuit describe their technological pedagogical content knowledge.

Objective 3:

To understand how integrating technology in the classroom support and/or constrain mathematics teacher's technological pedagogical content knowledge development in Okahao education circuit.

Main research question

The main question for the study is:

How do senior primary school mathematics teachers in Okahao education circuit develop their TPACK as they integrate technology in the mathematics classroom?

To address the main research question, the following sub-questions were used:

Sub-research question 1

How do senior primary school mathematics teachers describe their ways of integrating technology in Okahao education circuit?

Sub-research question 2

How do senior primary school mathematics teachers describe their technological pedagogical content knowledge Okahao education circuit?

Sub-research question 3

What challenges do mathematics teachers have as they try to integrate technology and develop technological pedagogical content knowledge Okahao education circuit?

1.6 Definition of terms

To ensure clarity, the researcher provided concise explanations of crucial terms used in the research's purpose, objectives, main question, and sub-questions. These terms include:

Technology: Technology refers to the collection of techniques, methods, skills, and processes used in the creation, development, and application of tools, systems, and devices to solve problems and achieve specific goals. It encompasses a wide range of knowledge and practices, including design, electronic devices, software, and various other innovations.

Technology Integrating: This study centers its focus on the integration of technology in teaching mathematics, where technology integration in education pertains to skillfully incorporating technology into instructional practices to enhance the overall learning and teaching experiences (Ruggiero & Mong, 2015). As Cartwright & Hammond (2003) assert, this process involves utilizing technology to achieve educational objectives and empower students' learning throughout the instructional program.

Information communication and technology: Refers to the diverse set of technological tools

and resources used to communicate, create, disseminate, store and manage information. These technologies include computers, network hardware, software, mobile phones, faxes and broadcasting technology such as radio, television and interactive whiteboards (Tinio 2002).

Technology Integrating in Mathematics: The process of technology integration in mathematics entails utilizing specialized technological tools to improve and bolster teaching and learning activities in the subject, as indicated by Chai, Koh & Tsai (2013). In the context of this study, educators integrated technology into their mathematics classroom instruction.

Challenges of Technology Integration: The challenges of technology integration refer to the hindrances and complexities that educators may face while integrating technology into their instructional approaches, along with strategies for overcoming them, as outlined by Fu (2013). Teachers in this context share their experiences of the obstacles encountered when incorporating technology into their mathematics teaching.

Teachers' perception of technology integration: refers to teachers' attitudes, beliefs, and opinions regarding the use of technology in educational settings. This perception can vary widely among educators and is influenced by a range of factors, including their level of familiarity and comfort with technology, their pedagogical philosophies, and their experiences with using technology in the classroom.

Technological Pedagogical Content Knowledge (TPACK): Refers to the knowledge and understanding of how to integrate technology, pedagogy, and subject matter knowledge to facilitate meaningful learning. TPACK serves as a framework to guide educators in effectively incorporating technology into their teaching practices (Mishra & Koehler, 2006). The study under consideration focuses on exploring the development of TPACK in the context of integrating technology while teaching mathematics as a subject.

Socio-culture theory: is a psychological framework developed by Lev Vygotsky that emphasizes the significance of social and cultural influences on human development, cognition, and learning. It also highlights the dynamic interplay between individuals and their cultural context, underscoring that learning and development are deeply intertwined with social experiences and

cultural practices.

Social Interactions: Refer to the exchanges, communications, and relationships that occur between individuals within a society or a community. These interactions can take various forms, including verbal conversations, non-verbal cues, gestures, and shared activities. They play a crucial role in human development, as they enable individuals to learn from one another, form connections, and establish a sense of belonging within a social group.

Mediation of learning: It refers to the process by which individuals gain knowledge and skills with the aid of a more knowledgeable person like a teacher, mentor, or peer. The mediator employs tools like language, symbols, and cultural artifacts to enhance the learning experience. This interaction is dynamic, enabling learners to integrate and apply new knowledge within their own cognitive frameworks.

1.7 Thesis outline and organization

This thesis is structured into six chapters, all centered on integrating technology for teaching mathematics and developing technological pedagogical content knowledge among senior primary mathematics teachers in the Okahao educational circuit. Each chapter brings a different point of view that contributes to the main idea of the thesis.

Below is a brief overview of what each chapter covers.

Chapter One provides an introduction, presenting the background, problem statement, and the significance of the study. It outlines the research's main purpose, main research questions, and sub-research questions. This initial chapter gives readers an overview of where the study stands and what it encompasses.

Chapter Two delves into the most current and pertinent literature pertinent to the study's subject matter. The investigation initiated by the research questions in chapter one directed the process of conducting this literature review. The sources consulted included authoritative electronic databases such as Google Scholar, Mathematics Direct, and Web of Mathematics. Due to the limited literature available on the integration of technology in the Namibian context, the

review predominantly encompasses international literature. The focus of the literature review centers on the utilization of technology in teaching Mathematics at the primary school level. This chapter additionally delineates the application of Vygotsky's socio-cultural theory and TPACK as the theoretical framework for the study.

Chapter three delves into the research design employed, situated within the interpretive qualitative research paradigm, utilizing a case study approach. The rationale behind opting for the qualitative design and case study approach is thoroughly examined and justified. Moreover, the chapter expounds on the sample size and sampling criteria, providing a rationale for their selection. The data generation methods employed, namely semi-structured questionnaires, semistructured interviews, focus group interviews, and observation, are explicated, highlighting their strengths and acknowledging any limitations. This chapter demonstrates the study's coherence and consistency by illustrating how the methodology aligns with the research questions and how the design and execution are suitable for addressing these questions and analyzing the data. Additionally, it delves into the thematic data analysis process, triangulation, and research evaluation, which encompasses aspects of credibility, transferability, dependability, confirmability, validity and trustworthiness. Research position and Ethical considerations pertinent to the study are also addressed in the concluding section of the chapter.

Chapter Four of the study presents the findings from the study. Data generated through semi structured questionnaires, semi-structured interviews, focus group interviews, and observation were all at the centre of this chapter. The findings of the study, which are consistent with the methodology, are clearly and correctly presented in this chapter. The findings are presented according to themes that emerged from the analysis of the data based on the research questions. Considering the importance of dependability, great effort is made to provide teachers' responses in their own words, so that readers would be convinced that the data generated had led to the results presented by the researcher.

Chapter five of the study presents a discussion of the findings of the study. The discussion of the findings shows insight and originality by suggesting implications and making recommendations that are applicable and useful. The research questions are comprehensively answered in this

chapter, and the conclusions that this study comes to are justifiable in terms of methodology and the applicable results presented and discussed in this chapter.

Chapter six is the final chapter of this study. The chapter provides an overview of the whole study. It also presents the summary of the major research findings from which conclusions are drawn, recommendations suggested and highlights the gaps which would serve as possible focus areas for future studies.

CHAPTER TWO: REVIEW OF LITERATURE

2.1 Introduction

The preceding chapter presented the introduction, background, and problem statement, significance of the study, research purpose, and questions. This chapter presents the literature review. Raghu & Rodrigues (2020) define a literature review as a review of a body of knowledge comprising what has been found as well as methodological contributions. A literature review presents what is known about the problem under consideration (Ary, Jacobs, Irvine & Walker, 2018). The purpose of the literature review in this study was to provide a foundation of knowledge on the research topic (Frank & Hatak, 2014), identify areas of prior scholarship to prevent duplication (Babu, 2020), identify gaps and conflicts in previous studies (Müller-Bloch & Kranz, 2015), and place this research within the context of existing literature and thus making a case for why this study is necessary (Okoli & Schabram, 2015).

This chapter delves into the most current and pertinent literature concerning the incorporation of technology in primary-level mathematics education. It consists of 6 sections, commencing with 2.1 Introduction 2.2 Integrating technology in the curriculum, followed by 2.3 Technology integration in teaching Mathematics, 2.4 Integrating Technology into Teachers' Pedagogical Content Knowledge (PCK), 2.5 Theoretical framework and 2.6 the Comprehensive summary.

2.2 Integrating technology into the curriculum

Integration of technology involves seamlessly blending technological tools into the curriculum to improve learning in specific subject areas or across various disciplines. (Mouza, Yang, Pan, Ozden & Pollock, 2017). Successful technology integration occurs

when teachers and learners can skillfully utilize technology tools to access, analyze, synthesize information, and present it professionally (Aslam, Khan & Ahmed, 2020). Falloon (2020) defines technology integration as the incorporation of hardware, software, and subject-specific elements into the curriculum to improve learning outcomes and meet curriculum standards and learners' objectives in each lesson, unit, or activity. Over the past decades, policymakers, administrators, and educators have shown a growing interest in integrating technology into the teaching and learning processes (Qian & Clark, 2018; Willias, 2021; Conger et al., 2016).

Numerous national and international studies have explored the integration of technology into the curriculum. Some of these studies include Cavas (2009), Al-Zaidiyeen, Mei & Fook (2010), Hue, & Ab Jalil (2013), Webber & Tschepikow (2013), Kisirkoi & Mse (2016), Tyler-Wood, Cockerham & Johnson (2018), Nuere & De Miguel (2021), and To (2022). These researchers have found various applications of technology in the curriculum. Kisirkoi et al. (2016) emphasized that integrating technology into the curriculum enhances teaching, improves learners' learning experiences, and fosters a learner-centered classroom environment. In line with this notion, Al-Zaidiyeen et al. (2010) noted that teachers with positive attitudes toward ICT are more motivated and likely to integrate technology into their classrooms. However, having technical proficiency with ICT tools does not guarantee effective teaching using technology (Nuere & De Miguel, 2021; Conger et al., 2015).

Additionally, it has been suggested that the integration of technology into the curriculum lead to significant changes in teaching and learning (Waxman, Evas, Boriack & Kilinc, 2013; Ruggiero & Mong, 2015). These changes include higher learner achievement, improved self-concept, positive attitudes, and enhanced teacher/learner collaboration facilitated by interactive learning through technology integration. Likewise, the Namibian curriculum suggests the incorporation of various technological tools to enhance teaching and learning, including interactive lessons, access to educational resources, and collaborative learning experiences through ICT (National Curriculum for Basic Education [NCBE], 2016). Learners could also benefit from accessing current information, conducting research, and developing digital competencies for their future careers through ICTs (NCBE, 2016). Although Namibia

has implemented initiatives like the National ICT Policy for Education, challenges remain in terms of infrastructure, teacher training, and equitable technology access in schools (Nepembe & Simuja, 2023). Despite the ongoing evolution of ICT in the curriculum, I observed that some mathematics teachers in schools within the Okahao education circuit have not given it sufficient attention. This study aims to investigate how these teachers integrate technology into their teaching practices, considering the significance of ICT in ensuring education quality and preparing students for the digital era.

Similarly, while the majority of the reviewed studies have shown that integrating ICT into the curriculum improves educational outcomes (Becker & Park, 2011; Cheung & Slavin, 2013; Ghavifekr & Rosdy, 2015), some researchers have specifically focused on technology integration in teaching mathematics education (Becker & Park, 2011; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur & Sendurur, 2012; Chai, Koh & Tsai, 2013). Consequently, the following sections will delve into a detailed discussion of technology integration in Mathematics education.

2.3 Technology integration in teaching Mathematics

Integrating technology in mathematics education has been praised for numerous advantages in teaching mathematics, including improved conceptual understanding, complex decision-making abilities, and deeper learning opportunities (Waiganjo, 2021). Studies by various researchers (Kaput et al., 2008; Sheehan & Nillas, 2010; Goos, 2014; Sen & Ay, 2017; Young, 2017) support the positive impact of technology on learners' abilities to simulate scenarios, generate visualizations, and connect dynamic notations with symbols. The NCTM (2000) also recommends the responsible use of technology to enhance mathematics learning, motivating teachers to integrate appropriate technology in classrooms for better teaching and learning outcomes.

Another study by Polly, Mims, Shepherd & Inan (2010) highlights the belief and agreement that technology integration positively affects mathematics instructional engagements. The significance of teachers' use of technology in enhancing teaching is also emphasized (Polly et al., 2010). Equipping teachers with sufficient knowledge and

skills for effective technology use in classrooms is crucial (International Society for Technology in Education, 2000). Gorder (2008) emphasizes several important factors for effective technology use in mathematics classrooms, with teachers' competence and technological knowledge being the most critical ones. Therefore, the study aims to investigate how the senior primary mathematics teachers integrate technology and developed their TPACK.

Technology integration in mathematics education in Namibia has great potential to transform the learning experience and enhance students' mathematical skills and understanding. Several studies conducted by numerous researchers, such as Ngololo (2010) and Hamukwaya (2021), have identified the beneficial effects of incorporating technology in mathematics. Ngololo (2010) found that integrating technology in mathematics lessons can captivate students' interest, motivate active participation, and provide interactive visualizations and simulations to help them grasp abstract concepts. Hamukwaya (2021) revealed that technology allows for adaptive learning platforms, personalized feedback, demonstrates practical relevance in various fields, and offers access to a wealth of online resources and interactive tools to supplement traditional teaching materials.

The success of ICT integration in teaching and learning is not solely dependent on the availability of technology but also relies heavily on attitudes towards its use (Salehi & Salehi, 2012). Teachers' perceptions of ICT play a pivotal role in shaping how technology is utilized in educational settings, particularly in the context of mathematics education (Liu, Geertshuis & Grainger, 2020; Krauss et al., 2015). When mathematics teachers perceive ICT as valuable tools for enhancing teaching and learning, they are more likely to incorporate them into their instructional practices. Moreover, research suggests that increased exposure to diverse educational technologies can have a significant impact on encouraging mathematics teachers to explore and incorporate them into their teaching methods (Khlaif, 2018). Professional development programs and initiatives that expose teachers to various ICT tools and their potential applications in mathematics education can be instrumental in fostering this integration (Ruthven, 2014; Kafyulilo, Fisser, Pieters & Voogt, 2015; Barakabitze, William-Andey, Lazaro, Ainea, Mkwizu, Maziku, Matofali & Sanga, 2019)

Furthermore, positive attitudes toward innovation are essential for the successful adoption of educational technology in mathematics education (Khlaif, 2018). Teachers who are open-minded and receptive to exploring new tools and methodologies are more likely to embrace technological innovations and effectively integrate them into their teaching strategies (Imoyiannis, Tsiotakis, Roussinos & Siofrenta, 2013). This positive attitude towards innovation not only enhances the learning experiences of students but also promotes a culture of continuous improvement and adaptation in the field of mathematics education (Xie, Kim, Cheng & Luthy, 2017).

It is important to note that these are general trends and not all teachers will share the same perspectives (Bowman, Vongkulluksn, Jiang & Xie, 2022). Some may be enthusiastic advocates for technology integration, while others may be more cautious or prefer traditional teaching methods (Kang, 2019). Additionally, individual experiences and exposure to effective technology integration practices can greatly influence a teacher's perception. In a Malaysian study by Samira, Faizah Mohamad & Marzila (2013), teachers showed positive perceptions of using technology in the classroom. They recognized its value and expressed intent to integrate it into teaching. Conversely, Gebremedhin and Fenta's (2015) Ethiopian study revealed that many teachers faced challenges integrating ICT due to resource shortages, leading to inadequate ICT use in classrooms.

Multiple studies conducted in Namibia, including those by Iipinge and Sakaria (2010), Ngololo (2010), Simon (2014), and Jatileni & Jatileni (2018), explored teachers' perceptions of ICT use in Namibian primary education. Their findings revealed that Namibian teachers utilize ICT for flexible teaching, leveraging smart boards connected to e-Learning Management Systems to facilitate collaborative and creative instruction. Additionally, teachers in Namibia have shown enthusiasm and readiness to integrate ICT into their teaching and learning approaches (Iipinge and Sakaria, 2010).

Qasem's (2016) study revealed that insufficient knowledge and skills in ICT integration hindered teacher perceptions and beliefs regarding its incorporation in the curriculum. Isaacs, Kazembe, and Kazondovi (2018) noted teachers' absence of ICT pedagogy training due to time constraints, leading to apprehension during training sessions. Ngololo (2010) highlighted challenges in rural

areas, including scarce basic equipment, inconsistent electricity, and limited ICT resources like hardware and software. This lack of skills and resources can impede successful ICT integration in teaching, as echoed by Ang'ondi (2013).

2.3.1 Challenges to integrating technology in mathematics education

The utilization of ICT in teaching and learning, particularly in subjects like mathematics, is hindered by several obstacles that educators commonly encounter. As highlighted by Fox, Diezmann, and Lamb (2016), these challenges persist in the field. Ertmer (1999) further classifies these impediments into two distinct categories: first-order and second-order barriers. The first-order barriers encompass external elements such as availability of technology, time constraints, access to necessary support, and opportunities for professional development. Conversely, the second-order barriers are related to internal factors, primarily revolving around the teacher's self-assurance in utilizing technology and their perception of its efficacy in educational settings.

Numerous studies highlight external factors as dominant in their findings. Hechter and Vermette (2013) identified lack of resources, time, training opportunities, funding, and support as key obstacles to teachers' technology integration. Keengwe, Onchwari, and Wachira (2008) summarized poor training, equipment, time, administrative support, and technical issues as primary barriers. Many teachers perceive initial obstacles as hindrances to technology use, with Cuban, Kirkpatrick, Peck (2001), and Bauer, Kenton (2005) referencing time constraints for learning and instructional preparation as impediments to technology adoption.

Categorized as second-order barriers, these encompass teachers' internal factors such as attitudes, beliefs about educational technology, classroom practices, and resistance to change (Ertmer, 1999). Enhancing technology integration in classrooms is associated with technology-focused professional development. Educational institutions are increasingly offering diverse technology oriented training to cater to teachers in various implementation phases. Insufficient professional development quality (Koehler and Mishra, 2005) and equipment accessibility (Yan and Zhao, 2006) also contribute to initial extrinsic obstacles.

Numerous researchers have also highlighted several factors that consistently impact the incorporation of technology into mathematics education. For instance, Muhazir & Retnawati

(2020) conducted a study that revealed obstacles faced by mathematics teachers in the digital era regarding the implementation of technology in mathematics instruction. These challenges encompassed issues such as the suitability of mathematics learning materials and teaching aids for technology integration, considering the available facilities and infrastructure. Furthermore, the study found that schools' support for technology use in teaching and learning was insufficient, which was exacerbated by the teachers' proficiency in utilizing technology for mathematics education.

Similarly, in their literature focused on discerning Mathematics teachers' apprehensions about utilizing technology in their mathematics instruction, ClarkWilson, Oldknow, and Sutherland (2011) have identified several significant challenges. These encompass the teachers' lack of confidence in using digital technologies, apprehensions about problem- solving with technology, self-awareness of lower technology proficiency compared to their students, inadequate training, limited lesson preparation time, lack of awareness about technology's supportive role in learning, and the absence of clear integration of technology into their curriculum. Further hindrances to successful ICT integration in mathematics teaching are highlighted in studies by Mathevula & Uwizeyimana (2014), Korte & Hussing (2007), and Ngeama (2018). These obstacles include the teachers' inherent resistance to change, evident through negative attitudes toward changes, including technological advancements, and the teachers' limited access to computers or other ICT-related courses.

2.4 Integrating Technology Knowledge in Teachers' Pedagogical Content Knowledge (PCK)

Pedagogical Content Knowledge (PCK), introduced by Shulman in 1986, emphasized merging content knowledge with appropriate pedagogical expertise for effective subject delivery. Building upon Shulman's framework, Mishra & Koehler (2006) advocated the incorporation of technological knowledge into these ideas, forming three interconnected knowledge domains for teachers. Shulman, Koehler & Mishra underscore the interconnectedness of these domains, asserting that they work collaboratively. According to Mishra & Koehler (2006), effective technology integration-driven teaching hinges on teachers' grasp of the subject matter, concurrent pedagogy, and the technological tools best suited to facilitate student learning in specific contexts.

The scholarly literature presents a compelling view of the TPACK as a robust knowledge advocating for the strategic fusion of technological, pedagogical, and content knowledge to foster the seamless integration of ICT into the teaching and learning process (Chen & Jang, 2014; Cejas-León, Navío-Gámez, & Barroso-Osuna, 2016; Gómez, 2019). This innovative pedagogical-technological paradigm is actively reshaping educational dynamics, transcending traditional classroom boundaries (Turgut, 2017; BuenoAlastuey, Villarreal, & García-Esteban, 2018). Evidently, TPACK serves as a catalyst in elevating the realm of mathematics education, harnessing tools like Raptor software, YouTube videos, Facebook, WhatsApp, and Virtual Math Lab (Salas- Rueda, 2018). By providing comprehensive knowledge, it empowers educators to craft engaging, interactive teaching strategies in the realm of mathematics, effectively capitalizing on ICT integration (Chua & Jamil, 2014; Urban, Navarro, & Borron, 2018; Ozudogru & Ozudogru, 2019). Notably, the amalgamation of technological, content, and pedagogical knowledge, as illuminated by various scholars, stands as a transformative force, paving the way for the creation of dynamic virtual educational landscapes (Oster-Levinz & Klieger, 2010; Brantley-Dias & Ertmer, 2013; Phillips, 2016). In essence, TPACK emerges as a cornerstone in modern educational paradigms, fostering an enriched and technology-driven teaching and learning experience.

2.4.1 Technological Pedagogical Content Knowledge in Teaching Mathematics

Numerous researchers have made significant contributions to mathematics education using the TPACK (Mishra & Koehler, 2006). These researchers focused on pre-service teacher trainees in various universities, emphasizing the integration of ICT for collaborative learning (Koehler & Mishra, 2008). Incorporating ICT into teacher- education programs remains a challenge, requiring a deeper understanding of technological, pedagogical, and content knowledge and their impact on future pedagogical practices of graduating educators (Niess et al., 2009; Nepembe & Simuja, 2023).

Several researchers have made noteworthy contributions to mathematics education by utilizing the TPACK framework, which highlights the crucial interplay of Technological Pedagogical Content Knowledge (TPACK) in effective teaching (Niess, 2006). These studies have concentrated on pre-service teacher trainees across diverse universities, underscoring the integration of ICT for fostering collaborative learning environments (Chang Sung & Chen (2014). Despite progress, integrating ICT into teacher-education programs continues to pose a substantial challenge. A deeper and more comprehensive understanding of TPACK is needed, encompassing technological,

pedagogical, and content knowledge, to better comprehend its impact on the future pedagogical practices of graduating educators (Tondeur, Hermans, van Braak & Valcke, 2018;)

The TPACK framework, which emphasizes the intricate interplay of Technological Pedagogical Content Knowledge (TPACK), stands as a pivotal pillar in enhancing the teaching of mathematics (Koehler & Mishra, 2008; Theodorio et al., 2023). This comprehensive approach integrates three essential components – technology, pedagogy, and content knowledge – into a harmonious synergy that amplifies the effectiveness of teaching. Researchers, including Niess (2005, 2006, 2008); Niess et al. (2009); Chang & Chen (2014), & Tondeur et al., (2018), have remarkably illuminated the significance of TPACK in mathematics education. Their collective body of work underscores the transformative potential of incorporating technology within pedagogical practices specifically tailored for the mathematical domain.

By targeting pre-service teacher trainees enrolled in mathematics education programs, these studies have effectively demonstrated the tangible benefits of integrating ICT (Chang et al., 2014). The application of technology not only facilitates collaborative learning but also nurtures enhanced communication, knowledge-sharing, and engagement among students (Tan, 2016). The classroom dynamic has shifted from a traditional, one-dimensional instructional approach to a multidimensional, interactive learning experience, effectively aligning with the evolving needs of modern learners. While strides have been made in integrating ICT into teacher-education programs, challenges persist (Ansari & Khan, 2020; Mavuso & Makeleni, 2022; Gcabashe & Nhlumayo, 2023). A deeper understanding of TPACK, which encompasses technological proficiency, pedagogical creativity, and robust content knowledge, is imperative (Koehler & Mishra, 2009). This holistic perspective enables educators to seamlessly integrate technology into their teaching methodologies while maintaining the integrity and rigor of the subject matter.

As we move forward, the emphasis on Technological Pedagogical Content Knowledge (TPACK) in mathematics education becomes even more crucial. With technological advancements continuously reshaping the educational landscape, educators must possess the acumen to navigate this evolving terrain (Mishra & Koehler, 2006; Shambare & Simuja, 2022). The effective fusion of technology, pedagogy, and content knowledge equips educators to not only adapt to changing

paradigms but also to leverage these shifts to invigorate and elevate the teaching of mathematics (Niess, 2005;Shambare et al.,2022a).In this study, understanding Technological Pedagogical Content Knowledge (TPACK) is really important. TPACK means realizing how much technology is tied to learning math. It is like technology is a big part of how we understand mathematics.

Research on the development of Technological Pedagogical Content Knowledge (TPACK) among teachers, including mathematics teachers, indicates that several factors contribute to the acquisition and enhancement of these skills. Professional development programs focusing on TPACK integration have been found to be effective in supporting teachers' development of technological, pedagogical, and content knowledge simultaneously (Koehler & Mishra, 2009). These programs often provide opportunities for hands-on experiences with various educational technologies, as well as collaborative learning environments where teachers can share best practices and strategies for integrating technology into their teaching practices (Archambault & Crippen, 2009; Chai, Koh & Tsai, 2010; Boris, Campbell, Cavanagh, Petocz & Kelly, 2013). Additionally, studies suggest that ongoing support and mentoring from peers or instructional technology specialists can play a crucial role in helping teachers navigate the complexities of TPACK integration (Chai, Koh & Tsai, 2013;Simuja & Silvanus,2023). Furthermore, reflective practices, such as self-assessment and evaluation of one's teaching practices in light of TPACK principles, have been identified as key mechanisms for teachers to deepen their understanding and refine their instructional approaches (Angeli & Valanides, 2009; Koh, Chai & Tsai, 2013). Literature suggests that the development of TPACK skills among mathematics teachers is a dynamic process that involves continuous learning, experimentation, and reflection within supportive professional learning communities (Angeli & Valanides, 2014; Yigit, 2014;Simuja,2018).

2.4.2 Enhancing TPACK for Mathematics Teachers through Technology Integration as Pedagogical Practice

In the field of mathematics education, the integration of technology is considered a crucial pedagogical practice, offering new strategies to enhance teaching effectiveness and improve students' learning outcomes (Alshehri, 2012). The concept of Technological Pedagogical Content Knowledge (TPACK) is conceptualized as an integrative framework that emphasizes the dynamic

interplay between technology, pedagogy, and content knowledge ((Mishra & Koehler, 2006)). McCulloch et al. (2018) and Spangenberg et al. (2019) argue that frequent engagement with technology integration in mathematics teaching plays a significant role in enhancing teachers' TPACK, ultimately shaping their ability to effectively teach mathematics.

Longitudinal studies further emphasize the progressive nature of TPACK development among mathematics teachers as they engage in frequent technology integration (Voogt et al., 2013; Niess, 2005). Niess (2005) conducted a longitudinal study examining the TPACK development of pre-service teachers throughout their teacher preparation program. The findings revealed that pre-service teachers who frequently integrated technology into their mathematics teaching demonstrated continuous improvement in their TPACK over time, underscoring the importance of sustained engagement with technology in enhancing pedagogical practices.

Empirical studies provide evidence supporting the positive impact of frequent technology integration on TPACK development among mathematics teachers (Angeli & Valanides, 2009; Archambault et al., 2010). Angeli and Valanides (2009) highlight the importance of hands-on experiences with technological tools, emphasizing that regular opportunities for teachers to integrate technology into their mathematics teaching and learning lead to a deeper understanding of effective pedagogical practices. Similarly, Archambault et al. (2010) found that teachers who frequently incorporate technology into their teaching practices demonstrate higher levels of TPACK, highlighting the role of ongoing engagement with technology in improving teaching practices.

2.5 Theoretical frameworks

A theoretical framework is like a strong base for a research study. It is built from established ideas and theories that support the whole research process (Labaree, 2013). The framework brings together important concepts and theories from previous research. It acts as a solid foundation for analyzing and understanding the data in the study (Swanson, 2013). Explaining the philosophical, knowledge-building, methodological, and analytical aspects of research, not only directs the study but also shapes how it is approached overall (Eisenhart, 2019). In simple terms, a theoretical framework helps researchers choose what to measure and guides them in finding connections in

the data (Imenda, 2014).

Theories help researchers make sense of real-world situations and apply their understanding of contexts to explain behaviour and solve problems (Lodico, Spaulding & Voegtle, 2010; Kivunja & Kuyini, 2017; Gray, 2021). They provide a common starting point for researchers in a specific field. On the other hand, an analytical framework is crucial for interpreting data, deriving meaningful results, and providing a perspective for research focus and analysis (Goos, 2003; Simuja, 2016). It acts as a reference for making sense of research findings (Mpofu, Otulaja & Chikunda, 2013). According to Shepherd & Suddaby (2017), an analytical framework not only guides data collection but also shapes the analysis process, offering a lens through which research questions are approached and findings are comprehended (Jaakkola, 2020). This involves breaking down complex issues into simpler elements, making it easier to tackle problems (ibid.). So, using an analytical approach means having a method to break down complex issues. In this study, the theoretical framework is built upon Vygotsky's (1978) sociocultural theory, and Mishra and Koehler's (2006) Technological, Pedagogical, Content Knowledge (TPACK) theory, discussed below.

TPACK framework enhances teaching and learning through the integration of technology while some researchers are claiming that TPACK is a valuable framework for integrating technology into education, it does have its criticisms (Graham, 2011; Graham et.al, 2012; Fahadi, & Khan, 2022). It can be argued that knowledge of the different components of the TPACK framework does not necessarily mean the implementation of ICTs in teaching and learning (Kabakci Yurdakul & Çoklar, 2014; Olofson, Swallow & Neumann, 2016; Bibi & Khan, 2017). Its complexity requires teachers to possess a deep understanding of both technology and pedagogy in addition to their subject matter expertise (Koehler & Mishra, 2009; Chai, Koh & Tsai, 2013). Some argue that TPACK may not adequately address the rapidly evolving nature of technology, making it challenging for educators to keep up with the latest advancements and incorporate them effectively into their teaching practices (Harris, Mishra & Koehler, 2009; Laurillard, 2013). There is also a risk that rigid adherence to the TPACK framework could stifle creativity and innovation in teaching, as educators may feel constrained by a prescribed model rather than encouraged to explore alternative approaches to integrating technology in their classrooms (Young, 2012; Lötter,

2019; Rhicard, 2022).

2.5.1 Technological Pedagogical Content Knowledge (TPACK)

The study utilized the Technological Pedagogical Content Knowledge (TPACK) framework to analyze data from Mishra & Koehler's research (2006, 2009). TPACK, derived from Shulman's Pedagogical Content Knowledge (PCK), refers to teachers' knowledge for integrating technology across subjects. This framework has been embraced by various researchers and is seen as effective in merging technology with teaching practices. TPACK offers insights into the necessary teacher knowledge for technology integration (Mishra, Koehler, Cain, 2013; Celik, Sahin, Kiray, & Simsek, 2020). By employing TPACK, this study aims to understand how using ICTs in math classes can enhance TPACK development.

Mishra and Koehler (2008) constructed the TPACK diagram to demonstrate the framework within the subject context, as shown in Figure 2.1:

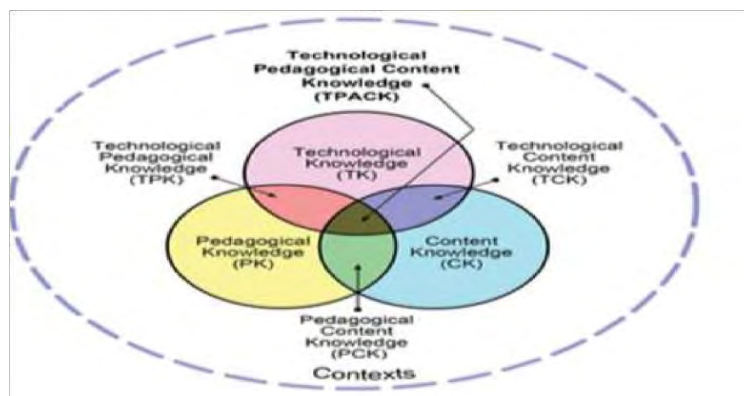


Figure 2.1: The TPACK framework and its knowledge components (adopted from Koehler & Mishra, 2009)

The study embraced all seven elements of TPACK to explore how senior primary mathematics teachers incorporate and utilize technology in their teaching, with the details of each component discussed subsequently.

(a) Content Knowledge (CK): involves the subjects taught and requires a teacher's grasp of the subject matter. It encompasses actual knowledge and mental organization, including comprehension and questioning across various domains (Jalkanen, 2015; Fishman, Dede &

Means, 2016; Mercado & Ibarra, 2019). Given the study's focus on integrating technology into math teaching, this element serves as a lens to comprehend teachers' math content knowledge and their adeptness in choosing suitable technological tools.

(b) Pedagogical knowledge (PK): pertains to teaching methodologies, encompassing teachers' understanding of instructional practices, processes, and techniques (Koehler & Mishra 2009). It also encompasses classroom management principles and strategies (Shulman, 1987: 8). This knowledge involves learning-teaching processes, methods, lesson planning, student evaluation, and adapting teaching to different learning styles. Teachers employ various approaches to elicit desired student behaviours and provide (Turvey & Pachler, 2020; Fawns, 2022) support. The integration of technology in the classroom aligns with pedagogical goals; technology should complement pedagogy, not

vice versa (McGee & Reis, 2012; Lai, Khaddage & Knezek, 2013; Philipp, 2013). In the context of this study's focus on technology integration in mathematics teaching, this component is analyzed to explore how mathematics teachers judiciously select technological tools that enhance their pedagogical practices.

(c) Technological Knowledge (TK): involves a comprehensive grasp of information technology and its effective application in teaching (Koehler & Mishra, 2009). It encompasses familiarity with diverse technologies and their utilization (Koehler & Mishra, 2005; Mishra & Koehler, 2006; Koehler et al., 2007; Koehler & Mishra, 2008; Mishra & Koehler, 2008; Harris et al., 2009; Koehler & Mishra, 2009; Schmidt et al., 2009). Technology is employed to aid content delivery, facilitate teacher-student interaction, and present subject matter to enhance student comprehension (Hammond & Manfra, 2009). Integrating ICT in teaching demands teachers possess knowledge and skills across various technologies in instructional contexts (Erdogan & Sahin, 2010). In the context of this study's focus on technology use in math teaching, this component is examined to illuminate teachers' proficiency in leveraging technology for effective mathematics instruction. This includes understanding how to integrate mathematics software like Geogebra and Photomath through laptops, cell phones, and computers.

(d) Pedagogical Content Knowledge (PCK): pertains to the instructional approach employed to teach course materials (Koehler & Mishra, 2009). It emphasizes teachers' pedagogical understanding in relation to the specific subject being taught. PCK encompasses the insight necessary to facilitate learning in both challenging and straightforward subjects (Shulman, 1986:

9). It encompasses knowledge of diverse teaching methodologies tailored to different subjects (Koehler & Mishra, 2005; Mishra & Koehler, 2006; Koehler et al., 2007; Koehler & Mishra, 2008; Mishra & Koehler, 2008; Harris et al., 2009; Koehler & Mishra, 2009; Schmidt et al., 2009). This fusion of pedagogy and content involves effectively presenting subject matter, addressing educational challenges, and adapting to various student interests and abilities (Shulman, 1987: 8). In this study, PCK serves as a perspective to comprehend teachers' approaches to teaching mathematical content.

(e) **Technological Content Knowledge (TCK):** encompasses utilizing technology to convey course materials (Koehler & Mishra, 2009). It concentrates on comprehending technology within a particular subject or field (Koehler & Mishra). TCK involves understanding how to effectively present both technology and subject matter, enabling adaptable and suitable technological choices for educational objectives (Koehler & Mishra, 2005; Mishra & Koehler, 2006; Koehler et al., 2007). Given the study's focus on integrating technology into math teaching, TCK was employed to grasp teachers' proficiency in merging technology with mathematical content and specific topics. This component aids the study in investigating whether teachers in the Okahao educational circuit utilize ICTs to generate and present mathematics content.

(f) **Technological Pedagogical Knowledge (TPK):** primarily addresses the comprehension of technology's impact on instructional approaches (Koehler & Mishra, 2009). It emphasizes teachers' understanding of techniques, strategies, and processes for teaching and learning through technology (Harris et al., 2009; Mouza, 2011; Bhasin, 2012). Moreover, Technological Pedagogical Knowledge involves the skill of employing technology to facilitate various teaching methodologies (Koehler & Mishra, 2008; Mishra & Koehler, 2008; Harris et al., 2009). With this study's focus on incorporating technology into math instruction, TPK was adopted to delve into how teachers employ technology integration methods within mathematics teaching.

(g) **Technological Pedagogical Content Knowledge (TPACK):** involves the adept use of technology across subjects while implementing effective teaching methods (Koehler & Mishra, 2009; Dawes, 2012; James Jacob, 2015). This knowledge amalgamation facilitates smoother

student learning through suitable pedagogy and technology (Koehler & Mishra, 2009; Schmidt et al., 2009). It surpasses a technology- centered approach, promoting innovative thinking among teachers (Harris et al., 2009). This is accomplished through TPACK's curriculum sampling process, which refines teaching experiences, elevates professionalism, and introduces fresh dimensions to educational technology (Mishra, Koehler, Zellner & Kereluik, 2012; Simuja, 2023).

TPACK underpins proficient technology-infused teaching, encompassing the comprehension of technology-based concept presentation, utilization of pedagogical techniques indirectly employing technology, insight into facilitating or challenging concepts, awareness of technology's educational value, understanding students' prior knowledge, and familiarity with epistemological theories (Mishra & Koehler, 2006; Koehler et al., 2007; Koehler & Mishra, 2008; Mishra & Koehler, 2008; Harris et al., 2009). To effectively apply the TPACK model, teachers must cultivate intricate, adaptable, and comprehensive knowledge of its components, selecting appropriate technologies and mastering their purposeful integration into teaching processes (Koehler et al., 2011). Notably, TPACK's interplay and teachers' choices impact classroom dynamics and student performance (Bos, 2011), thus making TPACK an essential framework for fostering technology integration in education (Kereluik et al., 2010; Nyirenda & Simuja, 2023).

In this study, TPACK was embraced to comprehend teachers' grasp of content (C), pedagogy (P), and technology (T) when teaching mathematics through technology integration. While the TPACK framework encourages reflective practice and the incorporation of technology in mathematics classrooms, it may not fully encompass teaching and learning through sociocultural interactions aided by technology (Hill & Uribe-Florez, 2020; Poitras & Lajoie, 2021). Hence, this study merges the TPACK framework with socio-cultural theory to explore the evolution of TPACK through technology use and integration in primary education within the Okahao educational circuit.

2.5.2 Socio-Cultural Theory

Vygotsky (1978) emphasized that meaningful learning happens through social interactions that involve culturally relevant materials. Socio-cultural theory emphasizes that learning is a collaborative process facilitated by social interaction and the use of cultural tools to mediate

understanding (Kendal, 2011; Mutekwe, 2018). Therefore socio-culture theory was used in this study to investigate the senior primary mathematics teachers when integrating technology in their teaching. The theory aims to emphasize the significance of social and cultural influences in shaping cognitive development (Allahyar & Nazari, 2012; Mahn & John-Steiner, 2012; Saxe & de Kirby, 2014). It underscores the roles of language, social interactions, and cultural tools in shaping individuals' thinking and learning processes (Kendal, 2011; Aimin, 2013; Pathan et al., 2018).

According to Vygotsky's sociocultural theory, learning and development are deep connected with social interactions and mediated by either more knowledgeable individuals or cultural tools (Vygotsky, 1978). These cultural tools serve as mediational that enable learners to grasp abstract concepts by providing support and guidance (Kendal, 2011; Allahyar & Nazari, 2012; Behroozizad et al., 2014). Through collaborative activities within a social context, learners engage with others, objects, and events, which in turn facilitate their learning process and aids in the internalization of new information and skills (Vygotsky, 1978). This collaborative learning environment allows learners to tackle ideas that may initially seem too complex for independent comprehension (Scott & Palincsar, 2013; Mutekwe, 2018; Alkhudiry, 2022). Therefore, within this theory, the research employed two components of sociocultural theory in conjunction: mediation of learning and social interactions.

(a) Mediation of learning

Effective teaching relies on incorporating tools that facilitate learning, thus underlining the crucial role of these tools in the educational process (Hourigan, & Murray, 2010; Blomberg, Sherin, Renkl, Glogger, & Seidel, 2014; Vlachopoulos & Makri, 2017). According to Vygotsky (1978), mediation, acting as the bridge between teachers and learners, significantly impacts learners' grasp of scientific knowledge and skills. Vygotsky (1978, as cited by Wertsch, 1985) asserts that the effectiveness of learning is rooted in the dynamics of social interactions between individuals possessing varying levels of expertise. This process entails guiding the learner to progress through successive layers of knowledge and understanding. Lantolf (2000) presents three mediation paradigms: mediation by external agents, mediation through internal dialogue or private speech, and mediation via artifacts such as tasks and technology.

Emphasizing Vygotsky's perspective, mediation within the learning process involves a symbiotic interaction between individuals and tools or artifacts. In the realm of modern education, technological tools have gained significant prominence as potent mediators (Mohd Saad, Mamat, Hidayat & Othman, 2023; Yen, Thi, Thuy, Tra & Thu, 2023; Yuan & Liao, 2023). The sociocultural theory of learning underscores the pivotal role of tools in this context. Notably, Shaffer and Clinton (2006) introduce the concept of a tool for thoughts broadening the scope of tools. This concept challenges the notion of human exclusivity in psychological analysis (ibid). Their argument extends to the assertion that diverse media, such as video games, word processors, and analytical tools, not only foster novel skills and cognitive patterns but also redefine the landscape of literacy by expanding beyond traditional print-centric approaches (Mohd Saad et al., 2023; Shambare et al., 2022).

This study explores how technological tools mediate mathematics teaching in senior primary education. These tools have a two-fold effect, guiding and limiting learning activities by providing access to some while restricting others, as explained by Pea (2004). In this dynamic, teachers emerge as skilled facilitators, managing various groups of learners, aided by the helpful presence of these tools (McConnell, Parker, Eberhardt, Koehler & Lundeberg, 2013; McDaniels, Pfund & Barnicle, 2016; Wang, Fang, Han, & Chen, 2016). Within this study's context, these technological instruments are acknowledged as mediation tools with the power to enhance the effective teaching of mathematics in various learning situations. Technology acts as a go-between or helper in the learning process (Dahal & Schlough, 2011; Vanderlinde, Dexter & Van Braak, 2012; Lee, Lee & Lee, 2017). It assists both teachers and students in understanding and working with mathematical concepts (Mohd Saad, Mamat, Hidayat & Othman, 2023; Yen, Thi, Thuy, Tra & Thu, 2023; Yuan & Liao, 2023). For instance, it might provide interactive tools, visual aids, or simulations that make it easier to grasp complex ideas (ibid). Mediation helps bridge the gap between the abstract nature of mathematics and the concrete understanding that learners need (Ali, 2011; Gravemeijer, 2016; Venkat & Askew, 2018). It essentially makes the learning experience smoother and more effective (Gee, 2008; Coburn & Stein, 2010; Askew, 2019).

Vygotsky (1962) talks about two kinds of tools. The first tools are human mediation tools. These are tools that involve interactions with people (Hemalataha & Pradesh, 2019). They refer to the

social and collaborative aspects of learning (ibid). For instance, when a teacher explains a mathematical concept, provides guidance, or engages in a discussion with a student, they are acting as a human mediation tool (Pea, 2018). Similarly, peers can also serve as tools by offering explanations, sharing ideas, or providing assistance in problem-solving (Kim & Hannafin, 2011; Askew, 2018; Yen et al., 2023). The key idea here is that social interaction and guidance from others are instrumental in the learning process (Mutekwe, 2018; Alkhudiry, 2022; Yuan & Liao, 2023)

The second tools are technical tools or physical objects. These are objects or artifacts that serve as aids in the learning process (Hemalataha & Pradesh, 2019). In the context of teaching mathematics, technical tools can include computers, interactive software, educational games, and other physical resources (Hoyles, 2018;. Shahid, , Aleem, Islam, Iqbal & Yousaf, 2019; Soboleva, Sabirova, Babieva, Sergeeva & Torkunova, 2021). These tools provide concrete means for students to engage with mathematical concepts (Hoyles, 2018 & Shahid et al., 2019). For example, a computer helps in performing complex computations efficiently, allowing students to focus on understanding the underlying principles rather than getting bogged down by arithmetic details (ibid). Furthermore, Vygotsky emphasized that both tools are crucial in human learning, as they enable learners to tackle more complex concepts and tasks than they would be able to do independently. (Mirolli & Parisi, 2011; Pea, 2018; Hemalataha & Pradesh, 2019).

Mediation tools have emerged as invaluable assets in the realm of mathematics education (Hew & Knapczyk, 2007; Coleman, 2014). From interactive software applications to physical manipulative, these tools serve as bridges that enhance the learning experience by providing dynamic, visual, and hands-on approaches to mathematical concepts (Hoyles, 2018;. Shahid et al., 2019; Soboleva et al., 2021). They cater to diverse learning styles and aptitudes, fostering a deeper understanding of abstract ideas (Coleman, 2014;Moloi et al.,2023). Additionally, mediation tools promote engagement, collaboration, and problem-solving skills among students, making mathematics a more accessible and enjoyable subject (Alvarez, Salavati, Nussbaum & Milrad, 2013; Vogel, Kollar, Ufer, Reichersdorfer, Reiss, & Fischer, 2016; Attard & Holmes, 2020). As teachers continue to harness the power of these tools, they pave the way for a more inclusive and effective mathematics education, preparing students for a future that demands proficiency in this

fundamental discipline (Häkkinen, Järvelä, Mäkitalo-Siegl, Ahonen., Näykki & Valtonen, 2017; Tzagkaraki, Papadakis & Kalogiannakis, 2021).

(b) Social Interactions

Socio-cultural theories emphasize knowledge as a collaborative construction among individuals or groups (Wang, Bruce & Hughes, 2011). Notably, Wang (2010) highlights the pivotal role of technological tools in shaping social interactions. Building upon this, Ellis (2000) & (Wang et al., 2011) contend that the essence of sociocultural learning emerges not just through interaction, but within it. This developmental progression involves children initially seeking assistance to complete tasks, subsequently internalizing the knowledge, and eventually performing the tasks autonomously (Ellis, 2000; Wang et al., 2011). This process underscores social interaction as a scaffold for intermediate learning (ibid). Importantly, this study also presupposes that teaching transpires during the integration of technology in mathematics teaching. As a result, this research employs a social interaction lens to meticulously explore how teachers adeptly foster conducive interaction opportunities, both between themselves and students and between students and technological tools, within the realm of mathematics education.

2.6 Chapter Summary

This literature review delved into the integration of technology into the curriculum, with a primary focus on its application in mathematics education. Particularly, the review explored this integration within the context of the Okahao educational circuit, specifically examining senior primary mathematics teachers. The literature highlighted that incorporating technology into mathematics lessons can enhance student engagement, encourage active participation, and offer interactive visualizations and simulations to facilitate the understanding of abstract concepts. Insights from the Okahao circuit primary mathematics teachers demonstrated their successful utilization of technology in teaching mathematics.

Additionally, the review investigated teachers' perceptions and attitudes toward the use of ICT in teaching mathematics, emphasizing the benefits of technology integration. It was noted that integrating technology enriches the learning experience by promoting engagement, customization, collaboration, feedback, and practical application. However, the literature also acknowledged

that obstacles, such as teacher motivation and various barriers can impede effective technology adoption in mathematics education. Notably, sustained professional development was recognized as crucial for bridging the gap between traditional and contemporary teaching methods.

The review further explored the concept of Integrating Technology into Teachers' Pedagogical Content Knowledge (TPACK), underscoring its significance in successful technology-driven teaching. Effective integration of technology relies on teachers' grasp of subject matter, pedagogy, and the appropriate technological tools for specific contexts. The study examined how teachers incorporate technological tools into subject content and teaching methodologies. It also delved into Technological Pedagogical Content Knowledge (TPACK) in teaching mathematics, emphasizing its pivotal role in enhancing the teaching of the subject. Teachers shared insights into their own TPACK development through their experiences of integrating technology in the classroom.

Moreover, the review questioned the importance of technology integration for primary school mathematics teachers in rural settings in developing TPACK. Theoretical frameworks, particularly Vygotsky's socio-cultural theory and the TPACK framework were identified to guide the purposeful use of ICT in teaching and learning. The literature concluded that technological pedagogical content knowledge plays a crucial role in determining teachers' readiness and capability to integrate technology effectively into mathematics education. The subsequent chapter will delve into this study's research design and methodology

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The preceding chapter delved into a literature review and the foundational theories that underpin this study, namely Vygotsky's socio-cultural theory and TPACK, serving as the theoretical and analytical frameworks, respectively. This chapter is focused on elucidating the research design and methodology employed in the study. Research design, according to Smith & Brown (2015), encompasses a structured plan outlining the entire research process. It includes strategies, methods, and procedures for data collection, analysis, and interpretation to address research questions or test hypotheses. Tait and Voepel-Lewis (2015) emphasize that a well-constructed research design ensures the validity, reliability, and generalizability of study findings. This study adopted a qualitative research design, as seen from the perspective of Busetto, Wick, and Gumbinger (2020). Methodology, as defined by Busetto (2020), comprises procedures for conducting research, including data gathering and analysis techniques involving quantitative and/or qualitative approaches. It entails specific procedures for identifying, selecting, processing, and analyzing information related to a topic. Hancock, Algozzine & Lim (2021) describe methodology as a structured process researchers employ to conduct investigations, gather relevant information, analyze data, and draw meaningful conclusions. It functions as a roadmap ensuring accuracy, reliability, and validity of findings. In essence, research methodology is a multifaceted concept encompassing theoretical considerations and practical techniques, guiding researchers in generating new knowledge (Hancock et al., 2021). It varies across disciplines and research paradigms, with the overarching goal of enhancing rigour and credibility (Grover & Lyytinen 2015). Gaur and Kumar (2018) assert that methodology aims to encompass a systematic approach and techniques for rigorous, reliable, and valid research. This chapter discusses qualitative research, case study, and research instruments employed for data generation, including semi-structured questionnaires, semi-structured interviews, focus group interviews, and observations. Additionally, the chapter explores data analysis, trustworthiness, triangulation, credibility, transferability, and confirmability, concluding with an examination of ethical considerations.

3.1 Research Design

This study employs a qualitative approach within the interpretive research paradigm, utilizing a case study design. Interpretive research seeks to grasp and interpret the meanings, experiences, and

viewpoints of individuals or groups within specific contexts (Matua and Van Der Wal, 2015). Its goal is to offer profound insights into human experiences and the intricate ways individuals and groups comprehend their surroundings (Ormston, Spencer, Barnard & Snape, 2014; Taylor, 2014; Mohajan, 2018). It can also unveil the concealed meanings, societal constructs, and personal realities that shape behaviours, beliefs, and interactions (Cuthbertson, Robb, and Blair, 2020). The study focuses on exploring how teachers integrate technology into mathematics teaching. Qualitative research, as a method of inquiry, delves into comprehending and interpreting the complexities of human behaviour, experiences, and societal phenomena (Ormston, Spencer, Barnard & Snape, 2014; Shambare et al., 2022b). Researchers often employ techniques such as interviews, focus groups, participant observation, case studies, and content analysis to gather data in qualitative research. These approaches enable the exploration of nuances, context, and subjective interpretations, with the aim of uncovering the underlying meanings, motivations, and patterns that shape human actions and interactions (Roller, 2019).

Qualitative research involves delving into and interpreting the hidden meanings, motivations, emotions, and experiences of individuals or groups (Mohajan, 2018). In this study, the qualitative approach was employed to explore interpretive material practices that shed light on the global landscape (Ormston et al., 2014). The investigation into how the integration of technology enhances the teaching of primary level mathematics holds significant importance. The choice of a qualitative design was apt, as it centres on deriving meaning from the narratives of participating teachers (Sturko & Gregson, 2008). This framework allowed participants to elucidate their experiences through avenues like semi-structured questionnaires, interviews, and focus group discussions (Habibi et al., 2018), enabling them to convey their perspectives without the confines of rigid, quantitative inquiries.

This research sought to delve into educators' pedagogical and technological insights, comprehending their encounters with technology in teaching mathematics, and unearthing challenges encountered during integration (Agyei & Voogt, 2012), paralleling the perspectives of Butina, Campbell, and Miller (2015). Qualitative researchers, as explained by Lee (2012), are dedicated to unraveling individuals' interpretations of their experiences, how they construct their realities, and the significance they attribute to these encounters. Lee (2012) also emphasizes that

research directed at discovering insights and understanding from the viewpoint of those under scrutiny has the potential to bring about meaningful change in people's lives.

Creswell (2012) outlines several key characteristics of qualitative research. Firstly, it typically takes place in a natural setting where data is collected face-to-face, allowing researchers to observe participants experiencing the phenomenon being studied without disrupting the context. Secondly, researchers themselves serve as the primary data collection instruments rather than relying on external tools. Thirdly, qualitative research involves gathering data from multiple sources such as interviews, observations, and documents to gain a comprehensive understanding. Moreover, qualitative analysis is often inductive, meaning data is organized from specific observations to general themes, allowing for the emergence of comprehensive conclusions or theories. Researchers prioritize understanding the meanings that participants attach to the phenomenon, rather than imposing their own interpretations. Additionally, the design of qualitative studies is often emergent, allowing for flexibility and adaptation as researchers engage with the data in the field (Creswell (2012;Krauss et al.,2015). Furthermore, qualitative researchers employ theoretical lenses, such as culture or social context, to frame their study and interpretations. They engage in interpretive inquiry, recognizing that their interpretations are influenced by their own background, context, and understanding. Finally, qualitative research aims to provide a holistic account by reporting multiple perspectives and considering various factors involved in the studied phenomenon, thus painting a broader picture of the subject matter (Creswell,2012).

Quantitative scholars critique qualitative studies, emphasizing issues like limited sample size and potential subjectivity in data analysis (Schreier, 2018), while qualitative research involves intricate processes such as coding and interpretation, which may yield varying results among analysts (Gale, Heath, Cameron, Rashid, & Redwood, 2013). However, these criticisms don't dismiss qualitative research's value. Instead, they underscore the need for rigorous methodology, transparency, and caution. Qualitative research remains essential for exploring complex phenomena, generating hypotheses, and enhancing contextual understanding alongside quantitative approaches (Ormston, Spencer Barnard & Snape, 2014).

3.2 Qualitative Case Study

This study used qualitative case study design. Hancock, Algozzine, & Lim (2021) define a case study as a thorough exploration conducted by a researcher to delve into the depths of a program, event, activity, process, or one or more individuals. Baxter & Jack (2008) characterize a case study as a research approach frequently employed across various disciplines to attain a profound and intricate comprehension of a distinct person, group, organization, event, or phenomenon. This method entails an exhaustive examination of a specific occurrence or instance, often incorporating diverse data sources like interviews, observations, documents, and historical records. Case studies focus on how specific groups of individuals address particular challenges, taking a comprehensive perspective on the situation (Wallin, Adawi & Gold, 2017). In this study, case studies were conducted, recognizing mathematics teachers as authorities not only in the domain of teaching mathematics but also in the adept integration of technology within their instructional practices.

Neale, Thapa & Boyce (2006:4) highlight the multitude of benefits that come with adopting a case study design, foremost among which is its capacity to yield comprehensive insights that might remain elusive via alternative approaches. This approach also allows for the assimilation and synthesis of information from diverse sources and varied research tools, culminating in a coherent and lucid explanation of the phenomenon (Neale et al., 2006; Shambare et al., 2022c). Aligned with Leedy and Ormrod (2005), Lichtman (2011) underscores that a case study equips researchers with a versatile toolkit for data collection, including interviews, observations, and scrutiny of archived materials. This toolkit enhances the likelihood of arriving at well-grounded conclusions. Given its relevance and suitability for this investigation, I opted for a case study design as the most fitting avenue for the study's successful completion. Moreover, the nature of this study, which delves into the development of teachers' technological pedagogical and content knowledge within the integration of ICT in the teaching of mathematics, finds an apt match in the case study framework. The focus of this study is senior primary school mathematics teachers, with the unit of analysis centering on the integration of technology and the evolution of technological pedagogical content knowledge.

When opting for a case study approach, I made a deliberate effort to acknowledge and address certain inherent limitations associated with this method. I observed that it has a limited capacity to

yield findings that can be universally applied to larger populations. Given that case studies predominantly centre on individuals or a select few cases, the outcomes might not hold relevance across varying settings, circumstances, or individuals. Consequently, this hampers the scope of drawing comprehensive theoretical or practical inferences (Kelliher, 2011). Notwithstanding this shortcoming, it remained crucial to recognize that the case study approach in this study retains the potential to offer valuable insights. Nevertheless, it was imperative for me as a researcher to exercise caution in light of these constraints and to adopt this approach prudently, taking into consideration the specific objectives of the research and the prevailing context.

3.3 Research Site and Participants

3.3.1 Selection of sites

The Okahao Circuit chosen as the site for education inspection was selected due to the researcher's familiarity with the Circuit. This selection facilitated a swift connection with the participants, streamlining data collection. Singleton (2011) emphasizes the importance of a setting aligned with the researcher's interests, enabling easy access and rapport-building with respondents. Opting for a different education circuit could have prolonged the research timeline and complicated data gathering.

This investigation aimed to assess the incorporation of technology into mathematics education. Various criteria guided the selection of the research site: the school's rural location, offering grades 4 to 7 (Senior primary phase), public status within the Okahao educational Circuit, possession of government-provided technological tools and internet access, provision of ICT training to teachers, and availability of ICT devices for teachers' use. All the participants were drawn from rural schools within the Okahao district of Omusati region. While numerous schools exist in the Okahao circuit, a purposive sampling approach focused on senior primary schools. Proximity and researcher accessibility guided the school selection process. The researcher's nearly four-year tenure as a teacher in the circuit facilitated easy access to contextual information about the chosen schools.

3.3.2 Selection of participants

Purposive sampling was employed to select participants. This method is utilized by researchers to access individuals who possess expertise on specific issues (Glenton & Lewin, 2019). Patton (2015) argues that the strength of purposeful sampling lies in selecting information-rich cases for in-depth study, which facilitates a deeper understanding of the subject matter. Purposive sampling is sometimes referred to as a judgmental or discriminative method, as it involves selecting units of analysis based on the researcher's findings (Cohen et al., 2011). This approach enables researchers to target individuals with specific characteristics who can contribute meaningfully to the study (Cohen et al., 2011; Andrade, 2018). Regarding sample size, Frederick (2013) notes that there are no fixed rules for determining sample size in qualitative research. He suggests that the sample size should be determined by the research purpose, the significance of the study, the desired level of credibility, and the available time and resources. Etikan, Musa, and Alkassim (2016, p.56) emphasize that the selection criteria and sample size should be based on what provides the clearest understanding of the phenomena under investigation.

In this study, purposive sampling was used since it focused only on the senior primary mathematics teacher. Purposive sampling is about selecting a small unit of the population that can provide sufficient and valuable information that can answer the research question(s) (Teddlie & Tashakkori, 2009). Merriam (2009) defines purposive sampling as the act, process, or technique of selecting a representative part of a population for the purpose of determining parameters or characteristics of the whole population. It is typically used in qualitative research to identify and select the information-rich cases for the most proper utilization of available resources (ibid). In this study, the focus was on identifying and selecting teachers who were well informed and experienced in integrating technologies into the teaching of mathematics. Besides possessing knowledge and experience, the significance of availability and willingness to participate, along with the ability to communicate experiences and opinions in an articulate, expressive, and reflective manner, was noted (Etikan, Musa & Alkassim, 2016; Shambare et al., 2022).

This sampling method is often employed in qualitative research, case studies, and exploratory research where the goal is not to generalize findings to the entire population but to gain deeper insights and understanding about a specific aspect or context (Patton, 2002). Researchers may choose participants based on their expertise, knowledge, experiences, or unique perspectives

related to the research topic, thus ensuring that the sample aligns with the research objectives. My argument based on my experience of conducting this study is that it is important to note that because purposive sampling involves a deliberate selection process, the sample may not be representative of the entire population, which limits the generalizability of the findings. However, it provided valuable qualitative data and in-depth insights that could not be achieved through other sampling methods.

The Mathematics teachers were the targeted participants in this study because, to this study specifically, they are part of the agents on the technology integration initiative within the teaching and learning process as introduced by the Namibian Education Department in 2019. In this study, the sampled population was consulted to give out their opinions. The study was conducted among the specifically sampled teachers who are teaching mathematics from grade four (4) to grade seven (7) within the same circuit. These participant mathematics teachers were selected from all the schools in Okahao educational circuit.

A purposive sample of mathematics teachers from different schools was chosen, taking into consideration factors of teaching experience, and subject area. This targeted approach was intended to investigate the incorporation of technology in teaching mathematics at the senior primary education level. It was anticipated that 35 senior primary mathematics teachers would take part in the semi-structured questionnaires. All the questionnaires were distributed during the mathematics and science circuit monthly meeting. In total, 35 individual questionnaires were distributed among these senior primary teachers. However, only twenty-seven questionnaires were retrieved. Apart from the eight unrecovered questionnaires, all the returned questionnaires were found to be completed. Within the questionnaires, participants were given the option to express their interest in engaging in individual interviews, observations, and focus group discussions. Six teachers agreed to take part in the semi-structured interview, five in a focus group interview, and three in classroom observation.

All the teachers had to meet the selection criteria below to participate in the study.

- i. Teachers possess qualifications as mathematics teachers.
- ii. Teachers had a minimum of three years of teaching experience or more.
- iii. Teachers have been deployed to serve in rural schools.

- iv. Teachers possess or access ICT equipment in their schools
- v. Teachers attended the ICT training offered by the government through the education circuit.

3.4 Data gathering techniques

Data gathering techniques are a range of approaches used in educational research to gather data (Cohen et al., 2018). Creswell (2014) defines data gathering techniques as diverse methods to gather information, facts, and observations for research, analysis, and decision-making. Successful data gathering ensures accuracy and reliability, supporting informed decisions (Rubin & Babbie, 2016). Technique choice depends on research goals, resources, ethics, and data type (Walliman, 2021), often involving a blend of methods for comprehensive understanding. This section describes how information was collected during the study. Semi-questionnaires, semi structured interviews, focus group interviews, and observation were used to gather data for the study.

Table 3.1 shows the matrix of a briefing overview of the entire data generating and analysis processes

Data gathering technique	Data analysis	Type of data
Semi-questionnaires	Thematic analysis	The tool captured the qualitative and quantitative data. Questionnaires consisted of closed and open-ended questions regarding respondents' responses to research question 1.

Semi-structured interview and focus group interview	Thematic analysis	The tools captured the qualitative data. Semistructured and focus group interview questions were used to respond to research questions 1, 2, and 3.
Observation	Thematic analysis	The tool captured qualitative data. Observations were done to observe the responses in order to questionnaires and semistructured i nterview methods and respond to all research questions 1, 2, and 3.

3.4.1 Semi-structured Questionnaires

A semi-structured questionnaire is a data-collecting instrument consisting of a series of both closed and open-ended questions and other prompts for the purpose of gathering data from the respondents (Mathiyazhagan & Nandan, 2010). Pitura (2023) defines semi-structured questionnaires as a type of survey instrument that combines open-ended and closed-ended questions. These questionnaires include a mix of predetermined questions with fixed response options, as well as open-ended questions that allow respondents to provide more detailed and personalized responses. Despite the fact that semi-structured questionnaires take time to develop (Delbert & Neil, 2002). They are favourable data-gathering tools since they can be completed without the presence of the researcher, and they are also easier to analyse (Cohen et al., 2011). Semi-structured questionnaires offer the benefits of standardized and open responses to a range of topics from a large sample or population, they can be cheap, reliable, valid, quick and easy to

complete (Cohen et al 2018).

In selecting the semi-structured questionnaire as the method for this study, the researcher acknowledged its limitations. These shortcomings encompassed the possibility that certain participants might not complete and return the questionnaires, as noted by Phellas, Bloch & Seale (2011). This reluctance could stem from the inconvenience participants might experience, echoing Berends (2012), who emphasized that asking individuals to complete questionnaires could be burdensome and time-consuming. Another concern was the potential for rushed responses, leaving some questions unanswered, particularly if the questionnaire proved excessively lengthy (Phellas, Bloch, & Seale, 2011). Cohen et al. (2011) emphasized the importance of designing a questionnaire that does not intimidate respondents, emphasizing the need to structure questions in a way that encourages participation.

The researcher devised a questionnaire layout that commenced with non-threatening inquiries, aiming to sustain respondent engagement. Furthermore, the questionnaire's length was kept reasonable while still encompassing all pivotal themes relevant to addressing the research inquiries. Significantly, the researcher participated in the mathematics and science meetings within the circuit, personally distributing the questionnaires to participants. This approach allowed for an elucidation of the questionnaire's purpose and its value in generating comprehensive insights. The participants were kindly requested to answer all questions, with an understanding that participation was voluntary and contingent upon informed consent.

The study's intention was to distribute questionnaires to 35 mathematics teachers in the Okahao Education Circuit. These questionnaires were disbursed during the mathematics and science teachers' monthly circuit meetings. However, only twenty-seven questionnaires were recovered. The questionnaire design incorporated both closed-ended and open-ended questions, strategically guiding the researcher while enabling respondents to provide insights aligned with the research objectives. Through this questionnaire-based approach, the researcher aimed to acquire pertinent information from senior primary teachers regarding their individual methods of integrating technology into teaching Mathematics. (See **Appendix E**).

3.4.2 Semi-structured interview

An interview is an oral interaction in which questions are posed by the interviewer to elicit oral responses from the interviewee (Haigh, 2013). Cohen, Manion & Morrison (2018 p56), clarifies that an interview enables the researcher to understand, evaluate or assess a person, situation, to test or develop hypotheses, to gather data as in surveys or experimental situations and to sample respondents' opinions. It also enables interviewers and interviewees to discuss their interpretations of the world in which they live and to express how they regard situations from their own points of view (Cohen et al., 2011). In this study, I used the semi-structured interview. This might have helped me ascertain teachers' experiences and understandings of integrating technology in teaching mathematics. The purpose was for me to establish desired certainty about their knowledge of TPACK.

A semi-structured interview is defined by Cohen et al. (2018) as a conversation between the researcher and the respondent. In addition, Smith (2008) defines semi-structured interviews as a qualitative research method used to gather information and insights from participants in a flexible and adaptable manner. In contrast to fully structured interviews with rigid sets of predetermined questions and unstructured interviews which are more open-ended and free flowing (Johnson, 2010), semi-structured interviews strike a balance between structure and flexibility (Gubrium & Holstein, 2002). Semi-structured interviews have a schedule of questions (mostly open-ended) but can be explored in any order, where the researcher is free to follow up on responses in any way deemed appropriate (Bartram & Christiansen, 2015).

In a semi-structured interview, the researcher prepares a list of key questions or topics to cover, providing a framework for the interview process. However, these questions are not asked in a strict order, and the interviewer has the freedom to probe deeper into certain responses, ask follow-up questions, and explore unexpected avenues of conversation (Galletta, 2013). Semi-structured interviews are commonly used in social sciences, psychology, anthropology, and other fields where a deeper understanding of individuals' beliefs, attitudes, experiences, and perceptions is sought (Fontana & Frey, 2005; Bernard, 2018). This approach allows for a more natural and participant-driven interaction, enabling interviewees to share their thoughts, experiences, and perspectives in their own words (Smith, 2003; Rubin & Rubin, 2011). Seven participants were

purposively sampled for interviews from those who had responded to the semi- questionnaire. However, I only managed to interview six participants. The six participants who were interviewed were selected using the criteria of having answered all the questions in the questionnaire, having integrated technologies into their teaching, and being willing to take part in the individual interview and focus group interview.

Interview schedules were given to the six participants electronically using WhatsApp or email. The purpose of these preliminary schedules was to allow the participants to familiarize themselves with the questions, reflect upon them, and be in a position to provide in-depth responses (Henning, 2004). The participants chose the date and time of their personal convenience for the interviews. All six participants were visited for interviews. During the interviews, the researcher listened carefully. Even though I had specific topics to cover from the research questions, I let the interviewees talk about different things if they wanted. Sometimes, I was able to ask questions to bring them back to the main topic. This approach, which involved being flexible and listening well, made sure the interviews were helpful for the people being interviewed. It was like having a conversation, as explained by Onwuegbuzie (2012). I also made sure to balance being flexible and sticking to the research questions. In this study, the interviews with each teacher were audio recorded, so they could be listened to again during the analysis part of the study. I also wrote down notes while listening. These recordings were later turned into written transcripts.

While semi-structured interviews offered numerous advantages in this study, several challenges were noted. These challenges included the lack of standardization in question phrasing and probing, which could result in variations in participant responses, thereby undermining data consistency and comparability. Moreover, the subjectivity of interviewers and participants' biases had the potential to distort the accuracy and reliability of findings. Additionally, the time-consuming nature of conducting, transcribing, and analyzing these interviews could strain available resources. The qualitative nature of the data collected also required intricate coding and interpretation, making analysis susceptible to subjectivity. Furthermore, the success of this approach heavily relied on the skills of the interviewer, raising concerns about the possibility of missing research objectives if not executed skillfully. Throughout the study, these drawbacks were addressed in alignment with the research goals to ensure the integrity and rigor of the research findings. (See Appendix F)

3.4.3 Lesson Observation

Maree (2010) defines observation as a systematic process of recording the behaviours of the participants without interacting or questioning them. According to Bertram and Christiansen (2015), observation entails the researcher going to the research site in order to collect first-hand information from the participants. This involves collecting the information as events are happening in the actual setting. In addition, Denzin (2017) defines observation as the act of closely and attentively watching, perceiving, or examining something in order to gain information or understanding about it. It involves using one's senses, such as sight, hearing, touch, taste, or smell, to collect data or gather insights about a specific phenomenon, event, object, behaviour, or process (Ciesielska, Boström & Öhlander, 2018). Observations can be conducted in various contexts, such as scientific research, everyday life, education, and problem solving, and they are fundamental to the process of acquiring knowledge and forming accurate interpretations of the world around us (National Research Council. 2012). In scientific research, careful and systematic observations are often used to gather data that can formulate hypotheses, theories, and conclusions (Rwegoshora, 2016).

Observation is a powerful and versatile research method that offers several distinct advantages in the realm of scientific studies (Sovacool, Axsen & Sorrell, 2018). Firstly, observation allows researchers to witness and record real world phenomena directly as they naturally occur, providing an unparalleled level of accuracy and authenticity (Smith, 2010). This method minimizes the potential for biases and distortions that might arise from participant self-reporting or memory recall (Jones et al., 2015).

Additionally, observation permits the study of behaviours and interactions in their genuine context, offering insights into the complex interplay between individuals and their environment (Brown & Lee, 2018). The non-intrusive nature of observation enables researchers to study sensitive or private behaviours that participants might be hesitant to disclose in other research methods (Williams et al., 2019). Moreover, observation can be particularly valuable when investigating topics where verbal communication is limited or not applicable, such as studying animal behaviour or nonverbal communication cues (Anderson, 2022). Through systematic observation, researchers

can identify patterns, trends, and nuances that might not emerge through other data collection methods, thus contributing to a more comprehensive understanding of the subject under investigation (Miller & Johnson, 2021).

Observation in studies can pose problems due to the risk of observer bias and subjectivity (Smith et al., 2022). This occurs when the presence of researchers influences participants' behaviour, leading to inaccurate or distorted data (Jones & Brown, 2021). Additionally, the selective nature of observations can lead to incomplete information, which hinders a comprehensive understanding of the studied phenomena (Garcia & Lee, 2023). The use of observation method in research comes with its drawbacks, including the potential for observer bias, where the presence of researchers alters participants' behaviour (McCambridge, Witton & Elbourne, 2014). This can result in the collection of inaccurate data. Moreover, observations might overlook underlying thoughts and emotions, limiting the depth of understanding (Guthrie, 2010). The intrusion of observers can also disrupt natural settings, potentially triggering the Hawthorne effect (Lopez & Whitehead, 2013). Ethical concerns about privacy and consent, along with the limited generalizability of findings, further contribute to the disadvantages of using observation in studies (Qu, & Dumay, 2011). Notwithstanding the drawbacks associated with utilizing observation in research, this method has proven instrumental in furnishing the study with pertinent insights into the integration of technology by teachers in teaching mathematics at the classroom level of education.

In this study, three (3) teachers among those who had undergone the semi-structured interview were visited and observed. Three lessons for each teacher's classroom were observed in an effort to see how they normally integrated any type of technological tools in their teaching of mathematics. However, I was only able to observe two participants three times each and one participant two times as he transferred to another region in the southern part of the country, making it impossible for me to reach him. Another reason for carrying out the observation of the three purposively selected participants was to reaffirm whether what was shared during questionnaires and semi-structured interviews corresponded with their actual classroom practices, relative to the integration of technology during mathematics lessons. The teachers who were observed while teaching were informed in advance, through WhatsApp, so that in their lesson planning and presentation, it would be clear how they integrated technology. (See Appendix G)

3.4.4 Focus group interview

Focus groups are a form of group interview in which reliance is placed on the interaction within the group, which discusses a topic supplied by the researcher (Morgan, 1988, p. 9), yielding a collective rather than an individual view (Cohen et al., 2018). It empowers participants to speak out, in their own words, encouraging groups, rather than individuals, to voice opinions. A focus group interview involves a small number of demographically placed participants included in a study (Morton, Ramirez, Mace, Demetriou, & Panter, 2018). According to Nyumba, Wilson, Derrick & Mukherjee (2018), a focus group interview promotes discussion between a small number of participants and the researcher on a specific topic.

The utilization of focus group interviews in this study offered several distinct advantages. Firstly, it fosters a dynamic interaction among participants, enabling the exploration of diverse perspectives and generating rich, in-depth insights into the research topic (Smith et al., 2017). This method also promoted a collaborative environment, potentially stimulating the exchange of ideas and the emergence of new concepts (Žur, 2020). Additionally, focus group interviews aided this study in uncovering tacit knowledge and unanticipated factors, enhancing the comprehensiveness of the study's findings. Moreover, the interactive nature of the approach allowed me to observe group dynamics and nonverbal cues, providing a deeper understanding of participants' viewpoints. Lastly, the cost-effectiveness and efficiency of conducting one interview with multiple participants contribute to the practicality of the focus group approach in obtaining multifaceted data (Stewart & Shamdasani, 2015).

Using focus group interviews in research studies comes with several disadvantages that researchers need to consider. One primary concern is the potential for group dynamics to influence participant responses. Group settings can lead to conformity, where participants might express opinions that align with the dominant viewpoint in the group or withhold their true thoughts to avoid conflict (Smith & Alisat, 2019). This can result in biased or incomplete data, limiting the depth of insights gained from the study. Additionally, focus group interviews might not provide a representative sample of the population under investigation. Participants who are more outgoing or dominant in group discussions could overshadow quieter individuals, leading to the underrepresentation of

certain perspectives (Faulkner, Watson, Pollino, & Shetterly, 2021). This can compromise the generalizability of findings to the broader population. Moderator bias is another drawback to consider. The facilitator's personal beliefs, attitudes, and communication style can inadvertently shape the direction of discussions and influence participant responses (Krueger & Casey, 2014). Despite efforts to remain neutral, moderators may unintentionally guide conversations in a certain direction, introducing potential bias into the collected data (Faulkner et al, 2021).

Furthermore, scheduling and logistical challenges can arise when attempting to coordinate a diverse group of participants with different availabilities. This can lead to difficulties in assembling a suitable group for the focus group session, potentially affecting the diversity and richness of perspectives the research aims to capture. Analyzing the data from focus group interviews can be complex and time-consuming (Stewart & Shamdasani, 2015). Transcribing and interpreting discussions from multiple participants can be challenging, and the qualitative nature of the data may require subjective judgments during analysis, leading to potential interpretation discrepancies (Vaismoradi, Turunen & Bondas, 2013). Despite the inherent limitations associated with employing focus group interviews as a research methodology, this approach has played a crucial role in enriching the study with relevant insights concerning the incorporation of technology by educators in the instruction of mathematics at the educational level of classroom settings.

During the study, six (6) senior primary mathematics teachers were the participants in the focus group interview, all of whom were interested in being part of the focus group interview. These were all the participants who had participated earlier in the semi- structured interview, three of whom had also undergone earlier observation. As a researcher, my role in the focus group was to initiate interview questions that all participants answered concurrently. The participants were requested to consent to the recording of the focus group interview. Therefore, a voice recorder was used to record the interview conversation. **(See Appendix H)**

3.5 Data analysis

Data analysis is a process whereby researchers reduce data to a story and interpret it to derive insights (Hair, Page & Brunsveld, 2019). Data analysis is the most crucial part of any research

(Wickham, 2016); it summarizes collected data and involves the interpretation of data gathered through analytical and logical reasoning to determine patterns, relationships, or trends (Hair, Page & Brunsveld, 2019). The data that was collected using semi-questionnaires, semi-structured interviews, observation, and focus group interviews has been analyzed inductively, allowing themes and categories to emerge from the raw data. According to Zikmund et.al. (2013) and Elliott (2018), data analysis was categorized into different stages: editing, coding, and creating an electronic data file. The data was checked for correctness, consistency, and legibility. Once it had been edited, it was coded, with symbols assigned to the raw data. In this study, the data collected from the questionnaires was analyzed quantitatively using descriptive statistics. Descriptive statistics transformed and summarized the data set into either a visual overview, such as a table or graph, or a single or a few numbers that summarize the data (Bertram & Christiansen, 2014).

The researcher used the two concepts of sociocultural theory: mediation tool, and social interactions (Vygotsky, 1978), as well as all the components of TPACK as adapted from Mishra and Koehler (2006), to serve as a lens for analyzing specific knowledge elements of technological pedagogical and content knowledge developed (or not) by the senior primary school mathematics teachers as they integrated technologies into their teaching in the Okahao education circuit.

The focus of the analysis was on how senior primary school mathematics teachers developed their TPACK as they integrated technology in the mathematics classroom. Finally, the researcher used different color highlighters to group the data, and then moved from coding to categories, sub-themes, and themes, and coded the data, which was the process of choosing labels and assigning them to different parts of the data. Codes, such as Q₁ (questionnaire), SSI₁ (semi-structured interview), FGI₁ (focus group interview), and O₁ (observation) were used in the study, (**see Table 3.2**).

Description	Code
Semi-questionnaires	Q ₁ Q ₂

Semi-structured interviews	SSI ₁ SSI ₂
Focus group interviews	FGI ₁ FGI ₂
Observation	O ₁ O ₂

3.6 Data triangulation

Baxter & Jack (2008) defined triangulation in research as the practice of utilizing multiple sources, methods, data sets, or perspectives to investigate a specific phenomenon or issue. This approach aims to enhance the validity and reliability of findings. Hussein (2009) added that triangulation involves combining two or more methodological approaches, theoretical perspectives, data sources, investigators, and analysis methods to explore the same phenomenon. The underlying concept behind triangulation is that by integrating diverse viewpoints and methodologies, researchers can mitigate potential biases and limitations inherent in relying solely on a single source or data collection method (Jonsen & Jehn, 2009; Peersman, 2014). Triangulation aims to bolster the validity and reliability of research findings by addressing the potential biases and limitations associated with singular sources of data or methods (Baskarada, 2014). Through cross-referencing findings from various sources or employing different methods, researchers can cultivate a more comprehensive and well-rounded understanding of the subject under investigation (Yin, 2014). Moreover, this approach helps counteract the subjectivity inherent in certain methods, such as interviews. Perhaps the most significant advantage of utilizing multiple sources of evidence and data collection methods is the cultivation of "converging lines of inquiry" (Yin, 2014). Flick (2002), as cited in Denzin and Lincoln (2013, p. 7), contends that triangulation serves as a "strategy that adds rigour, breadth, complexity, richness, and depth to any inquiry."

Harrison, Reilly & Creswell (2020) propose a classification comprising four distinct forms of triangulation: (a) Data Triangulation, involving the collection of information from various dimensions such as time, space, and individuals. (b) Investigator Triangulation, pertaining to the engagement of multiple researchers or investigators in a study to enhance credibility and comprehensiveness. (c) Theory Triangulation, encompassing the integration of multiple theoretical frameworks in a study to enrich the understanding of the investigated phenomenon. (d)

According to Harrison et al., (2020), methodological Triangulation, relating to the utilization of diverse data collection methods to study a single phenomenon, thereby deepening the analysis. Cohen et al. (2018), in a separate study, identified six types of triangulation: (a) Time Triangulation, (b) Space Triangulation, (c) Combined Level of Triangulation, (d) Theoretical Triangulation, (e) Investigator Triangulation, and (f) Methodological Triangulation. In this specific research project, the researcher chose to implement four triangulation methods considered most promising for a comprehensive understanding of the research inquiries. This decision aligned with the framework that Harrison, Reilly & Creswell (2020) proposed and supported by Cohen et al. (2018). The selected triangulation methods included: (a) Data Triangulation, entailing data collection from various sources. This approach facilitated gathering diverse viewpoints beyond the researcher's perspective. (b) Theory Triangulation, involving the integration of two distinct theories – Vygotsky's socio-cultural theory and TPACK theory to inform the study's conceptual framework. (c) Methodological Triangulation, employing multiple data generation techniques such as semi-structured questionnaires, semi-structured interviews, observations and focus group interviews. This diverse set of methods contributed to a holistic exploration of the phenomenon. (d) Investigator Triangulation, engaging different investigators and experts to assess and validate the study's outcomes.

The adoption of Harrison et.al (2020) four types of triangulation, combined with Cohen et al.'s (2018) framework, proved most suitable for this research endeavor. Through these carefully selected triangulation methods, the researcher effectively obtained a comprehensive and multifaceted understanding of the research questions. Four data generation methods were utilized in the study: semi-structured questionnaires, semi structured interviews, observations, and focus group interviews, aiding in triangulation.

3.7 Research evaluation

A number of efforts were made to ensure the trustworthiness of the research processes and findings presented in this study, in line with the four criteria for research evaluation in their work on qualitative research cited by Guba & Lincoln (1989), which are: Credibility refers to the degree of confidence in the truth of the research findings. It is similar to internal validity in quantitative

research and is concerned with establishing the accuracy of the data and interpretations; Transferability, which criterion assesses the extent to which the findings of the research can be transferred or applied to other settings or contexts. It's essentially about generalizability, but in qualitative research, the focus is on whether the findings can be relevant and useful beyond the specific study; Dependability, Dependability is equivalent to reliability in quantitative research. It deals with the consistency and stability of the findings over time and across different researchers or observers. It highlights the need for transparent documentation of the research process so that others can assess its reliability; Confirmability is concerned with the objectivity and neutrality of the research findings. It addresses the potential influence of the researcher's biases, perspectives, and interpretations on the results. To enhance confirmability, researchers should provide a clear audit trail of their decision-making process.

3.7.1 Credibility

According to Anney (2014), Credibility refers to the trustworthiness, authenticity, and believability of research findings or the overall study. In qualitative research, credibility is a crucial aspect that signifies the extent to which the data, analysis, and interpretations accurately represent the perspectives and experiences of the participants and the phenomenon being studied. It is about establishing the truthfulness and accuracy of the research results within the context of the research process and the participants' viewpoints (Moschkovich & Brenner, 2012). To ensure credibility, the researcher should involve several key practices (O'Connor & Joffe, 2020). Firstly, employing rigorous research methodologies and clear data collection processes helps establish a strong foundation. Peer review and validation by experts in the field enhance the reliability of findings. Transparency in reporting methods, results, and potential biases is crucial. Additionally, using multiple sources of data, cross-referencing information, and conducting independent replication studies contribute to credibility. Maintaining ethical standards, acknowledging limitations, and addressing potential conflicts of interest also play a vital role in establishing the credibility of research.

Credibility holds significance in qualitative research for establishing trustworthiness (Kornbluh, 2015); creditability ensures that research findings are dependable and can be trusted by both the research community and the broader audience (Cypress, 2017). When the research maintains

credibility, readers and fellow researchers can have confidence in the accuracy and authenticity of the data and conclusions, Validity; credibility is closely tied to the validity of qualitative research. (Toma, 2011).

In this study, the focus was on how junior primary mathematics teachers integrate technology to develop TPACK. The researcher employed semi-structured questionnaires, interviews, lesson observations, and focus group discussions to address the research queries. Interviews proved invaluable for capturing unobservable insights and showcasing a method to enhance credibility. In conclusion, credibility is a cornerstone of qualitative research that ensures the accuracy, trustworthiness, and authenticity of the findings. Establishing credibility requires careful attention to various aspects of the research process, from data collection to interpretation, and involves strategies that demonstrate the rigor and validity of the study's outcomes Christensen, & Miguel, 2018; Johnson, Adkins & Chauvin, 2020).

Transferability

Transferability in research is defined as the degree to which the outcomes, conclusions, or results derived from a study carried out within a particular context or environment hold relevance, applicability, or generalizability to alternative contexts or environments (Smith & Johnson, 2018; Jackson, 2020). This concept involves an evaluation of the extent to which the findings obtained through the study could possess significance and utility across diverse situations, geographical locations, or among distinct demographic groups, extending beyond the specific circumstances of the original research (Thomas, 2016; Williams et al., 2019). By enhancing transferability, the research gains increased value and practicality, as it enables the insights gleaned within one setting to potentially inform and benefit a range of other scenarios, thus amplifying the broader significance of the research's outcomes (Brown & Jones, 2021; Martinez & Lee, 2022).

The importance of transferability in qualitative research is underscored by its potential to expand the influence and pertinence of the study (Peterson, 2019). Through the contemplation of how findings might be pertinent in various contexts, researchers amplify the pragmatic usability of their insights (Creswell & Poth, 2018). Transferability stretches the scope of the study's conclusions, fosters collaboration, eases evidence-driven decision-making and contributes to the advancement of a comprehensive knowledge repository (Nowell et al., 2017; Morse, 2020). Essentially, the incorporation of transferability augments the study's aptitude to offer meaningful and relevant

insights that extend beyond its initial environment (Birks & Mills, 2015; Charmaz, 2014).

Incorporating transferability within a qualitative research study involves a series of pivotal stages. Firstly, researchers should furnish intricate depictions of the study's milieu, methodologies, and participants, enabling readers to gauge the potential relevance to alternative settings (Adelsberger, Collis & Pawlowski, 2013). Secondly, a proactive engagement in comparative analysis is imperative, entailing an exploration of concurrences and disparities between the study's outcomes and those from disparate research or settings (Morrow, 2005; Morse, 2020). This exercise aids in establishing the broader applicability of the findings. Thirdly, the preservation of lucid and transparent documentation pertaining to the research procedure, choices, and constraints facilitates external assessments of the transferability of the results (O'Reilly & Parker, 2013; Morse, 2020). Lastly, researchers should contemplate the transferability of their theoretical framework and conceptual insights, ensuring their alignment with diverse contexts (Nowell et al., 2017). Ultimately, by conscientiously addressing these constituents, researchers amplify the potential for transferability within the outcomes of their qualitative research study (Morse, 2020; Shambare et al., 2022c).

Transferability is assessed by "examining the comprehensiveness of the descriptions incorporated in the study, as well as the level of detail presented regarding the context in which the study transpired" (Kesavan, 2021, p. 24). Given that the reader of this thesis assumes the responsibility of evaluating transferability, "elaborate and densely detailed depictions empower the reader to formulate judgments about participant resemblance... as well as other attributes of the research site and their own site" (O'Kane, Smith & Lerman, 2021, p. 76). In the context of this thesis, transferability is not preoccupied with whether the study encompassed a representative sample; instead, it pertains to "how effectively the study has enabled readers to determine the feasibility of analogous processes" within their own settings (O'Kane et al., 2021, p. 77). Within this study, endeavors were undertaken to ensure transferability by adopting research methodologies previously employed in similar studies. This underscores the potential for a related study to be conducted in the future.

4.8.2 Dependability

Dependability in research refers to the quality and consistency of findings, methods, and interpretations throughout a study (Smith & Johnson, 2018). It encompasses the reliability and trustworthiness of the research process, ensuring that the study's results can be replicated and verified by other researchers (Jones et al., 2020). Achieving dependability involves maintaining rigorous and systematic data collection and analysis procedures (Brown & White, 2019; Simuja & Silvanus, 2023), minimizing bias and errors (Garcia & Martinez, 2017), and providing clear documentation of every step taken (Robinson, 2021). A dependable research study contributes to the credibility of the research field by offering results that can be confidently used as a basis for further analysis, decision-making, and building upon in future investigations (Thompson et al., 2022). The aim of dependability in research is to establish a solid foundation of reliability and consistency throughout the entire research process (Miller & Davis, 2016). This ensures that the methods, data collection, analysis, and interpretations are rigorous and trustworthy (Chen & Lee, 2019). By achieving dependability, researchers strive to produce findings that can be replicated, validated, and confidently used by other researchers, decision-makers, and practitioners (Brown et al., 2021), ultimately contributing to the credibility and advancement of knowledge within the field (Williams & Smith, 2020).

In the context of this study regarding the integration of technology in teaching mathematics to develop TPACK, ensuring dependability is crucial for maintaining the credibility and reliability of the study's findings. To achieve dependability, the researcher needs to employ consistent and well-defined research procedures throughout the study, from data collection to analysis, to enhance the study's reliability (Nassaji, 2020). Regularly reviewing and updating the research design to accommodate any changes or unexpected circumstances that may arise during the study further bolsters the dependability of the research process (Connaway & Powell, 2010). By implementing these strategies, the research study can establish a strong foundation of dependability, ensuring that its results are trustworthy and valuable for academics and practitioners in technology-integrated mathematics education (Robinson, 2021).

4.8.3 Confirmability

Confirmability is a vital concept within the realm of research methodology, particularly in

qualitative research paradigms (Ramani, & Mann, 2016). It refers to the degree of objectivity, neutrality, and dependability of the findings and interpretations derived from a study (Zohrabi, 2013). In other words, confirmability in research signifies the extent to which the data collected, analysis performed, and conclusions drawn are free from the researcher's bias or undue influence (Yilmaz, 2013). To enhance confirmability, researchers often employ systematic and transparent processes such as maintaining an audit trail of decision-making, engaging in peer debriefing or member checking, and employing multiple researchers or coders to assess and validate the interpretations (Klenke, 2016). By addressing confirmability, researchers aim to establish the credibility and trustworthiness of their findings, promoting the idea that their research outcomes are grounded in the data itself rather than being a reflection of personal predispositions or preconceived notions (Wesley, 2010). Confirmability is a crucial concept within the realm of research, particularly in qualitative studies, where subjectivity and interpretation play a significant role (Wahyuni, 2012). It refers to the degree to which the findings of a study are grounded in the data collected and the interpretations made, rather than being influenced by the biases, values, or perspectives of the researcher. In essence, confirmability ensures that the research outcomes are reliable and trustworthy, as they can be independently verified by others (Tolley, Ulin, Mack, Robinson, & Succop, 2016). By maintaining a transparent and systematic audit trail that documents the research process, decisions, and reflections, researchers enhance the confirmability of their work (Anney, 2014). This not only adds rigor to the research but also allows for potential replication and validation by peers, contributing to the overall credibility of the study's results (Forstmeier, Wagenmakers, & Parker, 2017). Ultimately, confirmability strengthens the validity of research by minimizing the potential impact of researcher bias and subjectivity, fostering confidence in the conclusions drawn from the data (Roller, & Lavrakas, 2015).

In this study, the utilization of interviews served as a robust method for data collection. The interviews were carried out in a one-on-one setting between the researcher and the respondent, making it one of the most potent data collection approaches (Creswell, 2014). Throughout the face-to-face interviews, the researcher ensured the display of respect towards the participants. For instance, the researcher maintained a certain distance to demonstrate regard for the respondents' personal space. Moreover, the researcher sought permission to employ a tape recorder during all interviews. Furthermore, transcripts of the interviews were submitted for member checking.

4.8.4 Validity and Trustworthiness

Validity is one crucial aspect of research that looks at how accurate and credible the research findings are (Creswell, 2014). Other definitions state that validity is the extent to which interpretations of data are warranted by the theories and evidence used (Ary et al., 2002, p. 267). The use of different data collection techniques enhances validity and trustworthiness. Validity and trustworthiness play pivotal roles in assessing the quality and reliability of a study's findings (Zhang, Jun & Palacios, 2023). In addition, validity is how we know that the data we collect is believable, accurate and appropriate. The data collection instruments were piloted beforehand to ensure their validity. According to Bertram and Christiansen (2015), piloting refers to the testing of instruments before they are used. The reason is to check if they will give the results that they are intended to give. It provides an ample chance to make changes to the questions that are to be asked so that the participants answer the research questions. Trustworthiness, on the other hand, relates to the credibility and dependability of the research. Internal validity concerns the extent to which a causal relationship can be established between variables, and it relies on proper experimental design and control (Abowitz & Toole, 2010). Reliability, an essential component of trustworthiness, involves the consistency and repeatability of study results over time and across different conditions Lakshmi, & Mohideen, 2013. Researchers enhance trustworthiness by employing rigorous research methods, transparently documenting procedures, and acknowledging potential biases (Rodham, Fox & Doran, 2015).

During this study, various data collection techniques were used to allow triangulation. Triangulation was used, involving two or more methods of data collection in the study of the same aspect of human behavior (Cohen, 2018). The researcher obtained a research permit from the participants and a permission letter from the Omusati region educational office. The researcher followed and adhered to the terms and conditions stipulated in the permission letters received by every school principal and the participants of the designated primary schools within the Okahao Circuit. Validity was further established by presenting the study findings at SAARMSTE colloquiums. Additionally, one paper has been submitted to the AER journal and is currently under review. (See Appendix B, C, and D)

3.8 Ethical Considerations

Ethical considerations in a study refer to the careful and responsible examination of the moral implications and potential impacts of research activities on participants, stakeholders, and society as a whole (Resnik, 2015). These considerations ensure that research is conducted in an ethical and responsible manner, with a focus on protecting the rights, well-being, and dignity of all individuals involved (Beauchamp & Childress, 2013). Ethical considerations are vital to maintaining the integrity and credibility of research, fostering trust between researchers and participants, and upholding ethical standards within the scientific community (Bromley, Mikesell, Jones & Khodyakov, 2015).

Ethical considerations help the researcher to ensure that; participants are fully informed about the nature of the study, its purpose, potential risks, and benefits before they agree to participate (Fouka & Mantzorou, 2011); Participants should be able to make an informed decision based on this information (Mikkelsen, Gjerris, Waldemar, & Sandøe, 2019); Safeguarding the privacy of participants by keeping their personal information and responses confidential (Lloyd-Richardson, Lewis, Whitlock, Rodham, & Schatten, 2015).

3.9 Summary of the chapter

The study aimed to explore how senior primary school teachers develop their Technological Pedagogical Content Knowledge (TPACK) when integrating technology into the teaching of mathematics. Specifically focusing on senior primary school mathematics teachers at the primary level, the research sought to unravel the nuanced dimensions of TPACK development resulting from technology integration. Employing a comprehensive array of data collection methods, including questionnaires, semi- structured interviews, observations, and focus group interviews, the study aimed to capture a holistic understanding of the multifaceted facets of TPACK. These diverse methods were strategically employed to address various aspects of TPACK, shedding light on the intricate interplay between technological knowledge, pedagogical expertise, and content knowledge within the context of mathematics education. The study aimed to offer insights into the impact of technology integration on the intricate dynamics of TPACK development among the participating senior primary school mathematics teachers.

Furthermore, the rationale for selecting a deliberate sample of thirty-five (35) participants from the population of senior primary school teachers in the education circuit was elucidated. The process of data collection and analysis was detailed, emphasizing the generation of codes and the discovery of themes. These identified themes serve as the foundation for the empirical findings, expounded upon in Chapter 4. Measures taken to ensure the credibility of the study were delineated, highlighting the significance of methodological triangulation and member checks. The researcher's role as an insider was disclosed, along with efforts to mitigate subjectivity and bias through verification and reliability checks. In conclusion, ethical considerations were addressed, including the acquisition of ethical clearance and the safeguarding of participants' well-being, confidentiality, and anonymity. Following this chapter is Chapter 4, where the gathered data is presented in alignment with the research questions, employing the techniques discussed in this chapter.

CHAPTER FOUR: EMPIRICAL FINDINGS

4.1 Introduction

Chapter 3 outlines the research methodology, with a focus on research design, data collection methods (semi-structured questionnaire, semi-structured interviews, observation, and focus group interviews), and ethical considerations. This chapter presents the findings and analysis of the study objectively, specifically regarding teachers' development of TPACK in the integration of technology during mathematics classroom teaching. The exploration aimed to provide the researcher with insights into the development of TPACK among senior primary mathematics teachers involved in the study. Information pertaining to teachers' integration of technology, their TPACK development, and challenges in technology integration was gathered through various data collection techniques, including semi-structured questionnaires, semi-structured interviews, focus group interviews, and classroom observation.

The data outlined in this chapter was collected through two distinct phases, as elaborated below:

First Phase

During this phase, the researcher gathered data collected from questionnaires. During the initial phase of the study, the researcher conscientiously collected vital data through meticulously crafted questionnaires. This crucial step in this study involved the creation of comprehensive questions tailored to extract teachers insights (see Section 3.5.1).

Second Phase

During this phase, the researcher gathered data through semi-structured interviews and observation which allowed more exploration of research questions. In the following stage of this research endeavor, after a meticulous examination of the gathered questionnaires, the investigator conducted a series of extensive research interviews. These interviews included both one-on-one sessions (see Section 3.5.2) and focus group interviews (see Section 3.5.4). This multifaceted approach enabled a deeper exploration of the research questions, facilitating a comprehensive grasp of the underlying intricacies and viewpoints. More so, the researcher triangulated the data collection at this phase by observing classroom teacher integration of technology (see Section 3.6.1)

In this chapter, a structured approach is adopted, organizing it into distinct sections. The initial

section, Section 4.1, functions as the chapter's introduction. It includes a recap of the preceding chapter, outlines the stages of the study, addresses the research questions, and provides background information about the participants. The subsequent sections, labeled 4.2 through 4.8, cover various aspects: Teachers self description of technology integration in teaching mathematics, Technology integrated during teaching and learning of mathematics, Use of technology in teaching mathematics, Mathematics teacher self description of their TPACK, Mathematics teachers TPACK development, Challenges experienced by mathematics teachers during technology integration, concluding section participants' background and information

Total number of participants	Gender		Age group range	Area of specialization	Teaching experience (year range)
	Female	Male			
	27	16	11	28-55	Mathematics

Table 4.1: presents the participants' background profiles

Research questions:

Chapter 1 introduced the main research question of this study, which is:

How do senior primary school mathematics teachers in Okahao education circuit develop their TPACK as they integrate technology in the mathematics classroom?

And the sub-research questions are:

RQ1: How do senior primary school mathematics teachers describe their ways of integrating technology in Okahao education circuit?

RQ2: How do senior primary school mathematics teachers describe their technological pedagogical content knowledge Okahao education circuit?

RQ3: What challenges do mathematics teachers have as they integrate technology and develop

technological pedagogical content knowledge Okahao education circuit?

To address research question 1, this chapter provides insights into the incorporation of technology by senior primary school teachers when teaching mathematics. It examines the available facilities in schools, the devices utilized for teaching and learning in mathematics, and the technologies employed to convey mathematical content to learners. Additionally, the chapter offers a concise overview of the methods of teaching and communication, whether utilizing technology or not, in the context of mathematics instruction. To tackle research question 2, the chapter delves into the development of teachers' Technological Pedagogical Content Knowledge (TPACK) during the integration of technology in the mathematics classroom. Lastly, in response to research question 3, the chapter explores the challenges experienced by mathematics teachers as they endeavor to incorporate technology in order to enhance their technological pedagogical content knowledge.

The study involved 27 senior primary school teachers, and in order to safeguard their privacy and uphold ethical standards, participants were assigned numbers and categorized based on their chosen research methods. All quotations from participants are presented verbatim, including any language-related issues like grammar, code switching, or word repetition. This approach ensures that the responses retain their original meaning, and for clarity and understanding, code switched words are annotated in brackets following each instance.

RQ1: How do senior primary school mathematics teachers describe their ways of integrating technology in Okahao education circuit?

In the initial phase of the study, participants who responded to the questionnaire reported that they have been incorporating technology into their mathematics teaching ever since the introduction of ICT policy in the curriculum. They also outlined the various technological tools they employ for teaching and assessing learning in mathematics, highlighting how they enhance both their teaching methods and their students' learning experiences. The table below illustrates the most commonly used and less frequently employed information and communication technologies (ICT) for teaching and assessing learning in mathematics.

Common used ICT	Less used ICT
• Computers • Internet • YouTube • WhatsApp • Mobile smartphones • Laptops • Radio • Facebook	• Skype • Google Meet • Ms team • Interactive White Board • Wechat • Zoom InstagramTiktok

Table 4.2 List of ICT used by the selected participant

The list of ICT in Table 4.2 is not exhaustive; however, it does indicate the common technologies used by mathematics teachers during teaching and learning even if some are only used on special occasions. Specifically, more participants indicated using laptops, radio and mobile smartphones. Another commonly used ICT mentioned by participants was the WhatsApp application. Similarly, participants also listed YouTube content and the Internet as their most commonly used ICT.

4.2 Senior primary school teachers' perception on the use and integration of technology in teaching mathematics

To answer the main question about how senior primary teachers integrate technology in teaching mathematics, participants were asked questionnaires, interviews and observations about their integrating technology in teaching and learning mathematics. All participants indicated their perception on technology integration in teaching mathematics. This informs the researcher that teachers have both positive and negative perceptions of technology integration in teaching mathematics. The table below indicates teachers' perception towards technology integration

Statements on perception towards the integration of technology	Yes %	No %
ICT is considered a priority for use in teaching mathematics	77	33
My school has access to digital teaching and learning tools	60	40
There is enough time to prepare lessons that incorporate ICT	65	35
I received training in technology integration	55	45

Table 4.3 Teachers Perception towards technology integration

Technology is a valuable tool for enriching teaching mathematics (Angeli & Valanides, 2009). A significant number of participants expressed positive perceptions regarding technology integration, emphasizing its significance and its facilitative role in teaching and learning. However, a minority of participants conveyed negative perceptions regarding the integration of technology. The interviews served as a platform for participants to articulate their perspectives on the importance of technology and its contributions to the teaching and learning processes. Notably, during the interviews, SS11 and SS13 elaborated on their views:

“Technology tools like graphing calculators, dynamic geometry software, and 3D modeling programs can help students visualize mathematical concepts, leading to deeper understanding”. (SS11)

“Technology can streamline administrative tasks for teachers, such as grading and record-keeping. It also allows for more immediate and detailed feedback to students”. (SS13)

SSI5 further explains the positive views on technology integration:

“Technology can help bridge gaps in access to resources, especially for students in underserved areas or those with disabilities. It can provide opportunities for remote or

asynchronous learning”.

SSI2 and SSI4 expressed a negative perception of technology integration in teaching mathematics. They explained that technology could result in passive learning or divert students' attention from developing crucial problem-solving skills on paper.

“When technology is integrated some students might become overly reliant on technology for visualization and struggle with manual methods when necessary”. (SS12)

“I have concerns about the digital tools. Not all students have equal access to technology, which may lead some teachers to be cautious about relying too heavily on digital tools”. (SS14)

During the interview, participants were asked to describe their initial experiences teaching mathematics with the use of technology. They explained that working with technology for the first time was hectic and challenging; however, as time passed, it became easier and more successful. This finding is in line with a study conducted by Ertmer (1999), which explored teachers' experiences with integrating technology into their teaching practices. Many participants in the study reported feeling overwhelmed and challenged when first incorporating technology into their teaching. They described their initial experiences as hectic and indicated that they faced various obstacles, such as technical difficulties and lack of familiarity with technology tools. SSI1, SSI2, and SSI3 shared their first-hand experiences with implementing technology. SSI1 expressed:

"At first, I was a bit uneasy because I felt like I was starting from scratch. I had developed numerous activities and lessons over the years, so now I had to introduce technology into my classroom and use it for teaching. I was genuinely uneasy about that. I didn't receive much guidance regarding technology integration. However, I persisted until I became accustomed, and that's when I took it upon myself to learn these things".

Some participants relied on a trial-and-error approach and experimentation when it came to integrating technology in their classrooms. This method afforded them the chance to try out technologies in the familiar setting of their own classrooms and refine their methods through

learning from their mistakes. SSI4 recalled how valuable the support from his colleague was in learning how to effectively use the laptop in his classroom. When he initially began incorporating the laptop, he had a younger colleague who had recently graduated from university, and she provided mentorship on technology usage.

This interaction allowed him to become proficient in technology integration. He emphasized that the support from his colleague, though he was initially nervous, greatly aided him in implementing technology in the classroom. For instance SSI4 said:

“A colleague gave me support until I found myself at the level of making a choice to integrate either educational math games or simulations into my lessons. I became fluent in utilizing interactive online platforms that enabled students to engage with math concepts in an enjoyable manner”.

Participants were then asked a follow-up question to share their experiences regarding how they integrate technology in teaching mathematics. Participants SSI2 and SSI3 explained:

"I created educational videos for my students to view at their own speed, which opened up class time for interactive activities and problem-solving sessions. I employed platforms for assigning homework, quizzes, and offering extra resources. This approach enabled me to customize my teaching to meet the unique needs of each learner and cultivate a more interactive learning atmosphere". (SSI2)

"I use technology in various ways such as; in lesson preparation, in lesson presentation, creating activities as well as creating teaching aids". (SSI3)

During the interview, participants were asked to describe the significant changes that have occurred in teaching with technology over the years. They pointed out that the integration of technology has led to a substantial transformation in the educational landscape. In the beginning, technology was limited to basic tools like projectors and calculators, offering supplementary support to traditional teaching methods. However, with the emergence of mobile phones, the internet, and digital devices, the role of technology in education has expanded exponentially.

Online learning platforms have revolutionized lessons, making them more engaging and dynamic. Furthermore, the proliferation of educational software, apps, and virtual reality has turned the classroom into an immersive learning environment, catering to various learning styles and providing access to a vast array of educational resources. Participants also noted that technology integration has facilitated after-school learning, making education more accessible worldwide. Consequently, teachers now have the ability to customize instruction, monitor student progress, and facilitate collaborative learning experiences, ushering in an era of education that is more adaptable, inclusive, and effective.

Modern mathematics games leverage technology to create interactive simulations, puzzles, and challenges that help students develop mathematical skills and concepts in a dynamic and enjoyable manner (Papastergiou, 2009). Most participants noted that the integration of mathematics games in teaching has evolved significantly over the years, progressing from rudimentary tools to sophisticated, interactive platforms. Initially, mathematics games were confined to physical board games or uncomplicated computer programs with basic arithmetic challenges. However, with advancements in technology, particularly the widespread use of smartphones, tablets, and educational software, the landscape has undergone a transformation. FGI5 underscores that:

"Now, math games manifest in various forms, ranging from immersive virtual reality experiences to adaptive apps that cater to individual learning levels, these games frequently integrate elements of gamification, providing rewards, tracking progress, and introducing competitive elements to motivate students, moreover, they furnish instantaneous feedback, enabling learners to grasp and rectify their errors in real-time, the incorporation of math games has not only rendered learning more engaging and enjoyable but also cultivated critical thinking and problem-solving skills, this shift towards interactive, technology-driven math games signifies a substantial enhancement in how mathematical concepts are conveyed and assimilated in educational settings".

The use of WhatsApp has led to a surge in the availability and diversity of educational content, as digital connectivity continues to expand and messaging apps become more prevalent (de Laat 2012). Educators are increasingly leveraging these platforms to share resources and enhance

teaching and learning experiences (Hodges et al., 2016). During the study, most participants expressed that, the use of educational materials downloaded from WhatsApp groups has seen a transformative evolution. Initially, these resources were confined to text-based documents or links to websites, typically circulated within small, localized communities. However, with the rapid expansion of digital connectivity and the surging popularity of messaging platforms like WhatsApp, the availability and diversity of educational content have surged. Presently, educators can tap into a broad spectrum of multimedia resources, encompassing videos, interactive presentations, and even virtual simulations, all conveniently shared through these channels. This has democratized the availability of high-quality educational materials, dismantling geographical barriers and granting access to a global audience.

4.3 Technology integrated during teaching and learning of mathematics

4.3.1 Most Common Technology available in the selected schools

The role of technology facilities is pivotal in enhancing mathematics education (Drijvers, 2015; Thomasian, 2011). These facilities encompass a wide array of tools and materials that have the potential to heighten student engagement, improve accessibility, and increase the subject's relevance (Attard & Holmes, 2022; Qadir, 2023). In an attempt to find out the type of technologies available at schools, participants who responded to questionnaires were asked to indicate the type of technologies that are available at their respective schools. The conclusive data from the questionnaire indicates that participants affirmed the presence of such technological facilities within their schools. It is noteworthy that a shortage of computer laboratory rooms was observed in nearly all schools within the Okahao circuit. However, computers or laptops are accessible in many schools, and almost every school is connected to the internet. The availability of ICT facilities at schools was also important as it could indicate that the teachers were acquainted with the use of technology (Technological Knowledge). This also reflects the government's concerted efforts to equip rural schools with the necessary technology for effective teaching and learning (Waiganjo & Paxula, 2020).

During interviews, some participants indicated that they don't have a computer laboratory at their schools, but they do have enough computers/laptops available. SS11 explained that:

"While we lack a dedicated computer laboratory, we do have computers/laptops available,

they are stored in the staff room and some in the principal's office, and nevertheless, if I wish to use any tools during a lesson, I can bring them to the classroom".

FGI3 further expressed:

"I have my own personal laptop, which was provided to me during ICDL courses".

Figure 4.1 below shows the summaries of the type of facilities available in participants' schools.

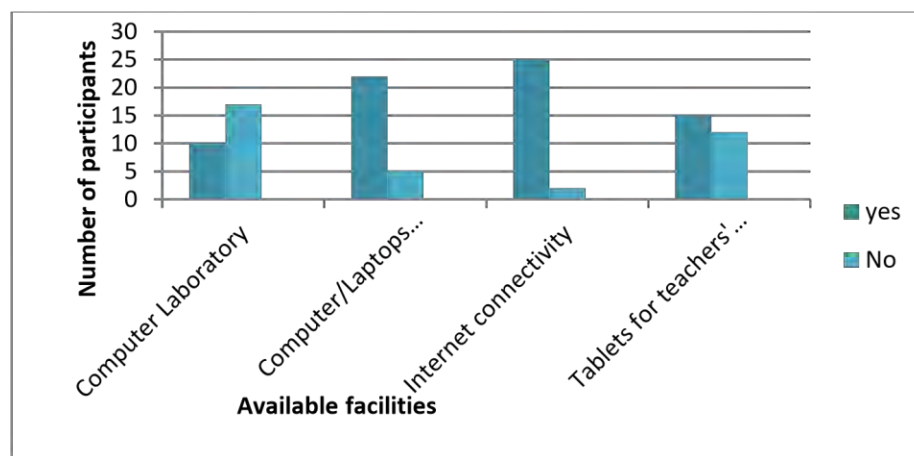


Figure 4.1: Facilities available at schools

The responses from the questionnaire reveal that 10 teachers indicated their schools have computer laboratories, while a large group of 17 participants reported the absence of such facilities in their schools. The majority (22 participants) stated that they were provided with computers and/or laptops for teaching and learning purposes. Almost all teachers (25 participants) indicated that their schools have internet connectivity. On average, 14 participants reported using tablets for teaching and learning purposes, while 13 participants did not have access to tablets for teachers' use.

It was observed that computers and laptops were available for teachers to use in teaching and learning mathematics during classroom observations. Similarly, participants in the focus group discussion mentioned that they frequently utilized their mobile phones and laptops with internet

access as primary ICT tools. Throughout the interview, they emphasized the significance of the Internet in contemporary teaching, acknowledging its vital role in the field of mathematics education. FGI2 and FGI4 expressed:

“I have discovered that having internet connectivity on all my devices significantly enhances my teaching. It allows me to download videos and search for other relevant teaching materials when my devices are connected to the internet”. (FGI2)

“I used to connect my smartphone and laptop to the internet to download various mathematics apps”. (FGI4)

4.2 Technological tools used in teaching and assessment of learning in

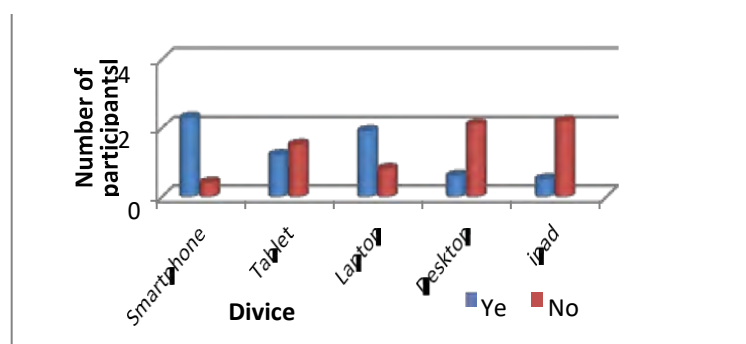


Figure 4.2: shows the technological devices used during teaching and assessment of learning in mathematics

Integrating technology devices into mathematics education holds significant importance in contemporary schooling. These tools provide dynamic and interactive platforms that effectively engage students at various levels, making abstract mathematical concepts more tangible and relatable (Velichova, 2011; Attard & Holmes, 2022). Technology empowers educators to offer visual representations, simulations, and real-world applications, thereby enhancing students' comprehension and retention of mathematical principles (Leighton & Crompton, 2017; Papanastasiou et al., 2019; Allayarova, 2023). In the semi-structured questionnaire, participants were asked about the use of technologies for teaching and assessing mathematics. Regarding the information provided about the availability of facilities during questionnaire. It was evident that the government made efforts to equip schools in the circuit with technological facilities. However, in terms of the utilization some of these available devices, the study reveals that some

are not being used for teaching and learning mathematics, despite being accessible in certain schools.

A significant number of 23 participants in the circuit reported using personal smartphones for teaching and learning mathematics, while only 4 participants indicated not using smartphones. Additionally, 12 participants indicated using tablets. Furthermore, 19 participants reported using laptops, while 8 participants did not use them. The study revealed that a small number of 6 participants used desktops, whereas a large number of 21 participants did not use them. Additionally, the findings indicated that only 5 participants used iPads, with the majority of 22 participants not employing them in the teaching and learning of mathematics.

During the interview sessions, some participants specified smartphones as the technology they use for teaching and learning mathematics. Some participants indicated that they have been using their smartphones because they are accessible anytime, everywhere, and easy to use. SSI5 expressed:

“I have been using my smartphone to download various materials related to mathematics, and then I print them out to use during mathematics lessons because it is easy for me to operate”.

Participants SSI1, SSI3, and SSI6 expressed that they use laptops for teaching and learning mathematics. They find them easily accessible, portable, and readily available at their schools. Additionally, teachers utilize laptops after school and at home to prepare lessons for the following day.

“I take my laptop home after school to prepare my lessons, and it's also the one I use for my teaching presentations. I simply connect it to the projector during the lesson”. (SSI3)

4.3.3 Technological tools employed to deliver mathematical content to learners during mathematics teaching.

In another section of the semi-structured questionnaires, participants were prompted to specify the types of technological tools and software they use in the process of teaching and learning

mathematics. They were provided with a five-point scale, ranging from 'always' to 'not at all,' to self-assess their usage. The results from the 27 participants are presented in the following.

Technologies	Always	Often	Some times	Lesser extent	Not at all
Blackboard collaborate	1	1	3	2	20
Zoom	0	0	1	1	25
Watsap group	0	2	8	6	11
Facebook group	1	4	5	5	13
SMS	0	3	4	2	18
Radio	0	2	8	7	10
Telephone	0	0	1	1	25
Television program	0	3	2	3	19
Telegram	0	0	0	1	26
Instagram	0	0	1	1	25
Email	0	0	1	0	26
Skype	0	0	1	1	25
Google meet	0	1	1	0	25
Ms Team	0	0	0	1	26
Twitter	0	0	0	1	26
Tiktok	0	1	0	2	24
weChat	0	0	1	0	26

Table 4.4: shows technological tools and software used in teaching and learning mathematics

The findings indicated that all 27 participants used various technological applications in their teaching of mathematics. Table 4.2 shows that certain applications were used by only one participant for teaching and learning mathematics. These applications include Telegram, Email, Microsoft Teams, Twitter, and WeChat. A small number of participants (two teachers per application) indicated usage of Zoom, Telephone, Instagram, Skype, and Google Meet. Additionally, three participants use TikTok. Seven participants indicated using Blackboard and Television, with eight participants. The most commonly used applications were WhatsApp, with 16 participants, Facebook with 14 participants, and Radio with 18 participants.

4.4 Use of technology in teaching mathematics

During the study, participants were requested to provide information regarding the integration of technology in teaching and learning mathematics. This information was collected through semi-structured questionnaires, interviews, and observations. The findings from mathematics teachers show a positive attitude toward the use of technology in mathematics. Additionally, it demonstrates that teachers integrate various technological devices into their teaching and learning of mathematics. These findings align with those of the study conducted by Johnson et al. (2018), which demonstrated a positive attitude toward the use of technology in mathematics education. Furthermore, the study findings are consistent with those of Lee and Smith (2021), who found that teachers integrate various technological devices into their teaching and learning of mathematics.

4.4.1 The use of WhatsApp groups and Facebook groups in teaching and learning mathematics

Information regarding the technologies employed in teaching and learning mathematics was gathered from participants through semi-structured questionnaires, interviews, and observations. The questionnaires revealed that the majority of participants reported frequent use of WhatsApp and Facebook. Similarly, during the focus group interviews and individual interviews, participants were asked to mention the technologies they

utilized in teaching mathematics, with the majority indicating WhatsApp and Facebook. These findings align with similar trends observed in studies by Naidoo & Kopung (2020), Durgungoz & Durgungoz (2022), and Garcia & Martinez (2023), where educators also emphasized the prevalent use of social media platforms like WhatsApp and Facebook in their mathematics instruction. This suggests a consistent pattern of utilizing WhatsApp and Facebook in teaching mathematics.

FGI2 mentioned:

“I use WhatsApp often in my teaching. I use it to communicate with my learners outside of class, address their questions, and provide them with additional resources”.

Furthermore, FGI3 elaborated on how he utilizes WhatsApp in his teaching and learning process.

“I use WhatsApp to share information with my learners about the learning of mathematics, such as activities and notes on the WhatsApp group”. (FGI3)

FGI4 and FGI6 both mentioned employing a Facebook group for teaching and learning mathematics with their students. They mentioned that they established a Facebook page to share information related to mathematics education. They pointed out that Facebook is user-friendly and easily accessible on any smartphone with proper login credentials.

FGI6 emphasized that:

“I used to share videos and presentations on the Facebook group, displaying mathematical content”.

FGI1 also supported the ideas for FGI2 and FGI3.

“I exclusively use WhatsApp groups to download videos that have been previously shared by fellow educators. I then present these videos to my learners during mathematics lessons”. (FGI1)

In a concise overview of how participants incorporated technology in teaching and communication with learners in the context of mathematics. FGI2 explained:

“I’ve been using WhatsApp groups to share mathematics-related videos downloaded from platforms like YouTube and TikTok”.

FGI5 provided additional insight into how he employs the Facebook platform for teaching and learning. FGI5 emphasized that:

“I record myself presenting a specific topic and then share it in the Facebook group for my learners to listen to whenever they find it convenient”.

From my observations during the classroom observation, two participants incorporated videos sourced from both Facebook and WhatsApp groups into their lesson introductions. This highlights how these two platforms facilitate teachers in seamlessly integrating multimedia elements into their teaching of mathematics, thereby enhancing the visual and interactive aspects of their lessons. The use of videos from social media platforms not only captures students' attention but also provides real-world examples and applications of mathematical concepts, making the learning experience more engaging and relatable (Nilimaa, 2023). Additionally, the ease of accessing and sharing educational content through these platforms enables teachers to diversify their instructional materials and cater to different learning styles, ultimately enriching the overall learning environment in the mathematics classroom. (Pitler, Hubbell & Kuhn, 2012). From my observations during the classroom observation, two participants incorporated videos sourced from both Facebook and WhatsApp groups into their lesson introductions. This highlights how these two platforms facilitate teachers in seamlessly integrating multimedia elements into their teaching of mathematics.

4.4.2 The use of smart television, radio and blackboard in teaching and learning mathematics

Another significant finding of the study, as observed during interviews and classroom observations, was that some participants utilize radio, smart television, and blackboard for teaching and learning mathematics. They emphasized the importance of incorporating TV and radio programs, as well as the use of blackboards, in teaching and learning mathematics, highlighting their major role in modern teaching methods and their substantial impact on mathematics education. This aligns with the findings of Vorderer, Krömer & Schneider (2016) and Hebebcı, Bertiz & Alan (2020), who also indicated that the majority of their participants revealed that their classrooms are equipped with a Smart Television and blackboard used to display important information to learners. Another study conducted by Olakulehin (2016) and Ayanwale et al., (2023) indicated that teachers utilize radio for playing audio materials for teaching and learning mathematics. This suggests a consistent pattern of utilizing radio, smart television and blackboard in teaching mathematics.

“I have found that using a Smart TV in my classroom has greatly enhanced my teaching, I am able to display and interact with digital content in a way that was not possible with

traditional teaching tools...For example, when teaching geometry, I use the TV to display three-dimensional models of geometric shapes and rotate them in real-time to demonstrate various properties, I also use the TV to display digital textbooks, which allow me to zoom in on specific equations and diagrams, making it easier for students to follow along". (SSI5)

Another significant finding of the study is that the majority of participants (17) identified radio as the most frequently utilized technology in teaching and learning mathematics, as revealed in the questionnaires. Furthermore, during interviews, two participants highlighted radio programs as one of their frequently used ICT tools. They emphasized its accessibility and ability to function without an internet connection. Additionally, they noted that they had been employing radio platforms long before other apps became prevalent in teaching and learning. This finding is consistent with the study by Olakulehin (2016) and Ayanwale et al. (2023), which also emphasized the significant role of radio in mathematics education. Radio stands out as the initial technological tool that teachers have relied on for many years (Na, 2015). For instance, participants SSI2 and SSI6 emphasized the significance of incorporating radio into their classroom teaching. SSI2 expressed that:

"I used radio during the presentation of a mathematics lesson through broadcasted educational programs. These programs are specifically designed to deliver mathematical content in an audio format. I used to tune in to educational channels or programs that focused on mathematical concepts and exercises. This allows students to listen and engage with mathematical content in real-time or on a scheduled basis".

SSI6 further explained that:

"Using radio during a mathematics lesson allows learners to listen and engage with mathematical content in real-time or on a scheduled basis. Radio provides an inclusive learning platform, as it can reach a wide audience, including those without access to the internet or digital devices. It also offers the flexibility to be incorporated into various learning environments, making it a versatile tool for enhancing mathematics education".

Some participants explained during interviews how they integrate Blackboard Collaborate in teaching and learning mathematics. They expressed that the interactive blackboard allows them to illustrate complex concepts in real time, making abstract ideas tangible for their students. Through its collaborative features, they solve problems together, fostering a deeper understanding of the

material. For instance, FGI1 and FGI5 expressed that:

“I found that integrating blackboard into my mathematics classes revolutionized the learning experience. Additionally, the recording feature proved invaluable for students to review lessons at their own pace, ensuring no one was left behind”. (FGI1)

“Blackboard completely transformed the way I approached teaching mathematics. Its intuitive interface empowered me to design visually appealing lessons that catered to diverse learning styles”. (FGI5)

FG4 supported the integration of Blackboard in teaching and learning mathematics. This integration allows for the incorporation of graphs, diagrams, and even simulations, making complex topics more digestible. Moreover, the platform's breakout room functionality facilitated small group discussions, enabling peer learning and problem-solving. Blackboard fostered a collaborative and interactive learning environment, enabling learners to not only grasp mathematical concepts but also apply them effectively. This finding is consistent with the studies by Naidoo & Kopung (2020), Durgungoz & Durgungoz (2022), and Garcia & Martinez (2023), which also emphasized the effective use of digital platforms like Blackboard in mathematics education. It encouraged active participation and engagement, as students could easily share their own work and solutions.

4.4.3 The integration of technology in teaching mathematics involving the use of laptops and computers

During the questionnaire, interview and observation some participants pointed out using computers and laptops in the instruction and learning of mathematics. Participants cited employing this technology to download a range of applications including Facebook, YouTube, Zoom, and other mathematics-related software, which were subsequently employed in the teaching and learning process of mathematics.

Another noteworthy discovery from the study pertains to the participants' conviction regarding the pedagogical efficacy of integrating laptops into the teaching process to enhance the comprehension of mathematical concepts among both teachers and learners. They underscored the importance of

utilizing laptops to deliver instructional content in diverse modalities, recognizing its potential to deepen students' understanding. This finding aligns with the scholarly discourse presented by Kaput et al. (2020) and Şad & Göktaş (2014), which similarly highlight the pivotal role of computers and laptops as valuable resources for teaching mathematics through varied modes of representation. Of particular significance is the perspective shared by Participant SSI1, who elucidated on the versatile instructional approaches facilitated by laptops in her lesson planning. She emphasized the deliberate selection of laptops to teach the concept of three dimensions, seamlessly integrating it with an overhead projector to augment the instructional process. This example underscores the thoughtful consideration given to leveraging technology to enhance the pedagogical delivery of complex mathematical concepts, as elucidated by Participant SSI1.

“I evaluate a concept or topic that requires coverage and determine whether using a laptop is the most effective tool for teaching mathematics”. (SSI1)

SSI2 views the computer as a technological tool that constantly revolutionizes the manner in which mathematics content is delivered to learners. She perceives this as having a positive impact on learner comprehension, suggesting that the versatility of computers and their ability to offer various teaching modes enhance students' understanding and engagement with the content in her classroom. She places emphasis on the potential benefits of integrating computers into teaching practices and underscores the importance of consistently exploring new approaches to presenting information to learners.

SSI3 further stated that:

“I also use the computer to download educational games that help my students practice their math skills in an enjoyable and interactive way. For example, there are various online games downloaded on a computer like Kahoot! that allow my students to work on their multiplication tables or fractions... These games are designed to be interactive and visually engaging, which helps maintain my students' engagement and motivation to learn”.

It was also observed that some participants used a laptop in their classroom presentation. One (1) participant connected the laptop to an overhead projector to teach learners how to draw different

types of angles and how to identify them. Furthermore, in the questionnaire, nineteen participants indicated using computers and laptops. They also provided descriptions of how they utilize them in teaching and communicating with their learners. For instance, QP14 and QP17 indicated that they use computers and laptops to download various apps for teaching and learning mathematics.

“I downloaded Facebook on my laptop.... Currently, I use it to download various mathematics presentations from other educators and incorporate them into my teaching and learning of mathematics”. (QP14)

Another significant finding of the study is the widespread integration of various technologies by mathematics teachers into their classroom instruction. Specifically, WhatsApp groups and Facebook groups emerged as among the most frequently employed tools for facilitating teaching and learning of mathematics. This observation is consistent with the findings of other studies within the same scholarly discourse (Kaput et al., 2020; Şad & Göktaş, 2014), which also highlight the prevalent use of digital platforms like WhatsApp and Facebook in mathematics teaching. Moreover, the study revealed that teachers predominantly utilize technology that is readily available to them, often due to a lack of access to more advanced technological tools. This aspect constitutes a significant challenge encountered by mathematics teachers in their endeavor to effectively teach and learn mathematics, as further explored in research question 3 of the study. This finding underscores the need for addressing issues related to technology accessibility and adequacy in the context of mathematics education, as highlighted by the participants in the study.

RQ2: How do senior primary school mathematics teachers describe their technological pedagogical content knowledge in Okahao education circuit?

Findings for addressing research question 2 were derived from a total of 27 participants in the study. Among them, 27 senior primary mathematics teachers responded to the semi-structured questionnaires. Additionally, a subset of 6 participants was selected from the initial group of 27 respondents who completed the questionnaire and expressed willingness to participate in individual interviews and group discussions. This subset provided valuable insights into their technological pedagogical content knowledge in relation to the integration of technology in teaching mathematics. Furthermore, the study delved deeper with 3 participants who were observed

teaching with technologies and where I observed lessons based on the components of TPACK in the context of technology integration during the teaching of mathematics.

4.5 Assessing Teachers' TPACK Development Levels through Technology Integration in Mathematics Classrooms

4.5.1 Technological knowledge (TK)

Participants who took part in the semi-structured questionnaires were asked to assess their technological knowledge using a four-point scale ranging from "strongly agree" to "disagree." The results are presented in Table 4.3 and Graph 4.3.

Technological knowledge	Strongly Agree %	Agree%	Neutral %	Disagree %
I know how to solve my own technical problems.	16	40	29	15
I can learn technology easily.	20	50	16	14
I keep up with important new technologies.	19	50	12	19
I frequently play around the technology.	20	49	18	13
I know about a lot of different technologies.	17	45	25	13
I have the technical skills I need to use technology.	10	44	30	16

Table 4.5 indicates the rating of technological knowledge of participants

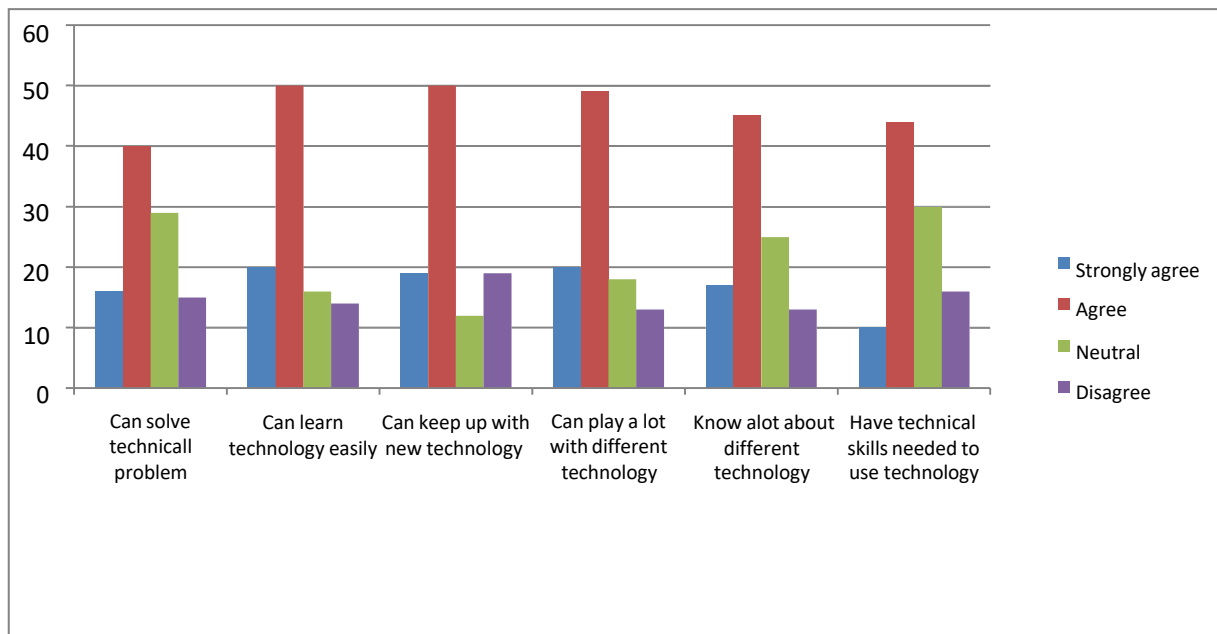


Figure 4.3: demonstrates technological knowledge

Findings from the participants indicate that 16% strongly agree on solving their own technical problems, while 40% of participants agreed. A total of 20% of the participants strongly agree that they are able to learn technology easily, and 50% of participants also indicated agreement on this. Furthermore, 69% indicated that they agreed with using new technology in their teaching of mathematics. Specifically, 20% strongly agreed and 49% agreed on mostly experimenting with technology. All the participants demonstrated a higher percentage of technological knowledge. This clearly indicates that most mathematics teachers possess the knowledge of how to operate various technological tools.

4.5.2 Content knowledge (CK)

Participants who took part in the semi-structured questionnaires were asked to assess their Content knowledge. The results are presented in Table 4.4

Content knowledge	Strongly Agree %	Agree%	Neutral %	Disagree %
I have sufficient knowledge about mathematics subject I teach	45	52	2	1
I can use content in mathematics subject.	50	48	1	1

Table 4.6 indicates the rating of content knowledge for participants

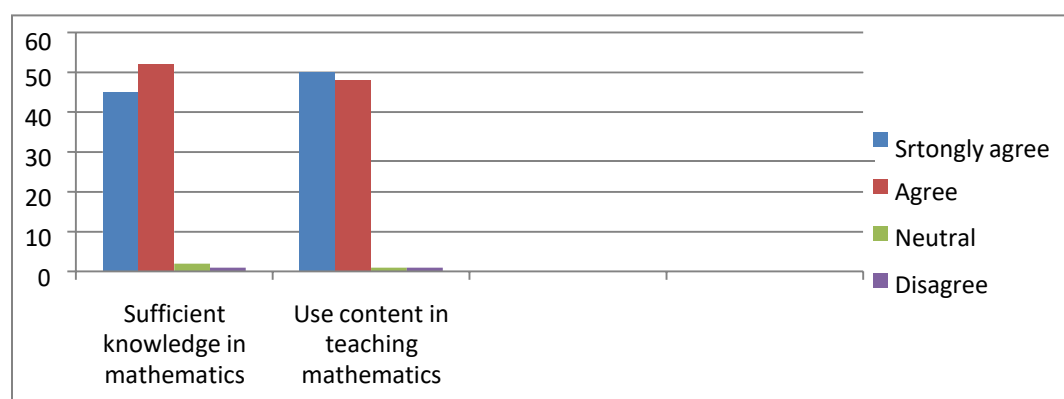


Figure 4.4: demonstrates content knowledge

Content knowledge is one of the components of TPACK that empowers teachers to integrate technology. Participants were asked to assess their content knowledge when incorporating technology in teaching mathematics. A greater number of participants demonstrated strong agreement (54%) and agreement (52%) with having sufficient content knowledge. Additionally, 50% strongly agreed and 48% agreed that they leverage their strong content knowledge in teaching mathematics. This can be attributed to the fact that all participants are certified teachers with three years of experience in teaching mathematics content. Only a small number indicated a neutral or disagreed stance. This finding aligns with studies conducted by Park & Olive (2008), Miranda et al. (2013), and van Driel (2021), which indicated that teachers who have been teaching for a considerable duration possess significant content knowledge, a factor determined by their teaching experiences.

4.5.3 Pedagogical Knowledge (PK)

Participants who took part in the semi-structured questionnaires were asked to assess their pedagogical knowledge. The results are presented in Table 4.5 and Graph 4.5

Pedagogical knowledge	Strongly Agree %	Agree %	Neutral %	Disagree %
I know how to assess student performance in a classroom.	28	68	1	3
I can adapt my teaching based on what students currently understand or do not understand.	29	71	0	4
I can adapt my teaching style to different learners.	28	69	0	3
I can assess student learning in multiple ways	12	79	7	2
I can use a wide range of teaching approaches in a classroom setting.	26	66	5	3
I am familiar with common student understandings and misconceptions.	27	68	2	3
I know how to organize and maintain classroom management.	24	70	1	5

Table 4.7 indicates the rating of pedagogical knowledge for participants

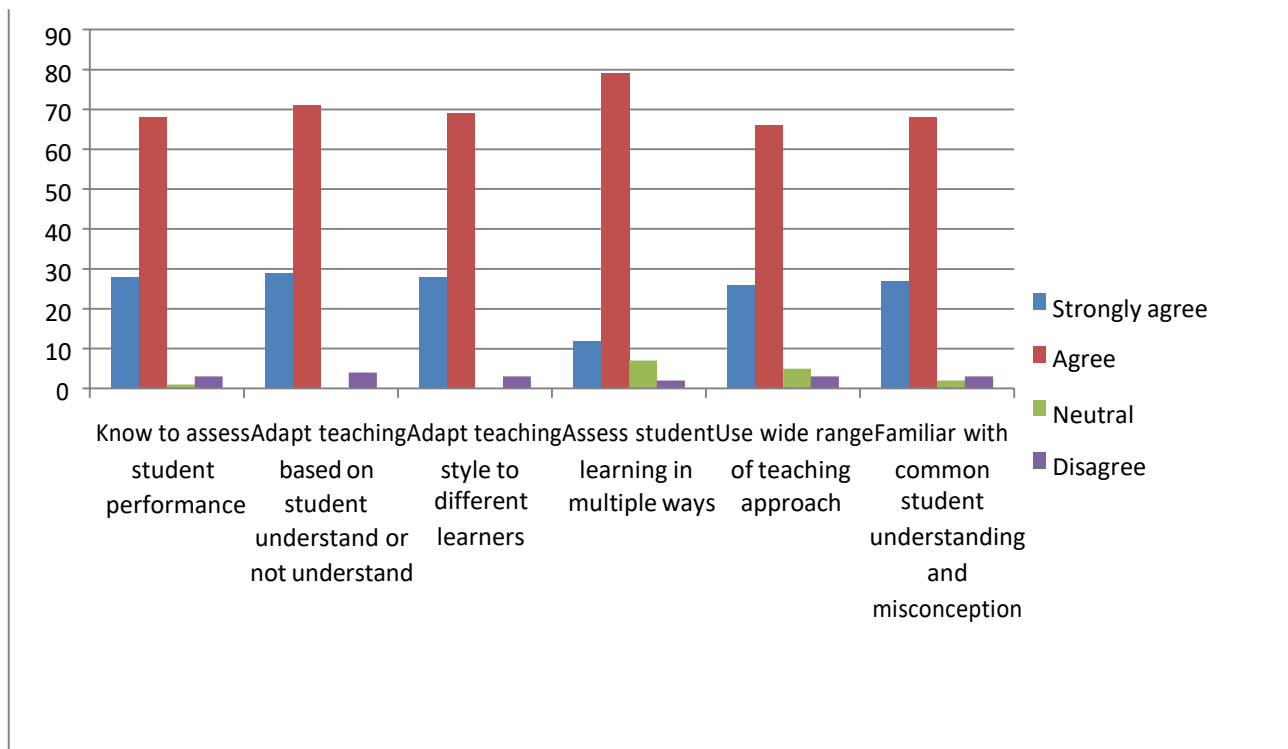


Figure 4.5 demonstrates pedagogical knowledge

The findings from 27 participants on the semi-structured questionnaire indicated that a higher number of participants possess sufficient knowledge in using various methods to teach mathematics. 26% strongly agreed and 68% agreed on assessing learners' performance. Participants also indicated that they consider their learners' level of understanding, with 29% strongly agreeing and 71% agreeing. This demonstrates that teachers include all learners in their teaching, regardless of their learning difficulties. Another significant finding of the study is that 28% strongly agreed and 69% agreed on adapting their teaching style to different learners. This aligns with the overall findings suggesting that teachers utilize appropriate teaching methods when integrating technology in the mathematics classroom. Only a few participants rated themselves as neutral or disagreed. This finding resonates with similar studies conducted by Park & Olive (2008), Miranda et al. (2013), and van Driel (2021), which also highlight the importance of teachers adapting their teaching styles to meet the diverse needs of learners, particularly in the context of technology integration in mathematics education.

4.5.4 Pedagogical Content Knowledge (PCK)

Participants who took part in the semi-structured questionnaires were asked to assess their pedagogical content knowledge. The results are presented in Table 4.6 and Graph 4.6

Pedagogical content knowledge	Strongly Agree %	Agree %	Neutral %	Disagree %
I can select effective teaching approaches to guide student thinking and learning in mathematics subject.	20	76	3	1
I have various ways and strategies for developing mathematics subject content.	18	79	2	1

Table 4.8 indicates the rating of pedagogical content knowledge for participants

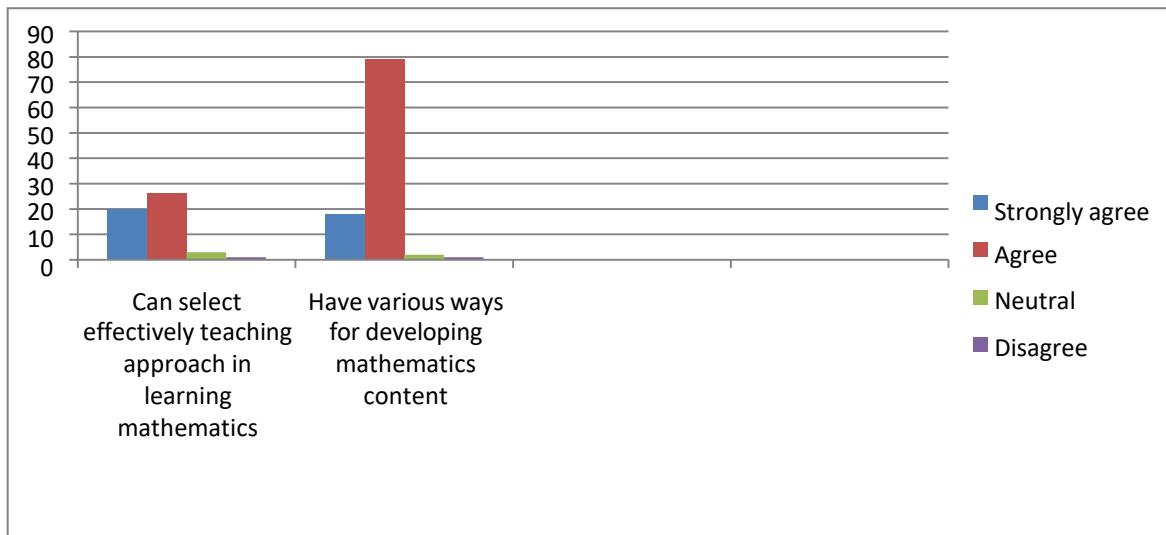


Figure 4.6 demonstrates pedagogical content knowledge

The findings indicated that 20% of participants strongly agreed and 76% agreed that they have a strong knowledge of selecting technology that fits into their teaching of mathematics. A few participants expressed some difficulty in choosing the best technological tools that align with mathematics content.

5.5.5 Technological content knowledge (TCK)

Participants who took part in the semi-structured questionnaires were asked to assess their knowledge of technological content. The results are presented in Table 4.7 and Graph 4.7

Technological content knowledge	Strongly Agree %	Agree %	Neutral %	Disagree %
I know about technologies that I can use for understanding and presenting subject content.	25	59	10	6

Table 4.9 indicates the rating of technological content knowledge for participants



Figure 4.7 demonstrates pedagogical content knowledge

Findings from 27 participants during the semi-structured questionnaires indicated that a larger number of participants are knowledgeable about the technology they can use to understand and present mathematical content. This is demonstrated by 25% strongly agreeing and 59% agreeing, making the total number of participants with this knowledge 84%. The total number of participants who were unaware or lacked knowledge about the technology they could use to present mathematics was only 16%.

4.5.6. Technological pedagogical knowledge (TPK)

Participants who took part in the semi-structured questionnaires were asked to assess their

technological pedagogical knowledge. The results are presented Figure 4.8

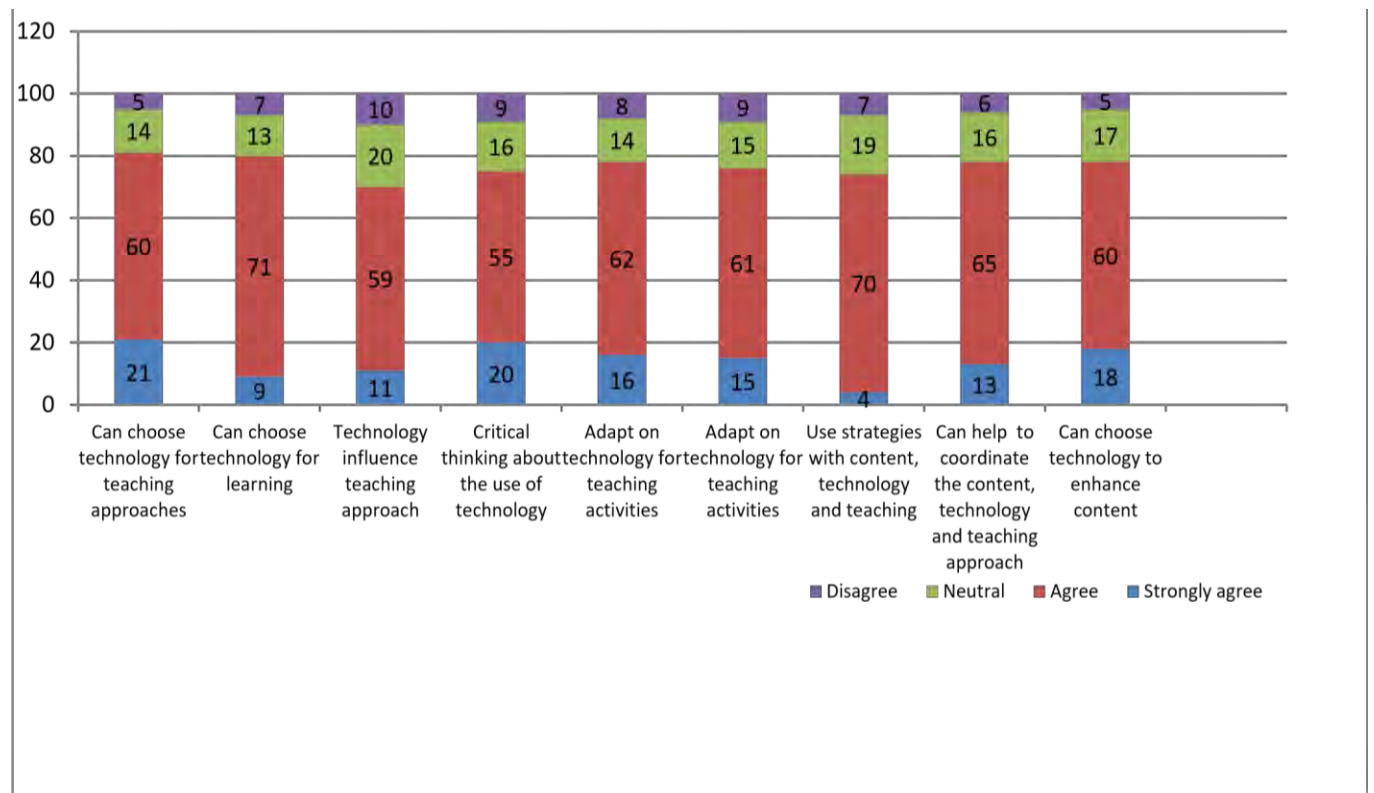


Figure 4.8 demonstrates technological pedagogical knowledge

The data collected indicates that 25% strongly agreed and 59% agreed on having knowledge in selecting technology to enhance the teaching approach for mathematics lessons. Additionally, 9% strongly agreed and 71% of participants agreed on choosing technology to promote learners' learning during mathematics lessons. 14% and 13% were in-between on selecting technology to promote both teaching and learning approaches in mathematics lessons. Moreover, 22% strongly agreed and 55% agreed on considering the use of technology in teaching mathematics. 74% of participants agreed with using different strategies that integrate content, technology, and teaching approaches they have learned in their classrooms. 65% of participants agreed, and 13% strongly agreed, with social interaction by providing leadership in assisting others in the use of both content, technology, and teaching approaches. Lastly, 18% of participants strongly agreed and 60% agreed on selecting the appropriate technological tools to enhance mathematics content during the lesson.

4.5.7. Technological pedagogical and content knowledge (TPACK)

Participants who took part in the semi-structured questionnaires were asked to assess their technological pedagogical and content knowledge. The results are presented in Table 4.9 and Graph 4.9

Technological Pedagogical knowledge and content knowledge	Strongly Agree%	Agree %	Neutral %	Disagree %
I can teach lessons that appropriately combine subject content, technologies, and teaching approaches	13	55	25	7

Table 4.11 indicated the rating of technological pedagogical and content knowledge for participants

Findings from this figure reveal that 13% of participants strongly agreed and 55% agreed with effectively integrating both components of TPACK: content knowledge, technological knowledge, and pedagogical knowledge. Meanwhile, 25% of participants held a neutral stance, and 7% disagreed with both components.

The comprehensive reflection on all aspects of TPACK reveals that, according to the semi structured questionnaire, the majority of mathematics teachers demonstrate a high level of proficiency in CK, TK, PK, TPK, as well as PCK. However, participants display a moderate level of expertise in TCK and TPACK. A few participants disagreed on some other TPACK components. This is due to various factors, including a shortage of technological resources, inadequate technological knowledge, and limited opportunities for professional development (Lux, Bangert & Whittier, 2011; Chai, Koh & Tsai, 2013; Huang, 2022).

4.6 Mathematics teachers TPACK development

TPACK represents the seamless interplay between technological knowledge, pedagogical strategies, and content expertise (Mishra & Koehler, 2006). In the context of mathematics teaching, this means understanding not only the mathematical concepts but also how to convey them effectively through technology-enhanced methods (Niess 2005, 2006, 2008; Niess, Ronau,

Shafer, Driskell, Harper, Johnston & Kersaint, 2009; Chang, Tsai, & Jang, 2014; Tondeur, Siddig & Baran, 2018). This synergy ensures that technology serves as a powerful tool to enhance learning rather than a mere add-on (Nhu, Keong, & Wah, 2018). It enables teachers to select the right tools, align them with the curriculum, and employ appropriate instructional strategies that cater to diverse learning styles (Dorian 2019). When TPACK is well-integrated, it fosters deeper comprehension, engagement, and critical thinking among students, ultimately preparing them for a rapidly evolving, technology-driven world (Mishra & Koehler 2006, 2009).

To further understand the participants' level of TPACK development, a semi-structured interview was conducted. Teachers expressed a keen interest in integrating technology into their mathematics instruction. They conveyed that, through access to and interaction with various technological tools, they had opportunities to enhance their TPACK. The study findings are in line with the study conducted by Mishra and Koehler (2006), which underscores the dynamic nature of TPACK, highlighting that teachers' TPACK evolves through ongoing interactions with technology, pedagogy, and content knowledge. They argue that teachers' experiences with technology in their instructional practices contribute significantly to the development of their TPACK. Similarly, those observed during classroom sessions demonstrated TPACK development while integrating technology into their mathematics teaching. These findings offer promising insights, suggesting that teachers can indeed enhance their TPACK through the integration of technology in their instruction. Both the semi-structured interviews and focus group interviews probed participants with various questions to describe their TPACK development when integrating technology in teaching mathematics. The results indicated that participants develop TPACK during the integration of technology. It is worth noting that all constructs identified in this study were meticulously recorded and analyzed.

Mathematics teachers TPACK development through social interaction

Mathematics teachers have the potential to significantly develop their Technological Pedagogical Content Knowledge (TPACK) through interactions with their colleagues, as collaborative discussions, sharing of experiences, and exchanging innovative teaching practices among peers can contribute to a deeper understanding of how technology can be effectively integrated into mathematics instruction (Mishra & Koehler, 2006; Archambault et al., 2010; Angeli & Valanides, 2009). The study findings indicated that mathematics teachers potentially are developing TPACK

through interaction with their colleagues. This was evident during the focus group discussion when the participants were asked to explain how social interaction with their colleagues, as they integrated technology in their classrooms, assisted in developing TPACK? Participants FGI2, FGI3, and FGI5 responded that:

“Social interaction assisted me in developing TPACK. Sometimes, I used to ask my colleagues, who were more knowledgeable in using technology to observe my lesson when integrating technology, then give me feedback and assist me with my weaknesses”.(FGI2)

“I used to seek help from my colleagues when I am planning to use technological tools. This helps me develop TPACK”. (FGI3)

“My colleagues used to advise me to put more effort into integrating technology into my everyday teaching of mathematics. They assisted me in the use of different technological tools during mathematics classroom teaching”. (FGI5)

Participants demonstrated a keen interest in interacting with their colleagues as they integrated technology into classroom instruction. The study's findings further indicated that participants devoted their free time to discussing and educating each other on how to effectively employ various technological tools in their mathematics teaching. Participant FGI1 explained:

“Initially, I was unsure about how to download different mathematics app. Through a social interaction, a colleague of mine taught me how to do it using my smartphone”.

FGI6 further explained:

“During our time at the university, we didn't receive any training on the use of technology. I began my teaching career without any knowledge of how to integrate technology. It was only through social interactions with colleagues that I started learning how to utilize various technological tools and integrate them into my teaching”.

Meaningful discussions and exchanges of teaching practices within professional learning communities contribute significantly to the development of teachers' pedagogical content knowledge, particularly in the context of technology integration (Archambault et al., 2010). In this section, it became evident that mathematics teachers enhance their Technological Pedagogical

Content Knowledge (TPACK) through meaningful social interactions. This study highlights the diverse nature of these interactions, encompassing collaborative planning sessions, peer observations during classroom instruction, and engaging group discussions focused on the effective integration of technology in teaching practices. Throughout the study, it was also observed that social interaction with colleagues through the use of technology plays a pivotal role in the development of TPACK. Teachers, during interviews, expressed that collaborative digital platforms such as WhatsApp groups facilitate the sharing of diverse perspectives, teaching strategies, and technological tools. This interaction cultivates a rich learning environment where educators exchange innovative ideas and refine their understanding of how to integrate technology effectively into pedagogical practices. Participants also articulated that through social interaction, teachers gain valuable insights into the nuanced relationship between content, pedagogy, and technology. This dynamic exchange not only enhances their proficiency in leveraging digital tools but also strengthens their ability to adapt these resources to specific educational contexts, ultimately fostering a more nuanced and effective approach to teaching and learning.

4.6.1 Mathematics teachers TPACK development through interacting and access with technology

Access to various technologies is crucial in developing teachers' Technological Pedagogical Content Knowledge (TPACK), as it empowers teachers to seamlessly integrate technology into their teaching practices by providing opportunities for experimentation, collaboration, and exploration of innovative instructional strategies (Archambault et al., 2010; Sang et al., 2010; Ertmer et al., 2012). During the study, it was observed that access to various technologies is crucial in developing teachers' Technological Pedagogical Content Knowledge (TPACK), as it empowers teachers to seamlessly integrate technology into their teaching practices. TPACK represents the intersection of technological knowledge, pedagogical knowledge, and content knowledge. Furthermore, it was noted that when teachers have access to a diverse range of technologies, they can explore different tools and platforms that align with their specific subject matter and teaching style. This exposure enables them to experiment, innovate, and discover the most effective ways to convey complex concepts to students. Additionally, a majority of teachers, during interviews, expressed that familiarity with diverse technologies helps them cater to different learning styles and abilities, creating a more inclusive and engaging learning environment. In essence, access to various technologies not only enriches the educational experience but also

equips teachers with the skills and knowledge necessary to navigate the ever-evolving landscape of modern education.

The findings indicated that all schools were equipped with different technological facilities. Participants were asked to specify the available facilities at their schools through a questionnaire, and the study revealed that most schools had a variety of resources. For instance, QP17 and QP19 highlighted that the presence of ICT facilities allowed for the integration of technology in teaching mathematics. QP19 indicated:

“We have a range of different available facilities at our school, and I make sure to incorporate them into my everyday teaching”.

Further insights were gathered during the focus group interviews, where participants were asked about the ways in which access to and interaction with various technological tools created opportunities for them to develop TPACK. They shared diverse perspectives on how access to technological tools facilitated the development of their TPACK. Participants emphasized that the availability of technological tools is a significant contributing factor to the successful integration of technology in teaching mathematics. FGI1, FGI3 and FGI5 expressed:

“The availability of technological tools sparks teachers' interest in integrating technology during mathematics teaching, which, in turn, helps me develop my TPACK”.(FGI1)

“We have various tools such as laptops, computers, and overhead projectors. This enables me to select the most suitable technology that aligns with my lesson content, thus contributing to the development of my TPACK”. (FGI3)

“Access has enabled me to develop my TPACK. I can vividly recall when I started my teaching career over 19 years ago. At our school, there were no technological tools available, and we relied on traditional teaching methods. With the introduction of technological tools, we are now able to teach with technology, greatly simplifying the teaching and learning process”. (FGI5)

The findings also indicated that teachers' interaction with technology enables them to teach lessons

that effectively combine subject content, technology, and teaching methods. Teachers can learn how to integrate technology when they engage with it. Interacting with technological tools encourages and motivates teachers to incorporate technology into their teaching, leading to the development of their TPACK.

FGI4 and FGI6 expressed:

“During my lesson presentations, I am now able to select the available technological tools that best complement the content and pedagogy of the lesson. This approach enables me to develop my TPACK”. (FGI4)

“Interacting with technology has been instrumental in incorporating technological tools into all of my lesson presentations”. (FGI6)

Participants explained that they developed more technological knowledge because they mostly interacted with technology. As they actively engaged with various technological tools in their teaching and learning practices, they gained hands-on experience and familiarity with digital resources and software. However, amidst their increased technological literacy, some participants also raised concerns about outdated technological tools. They emphasized that many of the available technologies no longer align with the current curriculum course line, rendering them ineffective or obsolete in meeting the educational needs and objectives of today's classrooms. This discrepancy between available technology and curriculum requirements underscores the importance of updating and aligning technological resources to ensure they remain relevant and beneficial for teaching and learning in contemporary educational settings. Therefore, they require advanced technological tools such as mathematical learning applications like GeoGebra and other computer software for learning mathematics.

Teachers who had access to a wider range of technological resources demonstrated a higher level of confidence and competence in utilizing technology to support mathematical learning outcomes (Jones & Wang, 2019). This emphasizes the importance of not only the availability but also the variety and quality of technological tools accessible to teachers in fostering the development of their Technological Pedagogical Content Knowledge (TPACK) for effective mathematics teaching (Smith & Clark 2016; Similarly et al., 2018). The findings from this section indicated that most

teachers have access to technological tools at their schools or personal technological tools that they can use in teaching mathematics and developing TPACK.

Interacting with various technologies has opened up abundant opportunities for teachers to enhance their TPACK (Koehler, & Mishra, 2016; Tondeur et al., 2020). By engaging with diverse digital tools, educators gain a deeper understanding of how technology can be effectively integrated into their teaching methods (Tondeur et al., 2020). This hands- on experience allows them to explore innovative ways to present content, engage students, and assess learning outcomes (Nhu et al., 2018). Through experimentation and adaptation, teachers refine their technological proficiency, aligning it with their pedagogical and content knowledge (Niess, 2008; Chang et al., 2014;). This dynamic interaction with technology not only fosters adaptability but also cultivates a more holistic understanding of how to leverage these tools to create enriching learning experiences (Niess et al., 2009). Ultimately, this process empowers educators to navigate the ever-changing educational landscape with confidence and creativity, ensuring that students receive a well-rounded and technologically enriched education (Abbitt, 2011).

4.6.2 Mathematics teacher’s self-reflection on TPACK when integrating technology in their teaching

During the interviews, participants were asked to describe their Technological Pedagogical Content Knowledge (TPACK) through the integration of technology. In the questionnaire, participants were also asked to self-assess their proficiency across all TPACK components. The findings indicated that participants are demonstrating a better development of TPACK when they integrate technology into teaching mathematics. In individual interviews, participants were asked to pinpoint the specific TPACK knowledge that resonates with the ways they integrate technology in teaching mathematics. Teachers were able to identify various constructs of this knowledge.

Table 4.12 shows different TPACK constructs that resonate with the ways the selected mathematics teachers integrate technology in teaching mathematics.

Participants	TPACK constructs
S11	TK, TPK

SI2	TK, TCK,TPK
SI3	TK, TCK
SI4	TK,
SI5	TK, TCK,
SI6	TK,

The findings indicated that all participants demonstrated a resonance with Technological Knowledge (TK) when integrating technology into their teaching. SSI3, SSI4 and SSI6 explained:

“When I am planning a lesson, I tend to consider the knowledge that I have about a particular technology”. (SSI3)

“I know how to use different technological tools in teaching mathematics; therefore, this shows that I resonate with Technological Knowledge (TK) when I am integrating technology in teaching”. (SSI4)

"I know how to use a computer and laptop for typing learners' activities. This shows the knowledge of TK in me."(SSI6)

The findings indicated that all the participants resonated with Technological Knowledge (TK) during their integration of technology. It is crucial for every teacher to possess technological knowledge in order to effectively integrate technology into teaching mathematics (Ertmer,et al.,2012; Voogt et al., 2013).

SSI2, SSI3, and SSI5 explained that they resonate with Technological Content Knowledge (TCK) in addition to TK. They clarified that they possess the knowledge required for selecting technological tools that align with the content of the lesson.

“During my teaching, I typically begin by selecting the topic content and then proceed to identify the technology that can seamlessly integrate with the lesson's content”. (SSI2)

“I select the available technological tools based on the content of the lesson.”(SSI3)

SI5 further expressed:

“When I teach a topic about geometry, I use GeoGebra to present the lesson. This means that the technological tool I selected fits into the lesson content”.

Participants also indicated that the availability of technology enables them to select the technological tools that can fit into the content. Poor access to ICT technology discourages them from integrating technology in teaching mathematics.

It was also evident during classroom observations that participants were adept at selecting technological tools that aligned with the content of the lesson. O1, during her lesson, used a laptop to show learners a video relevant to the lesson's content. O3 employed a cellphone to download videos on WhatsApp, integrating them into the mathematics content. This clearly indicates that participants apply Technological Content Knowledge (TCK) during technology integration.

Furthermore, SI1, SI2 and SI4 selected TPK construct, they explained that they use the knowledge for TPK they know how to select the technological tools that fit the teaching methods when integrating technology in mathematics.

“Whenever I am planning to teach my lesson, I select the tool that fits the content of the lesson”. (SSI1)

“I usually select the topic first, then the method, and find the technological tools that fit the teaching methods”. (SSI2)

SSI4 also supported the idea of SSI1 and SSI2. SI4 explained:

“I also know how to select the technology that fits into the teaching method during the integration of technology”.

During classroom observations, I also noticed that participants were able to select technological

tools that aligned with their teaching methods. For instance, in a classroom observation, a teacher organized students into groups, tasking them with utilizing computers to illustrate various angles through drawings. The teacher guides discussions on various types of triangles, enabling students to acquire the skill of drawing different angles using the computer.

During semi-structured interviews, participants were also asked to describe their own TPACK. SSI2 stated:

“I can say that I take a lot of initiative in using technology. For instance, I have noticed that I independently use technology during my teaching. I am also able to select the technological tools that fit the subject content. However, I struggle to integrate the technology into my teaching methods. Upon self-evaluation, I recognize that my stronger components of TPACK are TK and TCK, while my weaker component of TPACK is TPK”.

SSI5 explained her own TPACK:

“In my opinion, my TPACK lies in my ability to seamlessly integrate technology into my mathematics teaching. I have a strong foundation in both mathematics and pedagogy, and I'm proficient in using tools like interactive whiteboards, computers, smartphones, and educational apps. This allows me to tailor my teaching methods to cater to diverse learning styles, ensuring that all my students can grasp complex mathematical concepts”.

SSI3 and SSI6 further described their TPACK:

“I have a better understanding of how to teach a lesson by appropriately combining subject content, technologies, and teaching approaches. Therefore, my TPACK is strong in all components”. (SSI3)

“Though it is not easy for me to describe my own TPACK, I can simply say that I have a strong knowledge of using technological tools. However, I sometimes struggle to fit certain technological tools into specific subjects. This means that my stronger component of TPACK is technological knowledge”. (SSI6)

During the focus group interview, participants were also asked to express their views on the importance of primary school mathematics teachers in rural areas developing TPACK. All participants unanimously affirmed the significance of TPACK for rural primary mathematics teachers. FGI1 and FGI3 clarified:

“It is crucial for rural primary school teachers to develop TPACK in order to effectively integrate subject content, technology, and teaching approaches”. (FGI1)

“TPCK development enables rural primary mathematic teachers to become fluent in teaching the subject with technology”. (FGI3)

FGI5 further expressed:

“I believe that a rural primary mathematics teacher with TPACK will never struggle with technology integration”.

FG2 and FG6 emphasized the significance of junior primary mathematics teachers developing TPACK, as it enables them to seamlessly integrate technology into their teaching methodologies. This, in turn, facilitates a deeper understanding of mathematics among learners and ultimately leads to improved academic performance. The study finding that it is crucial for junior primary mathematics teachers to develop Technological Pedagogical Content Knowledge (TPACK) because it equips them with a comprehensive understanding of how to integrate technology effectively into their teaching practices. TPACK combines knowledge of content (mathematics), pedagogy (teaching methods), and technology, allowing educators to create engaging and meaningful learning experiences. In the context of junior primary education, where foundational mathematical concepts are introduced, TPACK empowers the selected teachers to leverage technology in ways that can make abstract ideas more concrete and engaging for young learners. By seamlessly blending content knowledge, pedagogical strategies, and technology, teachers can create a dynamic and interactive learning environment that fosters a deeper understanding of mathematics, setting a solid foundation for future academic success.

The qualitative data further indicated that all participants exhibited proficiency in Technological Knowledge (TK) in the ways they integrated technology in teaching mathematics, with a few also recognizing the importance of Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). Moreover, the findings underscored the development of Technological Pedagogical Content Knowledge (TPACK) among mathematics teachers. Some participants demonstrated a deeper comprehension of the various facets of TPACK. This suggests that participants enhance their TPACK when integrating technology in teaching mathematics.

RQ3: What challenges do mathematics teachers experience as they integrate technology and develop technological pedagogical content knowledge in Okahaoeducation circuit?

The integration of technology in education presents both opportunities and challenges, particularly in the context of developing Technological Pedagogical Content Knowledge (TPACK) (Adipat, 2021). The findings addressing research question 3 were derived from a total of 27 participants in the study. Among them, 27 senior primary mathematics teachers responded to the semi-structured questionnaires. Additionally, a subset of 6 participants was selected from the initial group of 27 respondents who completed the questionnaire and expressed willingness to participate in individual interviews and group discussions. This subset provided valuable insights into the challenges of integrating technology in teaching and learning mathematics. Furthermore, the study delved deeper with 3 participants who underwent classroom observations, during which I observed the challenges that teachers experience when integrating technology into their classroom teaching.

4.6 Challenges in technology integration during teaching and learning mathematics

4.6.1 Challenges in access and available ICT tools

During this study, it was identified that participants expressed concerns about the current integration of ICT in most primary schools in Namibia. Teachers explained that despite the benefits of integrating technology in teaching mathematics, they also face the challenge of being unavailable of relevant and updated technologies during the integration of technology. Findings from the questionnaire indicated that most of the schools in the circuit do not have a computer laboratory rooms. It was also indicated that some teachers do not have access to advanced technological tools such as graphing calculators, tablets with specialized educational apps, or virtual labs. This lack of access to advanced technological tools can limit teachers' ability to effectively integrate technology into their mathematics teaching and develop their Technological Pedagogical Content Knowledge (TPACK) to its fullest potential. During the individual interviews and focus group interviews, participants were asked to share the challenges of technology they encountered during their teaching.

During individual interviews, SSI2 and SSI3 explained their situation:

“Sometimes I find myself in a situation where I am planning a lesson that requires specific technology integration, but the necessary resources are unavailable at school”. (SSI2)

“At my school, the available technology is outdated. We aren't exposed to the advanced technology like Mathletics that most other schools are currently using”. (SSI3)

Despite receiving financial support from the government to acquire ICT tools, SSI4 highlighted the scarcity of certain advanced technologies, such as educational apps, noting:

“We are getting financial support from the government, but there is a low budget to maintain some advanced ICT tools like GeoGebra and Khan Academy”. (SSI4)

During the focus group interview, FGI5 further added that:

We've had the same technological devices for the past five years without any new additions. It's becoming boring for me to use the same technology throughout every lesson”.

Participants were further asked to explain how they overcome the challenges of integrating technology. They explained that they do their best to utilize the available tools and sometimes even share devices with neighboring schools. SSI3 and SSI5 explained:

"Whenever I plan a lesson that requires technology not available at my school, I borrow it and return it after my lesson presentation." (SSI3)

“I sometimes believe that the use of technology depends on where, how, and when to use it. I plan my lessons based on the available devices at school”. (SSI5)

The expressions of the participants indicate that the unavailability of technological devices can pose a challenge in integrating technology during the teaching of mathematics. A study conducted by Muhazir & Retnawati (2020) highlighted obstacles faced by mathematics teachers in the digital era when incorporating technology in mathematics instruction. These challenges encompass concerns regarding the suitability of mathematics learning materials and teaching aids for technology integration, taking into account the available facilities and infrastructure. While teachers may have an interest in integrating technology into their teaching, the lack of facilities at their schools may hinder them from doing so during their mathematics lessons. Therefore, if teachers do not integrate technology into their everyday lessons, they will not develop TPACK.

4.6.2 Lack of Teachers training on the use of ICT tools

During this study, it was also revealed that participants lacked the knowledge of how to integrate

different technological tools into their teaching. The findings were collected through questionnaires and interviews. It was identified during the questionnaire phase that schools were provided with technological devices, but some of them are just packed and remain unused because teachers do not have the knowledge of how to use them. This finding resonates with previous research by Johnson et al. (2019), which highlighted similar challenges faced by educators in effectively incorporating technology into their pedagogical practices. Furthermore, Smith and Jones (2018) found that despite access to technological tools, many teachers struggled with integrating them seamlessly into their teaching due to a lack of training and support. During focus group interviews and individual interviews participants were asked to explain challenges they encounter during technology integration in mathematics, FGI3 provides an example of one of his colleagues, stating,

“Despite his dislike for ICTs, he is respected and diligent. He does not utilize the laptop given because he lacks knowledge on how to use it, he requires his students to complete their assessments using traditional methods such as pencil and paper. However, nobody has any negative feedback about him”. (FGI3)

FGI2 and FGI4 shared their apprehensions regarding the influence of ICT on their teaching practices. Their concerns centered around the unexplored consequences of the rapid integration of technology in primary schools and mathematics classrooms. They contended that the extensive adoption of technology in schools is unprecedented, leaving much of its impact still uncertain. These concerns align with the findings of a study by Chen and Wang (2017) & Kim and Lee (2019), who highlighted the need for caution in the widespread adoption of technology in education due to the uncertain and unexplored impacts it may have on teaching and learning outcomes. Participants further explained that they were not given professional training on the importance of incorporating ICT in teaching mathematics, as well as on the use of ICT devices, as FGI4:

“Laptops were provided to teachers at our school without prior indication of what they could accomplish, or what we were expected to do with them and how to use them in teaching and learning”. (FGI4)

FGI5 and FGI6 participants expressed that the one-day ICT training offered to some individual teachers is insufficient to meet their needs. They pointed out that the ratio of qualified ICT trainers

to teachers in the Okahao Education circuit is inadequate to accommodate the increasing number of teachers. Consequently, teachers often find themselves using ICT without adequate training. This finding resonates with the findings of a study by Li and Ma (2018) & Johnson et al. (2020), which revealed that short-term, one-off ICT training sessions are often ineffective in equipping teachers with the necessary skills and knowledge to effectively integrate technology into their teaching practices. Teachers conveyed that they had undergone some technology usage training however, they noted that these training sessions were not tailored for specific subjects and this affects their TPACK development in teaching mathematics. FGI5 and FGI6 elaborated:

“I do not get any subject-related training in mathematics through the circuit as a subject teacher, but I received training online, which was solely focused on the use of ICT in education”. (FGI5)

“I underwent ICT training at the circuit and regional levels, focusing solely on how to use Microsoft Word and PowerPoint presentations on the computer”. (FGI6)

Furthermore, the increasing reliance on ICT in classrooms can sometimes lead to a shift in focus away from teachers as the primary facilitators of learning, potentially undermining their role and authority in the classroom (Chen et al., 2018; Wang & Liu, 2019; Lee et al., 2020). FGI1 participant claimed that the rapid integration of ICT in classrooms has resulted in negative consequences, such as undermining and downgrading the ‘teacher’s role while focusing the spotlight on technology. Both participants expressed concerns about the lack of comprehensive and ongoing professional development and support for teachers to effectively integrate technology into their teaching practices.

The absence of professional development tailored to integrating Information and Communication Technology (ICT) in teaching mathematics is a pressing concern in contemporary education (Johnson et al., 2020). Researchers indicate that many educators lack the necessary skills and knowledge to effectively incorporate ICT tools and resources into their mathematics instruction (Muhazir & Retnawati, 2020). Without adequate training and support, teachers may struggle to harness the full potential of technology to enhance student learning experiences in mathematics classrooms (Johnson et al., 2020; Li & Ma, 2018). During the study, most participants revealed

that the absence of professional development in ICT use significantly hampers the development of Technological Pedagogical Content Knowledge (TPACK) among teachers. TPACK is a crucial framework that combines knowledge of subject matter, pedagogy, and technology to enhance effective teaching (Tondeur et al., 2018). When educators lack adequate training in utilizing technology for instructional purposes, they struggle to integrate it seamlessly into their teaching methods (Li & Ma, 2018; Johnson et al., 2020). This deficit inhibits their ability to adapt and apply technological tools in ways that enhance the learning experience for students (Muhazir & Retnawati, 2020). Without the necessary skills and knowledge, teachers may resort to traditional, less engaging methods, potentially missing out on the transformative potential of technology in education (Chen et al., 2018). Thus, investing in professional development in ICT is essential for nurturing TPACK, ultimately benefiting both educators and students in today's digitally-driven learning environments (Wang & Liu, 2019).

4.8 Summary of the chapter

In this chapter, the researcher has presented the findings derived from four data collection techniques: semi-structured questionnaires, individual interviews, focus group interviews, and classroom observation. The data is systematically organized based on the research questions, employing a combination of textual presentation, graphs, and tables. The study, focusing on technology integration in mathematics teaching to develop Technological Pedagogical Content Knowledge (TPACK), highlights the pivotal role of technology in enhancing educators' proficiency. Participants generally expressed positive perceptions of technology integration, emphasizing its significance in teaching and learning mathematics.

Social interactions emerged as a critical factor in TPACK development, fostering collaboration, idea exchange, and nuanced insights. The importance of access to various technologies was emphasized, enabling teachers to seamlessly integrate technology into their practices and address diverse learning styles. However, challenges were identified, particularly the need for subject specific technology training. The chapter concludes by comprehensively exploring the intersection of technology, pedagogy, and content knowledge, contributing to a more nuanced and effective approach to teaching and learning mathematics. Chapter Five will delve into a detailed presentation and discussion of the findings, comparing them to existing data and the works of

other researchers, while also considering the analytical and theoretical frameworks outlined in Chapter Two.

CHAPTER 5: DISCUSSIONS OF THE FINDINGS

5.1 Introduction

The preceding chapter outlined the study's findings. In this section, the researcher engages in a comprehensive discussion of these results. These findings are compared and contrasted with the existing literature reviewed in Chapter Two. The discussion offers valuable insights and original contributions, akin to the work of Tondeur, Hermans, van Braak, and Valcke (2018), in detailing how teachers integrate technology in mathematics to enhance their Technological Pedagogical Content Knowledge (TPACK). This chapter is structured into four distinct sections, commencing with an introduction, followed by a synopsis of the findings, an in-depth discussion of pivotal results, and culminating in a chapter summary. These findings are examined in accordance with the three primary research questions, and they are also juxtaposed against the pertinent existing literature, encompassing the theoretical and analytical frameworks employed for data analysis. The three key questions addressed are:

RQ1: How do senior primary school mathematics teachers describe their ways of integrating technology in Okahao education circuit?

RQ3: What challenges do mathematics teachers have as they try to integrate technology and develop technological pedagogical content knowledge Okahao education circuit?

RQ2: How do senior primary school mathematics teachers describe their technological pedagogical content knowledge Okahao education circuit?

5.1 Discussion of Findings

RQ1: How do senior primary school mathematics teachers describe their ways of integrating technology in Okahao education circuit?

The research findings revealed teachers' perspectives on the integration of technology in the teaching of mathematics. Both positive and negative viewpoints regarding the incorporation of technology in teaching practices were identified. The study emphasized the significant impact of technology integration, bringing about a profound transformation in the educational landscape. Notably, technology serves as a complementary tool to traditional teaching methods,

revolutionizing lessons by enhancing engagement and dynamism (Henock, 2015; Sanus, 2022). The utilization of educational software, apps, and virtual reality has successfully transformed classrooms into immersive learning environments, accommodating diverse learning styles and granting access to an extensive range of educational resources (Na, 2015; Yuso et al., 2019; Onu et al., 2023).

Furthermore, the study highlighted that technology integration has played a pivotal role in extending learning beyond regular school hours, thereby increasing accessibility to education on a global scale. As a result, teachers now possess the capability to tailor instruction, monitor individual student progress, and facilitate collaborative learning experiences (Qian & Clark, 2018; Willias, 2021). This has ushered in an era of education characterized by adaptability, inclusivity, and effectiveness (Waxman et al, 2013 ;Ruggiero & Mong, 2015). Nevertheless, the research findings also pointed out potential drawbacks, such as the risk of technology fostering passive learning and diverting students' attention away from the development of essential problem-solving skills through traditional means.

The study's findings indicated that schools were equipped with various technological facilities for teaching and learning mathematics. The most commonly used facilities at schools, as reported by teachers, were smartphones, radios, and internet connectivity in their teaching and learning of mathematics. Teachers demonstrated proficiency primarily with the technologies they had regular access to. Therefore, there is a need to provide them with new or advanced technological tools, such as computer software, Desmos and GeoGebra, along with additional training on their effective utilization in teaching.

Integrating various technological tools into mathematics education to enhance teaching effectiveness, facilitate collaborative learning experiences, and improve students' understanding of mathematical concepts (Ngololo, 2010; Hamukwaya, 2021 & Waiganjo, 2021). The study provided insights into how various technological tools were integrated into the teaching and learning of mathematics. It was observed that a majority of participants frequently utilized WhatsApp both inside and outside the classroom. Additionally, teachers were found to employ a Facebook group as a platform for teaching and sharing mathematical information with their students. This interactive space proved to be beneficial for enhancing mathematical

understanding.

Moreover, using a laptop to present mathematical concepts is deemed a meaningful approach for both educators and learners (Cuban, 2001). Laptops provide educators with the flexibility to incorporate multimedia elements and interactive simulations, enhancing the visual representation of mathematical concepts and promoting active learning among students. (Zhao, 2001). The study highlighted the effectiveness of an interactive blackboard in enabling teachers to elucidate complex concepts in real-time, thereby making abstract ideas more accessible to students. Importantly, the research underscored the significance of using a laptop to present mathematical concepts, deeming it a meaningful approach for both teachers and learners. This method was shown to enhance student comprehension through various delivery techniques. Ultimately, the study recognized laptops, smartphones and internet access as invaluable tools for imparting lessons and providing diverse modes of representation.

RQ2: How do senior primary school mathematics teachers describe their technological pedagogical content knowledge Okahao education circuit?

The research addressed question two through a combination of semi-structured questionnaires, classroom observations, and interviews, ensuring the validity of the findings. Participants offered valuable insights into their Technological Pedagogical Content Knowledge (TPACK) concerning the integration of technology in mathematics instruction. Analysis of the questionnaires revealed that the majority of mathematics teachers exhibit a high proficiency in Content Knowledge (CK), Technological Knowledge (TK), Pedagogical Knowledge (PK), Technological Pedagogical Knowledge (TPK), as well as Pedagogical Content Knowledge (PCK). However, there was a moderate level of expertise observed in Technological Content Knowledge (TCK) and Technological Pedagogical Content Knowledge (TPCK). This indicates that TCK and TPCK may be relatively less emphasized components within the broader TPACK framework for teaching and learning mathematics.

The study found that teachers demonstrate proficiency in operating readily accessible technological tools like smartphones and laptops/computers. Furthermore, it highlighted the significant impact of available facilities on the integration of technology in teaching and learning

mathematics. The research showed that teachers excel in using devices they have regular access to. Additionally, the findings revealed that mathematics educators exhibit proficiency in choosing technologies that align with their lesson content. They consider it essential to incorporate technology for its manifold advantages in teaching and learning, which encompass capturing students' interest, promoting active participation, and offering interactive visualizations and simulations to enhance the comprehension of abstract concepts. Moreover, the study indicated that teachers enhance their proficiency in Technological Content Knowledge (TCK) through practice in sharing content, and they also demonstrate a better understanding of the Technological Pedagogical Knowledge (TPK) component. Participants' knowledge extends to various technologies that support their teaching strategies.

The findings further revealed that teachers cultivate TPACK through the integration of technology in their mathematics instruction. They demonstrate expertise in selecting appropriate tools from their school resources and seamlessly integrating them into both the lesson content and instructional approaches for teaching mathematics. Throughout the study, teachers consistently displayed a strong interest in integrating technology and exhibited a high level of confidence in its application within their classrooms.

RQ3: What challenges do mathematics teachers have as they try to integrate technology and develop technological pedagogical content knowledge Okahaoeducation circuit?

The findings highlighted that teachers faced challenges when it came to integrating technology into their mathematics instruction. These difficulties included assessing the compatibility of mathematics learning materials and teaching aids with technology while taking into consideration the existing facilities and infrastructure. Additionally, it was noted that some teachers were eager to incorporate technology into their teaching, but the absence of mathematics-related technologies in their schools hindered their efforts during mathematics lessons. Furthermore, the findings underscored that without the integration of technology in their daily lessons due to the unavailability of technology, teachers would not be able to develop their Technological Pedagogical Content Knowledge (TPACK).

The study also brought to light that participants have a deficiency in integrating technology

effectively in teaching and learning mathematics. Furthermore, it revealed that the lack of professional development in Information and Communication Technology (ICT) usage significantly impedes the cultivation of Technological Pedagogical Content Knowledge (TPACK) among teachers. TPACK is a pivotal framework that amalgamates subject matter expertise, pedagogy, and technology proficiency to elevate teaching effectiveness. When teachers lack ICT training in harnessing technology for instructional purposes, they encounter challenges in seamlessly incorporating it into their teaching methodologies (Niess 2005, 2006, 2008; Niess et al., 2009; Chang et al., 2014). This gap hinders their capacity to adapt and employ technological tools in ways that optimize the learning experience for students (Nhu et al., 2018). Without the requisite skills and knowledge, teachers may revert to conventional, less interactive methods, potentially missing out on the transformative potential of technology in education. Therefore, investing in professional development in ICT is imperative for nurturing TPACK, ultimately benefiting both educators and students in today's digitally driven learning environments (Hill, 2020).

In addition to the challenges related to ICT infrastructure, the study uncovered concerns among participants regarding technological professional training. Several participants shared their sentiments about the nature of the training they received, highlighting a specific concern about the generalization of ICT training. They emphasized that the training they underwent was broad and encompassed various aspects of information and communication technology (ICT) but lacked specificity in terms of its application to subjects, particularly in the context of mathematics. The study findings are in line with the study by Hughes and Zacharia (2013), which found that teachers need more specialized training focused on the unique demands of teaching mathematics. They highlighted the importance of understanding how to effectively use technology to teach mathematical concepts and facilitate student learning.

These teachers expressed a desire for more targeted and subject-specific professional development opportunities, especially in the realm of mathematics education. The sentiment was that while they had received general ICT training at the circuit level, the applicability of the acquired skills and knowledge to the intricacies of teaching mathematics was not adequately addressed. Participants articulated a need for specialized training sessions that would delve into the nuances of integrating

technology specifically within the mathematics curriculum. This concern underscores the importance of tailoring professional development initiatives to the specific needs of teachers within their subject domains. Subject-specific training can enhance the relevance and effectiveness of technological integration in the classroom, allowing educators to apply their acquired skills more directly to the challenges presented by teaching mathematics. Addressing this aspect of professional development could contribute significantly to overcoming the barriers to successful technology integration identified in the study.

5.2 Discussion of findings in relationship with related literature

The discussion of the findings in this study is organized around the themes that emerged from the raw data, as analyzed through the theoretical and analytical frameworks guiding this research. It is presented in coherence with the existing literature in the field of technology in education, particularly in the context of teaching and learning mathematics. Furthermore, the discussion aligns with the theoretical frameworks employed to analyze the findings. The following are the themes that emerged from the analysis and they are discussed in the following section.

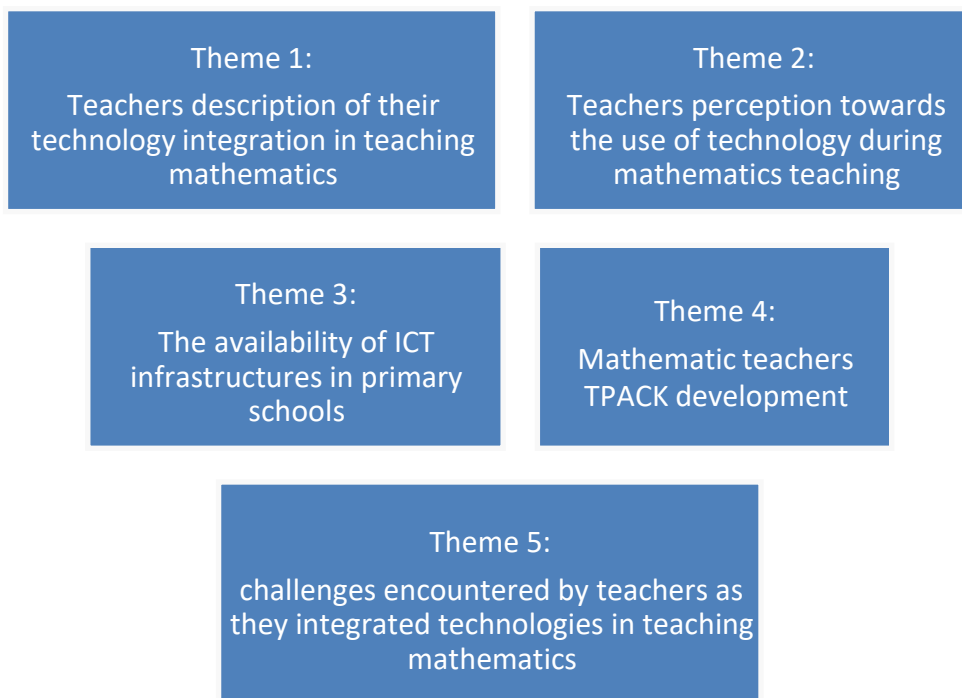


Figure 5.1: Themes emerged from the analysis

Theme 1: Teacher description of their technology integration in teaching mathematics

The literature affirms the positive impact of integrating technology into the teaching and learning of mathematics (Waiganjo, 2021). This integration not only prepares students for the demands of the digital age but also equips them with essential skills necessary for success in the modern workforce (Jones & Williams, 2021). Additionally, educators can leverage technology to construct dynamic and adaptive learning environments that promote the development of critical thinking and problem-solving abilities among students (Garcia, 2017). The participants in the study demonstrated a keen interest in the integration of technology in mathematics education. Nevertheless, some participants believed that successful technology integration in the classroom hinges on the availability of suitable technological resources for teaching and learning mathematics. Effective integration of technology is achievable when educators dedicate more time to practicing its incorporation, as highlighted by Gorder (2008). Furthermore, the literature emphasizes that teachers accumulate valuable experiences in technology integration through consistent practice (Gorder, 2008). Interactions with peers play a pivotal role in achieving a successful integration of technology in teaching mathematics, aligning with Vygotsky's (1978) emphasis on social interaction. The study's participants indicated that they learned how to effectively integrate technology by engaging with fellow educators. They noted that their colleagues provided guidance on utilizing various technological tools in their teaching and learning endeavours.

The study's findings indicate that teachers employ a diverse array of technological tools to augment the teaching of mathematics, aligning with Vygotsky's (1978) proposition that tools can serve as mediators in the learning process. These tools encompass a broad spectrum, ranging from traditional computers and laptops to more contemporary devices such as cell phones, radios, smart TVs, iPads, tablets, and applications like WhatsApp and Facebook. Furthermore, various software applications specifically designed for teaching and learning mathematics are also being utilized by educators. This multifaceted integration of technology underscores the dynamic and evolving nature of the tools employed to enhance the learning experience in the realm of mathematics education. Participants emphasized that the integration of technology can be advantageous for both

teachers and learners in the process of teaching and learning mathematics. Existing literature supports the notion that technology plays diverse roles in both teaching and learning, as highlighted by Bransford (2000).

Additionally, Information and Communication Technology (ICT) holds significant potential for enhancing student achievement and fostering teacher development, as highlighted by Kaput et al. (2008). Wong (2006) further accentuates the pivotal role of technology in supporting both traditional in-person and remote instruction. Scholars argue that computers not only facilitate knowledge acquisition but also diminish the necessity for direct instruction, empowering teachers to offer personalized assistance to learners with specific needs. Gillespie (2006) underscores the multifaceted benefits of technology, ranging from facilitating information retrieval to promoting interactive resource utilization, communication, and collaboration. Moreover, participants in this study emphasize that the successful integration of technology is more likely when utilizing advanced technological tools. Osborne and Hennessy (2003) assert that the incorporation of new technologies can enhance student motivation, encourage clearer thinking, and cultivate essential data interpretation skills, ultimately contributing to improved learning outcomes. The comprehensive use of advanced technology in educational settings emerges as a key factor in harnessing its full potential for enriching the teaching and learning experience. (Whiteside et al., 2023 & Fatmasari et al, 2023).

Theme 2: Teachers Perceptions and attitudes towards the integration of technology in teaching mathematics

Existing literature emphasizes that the effectiveness of integrating Information and Communication Technology (ICT) into teaching and learning is intricately tied to the attitudes toward its adoption (Salehi & Salehi, 2012). Furthermore, it underscores the significant influence of mathematics teachers' perceptions on the actual usage of ICT in the educational context (Liu, Geertshuis & Grainger, 2020). This implies that educators' attitudes and perspectives play a pivotal role in shaping the successful implementation and utilization of ICT tools and strategies in the teaching and learning of mathematics . The correlation between attitudes and usage suggests a need for a comprehensive understanding of teachers' perceptions to foster more effective integration of ICT in mathematics education. The results of this study provide encouraging insights into teachers'

perceptions of technology-integrated learning. Integrating technology in mathematics classrooms can help learners to master concepts such as probability, risk, and certainty as well as allowing them to make complex decisions in the contemporary democratic society with various social or personal implications (Kaput et al., 2008). The majority of educators believe that incorporating technology in mathematics education enhances both teaching and learning. This affirmation is supported by feedback gathered through semi-structured and focus group interviews. Participants expressed that technology has become a catalyst for adaptability in instruction, allowing educators to tailor their approach to the unique requirements of each student. Furthermore, the consensus highlighted the role of technology in providing supplementary support to traditional teaching methods, resulting in a paradigm shift that has revolutionized lessons, making them more engaging and dynamic.

The integration of educational software, apps, and virtual reality was a focal point in participants' discussions, with a unanimous acknowledgment that these tools have turned classrooms into immersive learning environments. This shift, participants noted, has effectively catered to various learning styles, ensuring a more inclusive and diverse educational experience. Additionally, the incorporation of technology has democratized access to a vast array of educational resources, opening up new avenues for learning and exploration. Comparatively, other literature also supports the idea that technology enhances educational access and opportunities (Warschauer, 2003). Similarly, a report by the study conducted by Falloon (2020), highlighted that technology increases access to education and removes traditional educational barriers in many teaching and learning contexts. Participants echoed the view that technology has not only redefined the way educators teach but has fundamentally transformed the learning experience for students. The shift towards personalized, engaging, and dynamic education, facilitated by educational technology, underscores the pivotal role these tools play in shaping the future of learning.

Furthermore, it was noted that technology streamlines administrative tasks like grading and record-keeping, while also affording prompt and comprehensive feedback to students. Furthermore, ICT tools were highlighted for their effectiveness in teaching, enhancing learner performance, promoting peer interaction, and aiding in visualizing mathematical concepts. These viewpoints align with the findings of previous studies conducted by Salehi & Salehi (2012), Liu,

Geertshuis & Grainger (2020), Khlaif (2018), George, and Kolobe (2014), as well as Musawi, Ambusadi, Al-Balushi, S. and Al- Balushi (2015). These researchers consistently underscored the affirmative influence of incorporating technology into mathematics education. Their emphasis centered on technology's ability to facilitate adaptive learning platforms, provide personalized feedback, showcase practical relevance across diverse fields, and grant access to a plethora of online resources and interactive tools, effectively complementing traditional teaching materials.

On the flip side, it is important to acknowledge that while the majority of teachers displayed a positive inclination towards utilizing technology in their teaching practices, two participants held differing views on technology integration. These individuals expressed concerns that some educators might fear an over-reliance on technology leading to passive learning or diverting attention from honing vital problem-solving skills on paper. Additionally, there was apprehension that students could become overly dependent on technology for visualization, potentially struggling with manual methods when necessary (Muhazir & Retnawati, 2020). These participants also raised valid concerns about the digital divide, where not all students have equal access to technology, which might prompt some teachers to exercise caution in relying too heavily on digital tools. It is worth noting that the belief that technology-enhanced teaching is not necessarily more effective than traditional instructional methods has been documented in prior studies by Almekhlafi & Almeqdadi (2010), Marwan & Sweeney (2010), Kopcha (2012), and Kaleli-Yilmaz (2015), as well as Sawyer (2017). For instance, Kaleli-Yilmaz (2015) conducted a study on the views of mathematics teachers regarding factors influencing the integration of technology in mathematics courses, involving 10 mathematics teachers in Australia. The findings indicated that a significant portion of teachers still maintained the belief that instruction enhanced by ICTs is not superior to traditional chalk-and-talk methods. This contrasts with the results of the present study, where the majority of participants expressed the view that ICTs indeed enhance the effectiveness of teaching.

Theme 3: The availability of ICT infrastructures in primary schools

The findings of the study reveal that some primary schools within the Okahao education circuit are equipped with technological resources, empowering teachers to integrate technology into their mathematics instruction. Participants, as evidenced by responses from questionnaires, interviews, and focus groups, possess a variety of ICT devices, including computers/laptops, mobile phones,

and reliable internet access, which were widespread across many schools. The study also identifies commonly used tools such as specific software, WhatsApp, Facebook groups, and radio for the integration of technology into mathematics education. Smartphones and laptops were utilized to download videos and other learning materials from the internet. Teachers downloaded videos from the WhatsApp group and incorporated them into their classroom presentations. Additionally, teachers use WhatsApp groups to communicate with their students outside of the class, providing additional materials to enhance the learning of mathematics. Literature corroborates the practice of using messaging platforms like WhatsApp to facilitate communication and share educational resources among teachers and students. For instance, a study by Lugo and Schurmann (2015) found that teachers often utilized the platform to distribute supplementary materials, such as videos and worksheets, to support learning outside of the classroom. Similarly, a research paper by Kaur and Singh (2016) highlighted the effectiveness of WhatsApp in enhancing communication between teachers and students, as well as in providing additional resources for learning mathematics.

Furthermore, in the course of teaching presentations, some educators leverage smart TVs, radio programs, and blackboards for the instruction and learning of mathematics. Smart TVs serve as a platform for displaying mathematical content, allowing students to visually engage with the material during lessons. Radio programs are utilized to broadcast educational content related to mathematics, expanding the reach of instructional resources. Blackboards, on the other hand, are employed to illustrate complex concepts in real-time, transforming abstract ideas into tangible learning experiences. The collaborative features of blackboards facilitate group problem-solving activities among learners. The extensive use of these technological tools provides clear evidence of teachers' keen interest in incorporating technology into their mathematics teaching practices. The variety of available tools encourages teachers to adopt technology, enabling more effective and customized teaching methods. These findings align with earlier studies by Walshaw & Anthony (2008), Fatima (2012), and Gil- Flores, Rodríguez-Santero & Torres-Gordillo (2017), all highlighting the crucial role of ICT facilities in the teaching of mathematics. The existing literature emphasizes that the presence of ICT tools significantly supports teachers in integrating technology into their teaching and learning practices (Jimoyiannis & Komis, 2007). The study underscores

the notion that the accessibility of ICT tools empowers teachers to seamlessly integrate technology into the teaching of mathematics. Teachers expressed their reliance on the available ICT tools, with many indicating the use of laptops and smartphones connected to the internet due to their widespread availability in their schools.

Furthermore, the study uncovered that participants possessed knowledge regarding the integration of ICT facilities in teaching mathematics. Some participants specifically mentioned that incorporating ICT tools into their teaching practices enhanced their proficiency in technology integration. However, a significant revelation was that, despite the presence of technological resources in schools, some remained underutilized due to teachers' limited expertise in their application. For instance, during the study, some teachers expressed interest in using technology but refrained from doing so due to a lack of knowledge. Existing literature emphasizes that a lack of understanding of technology integration can lead to its ineffective implementation, potentially diminishing teachers' enthusiasm for utilizing technology in teaching mathematics (Amuko, S., Miheso, M., & Ndeuthi, S., 2015; Dahal, B., & Dahal, N., 2015).

Studies, including the one conducted by Dahal and Dahal (2015), underscore the necessity for professional development to equip teachers with the skills needed to effectively integrate technological resources into mathematics education. During the study, teachers expressed their desire to receive proper training specifically for integrating technology, particularly in the context of teaching mathematics. Additionally, some teachers conveyed the belief that a shortage of available ICT tools can hinder the integration of technology in teaching mathematics. Participants further observed that while schools receive financial support from the government, it often falls short of covering the expenses associated with acquiring advanced technological facilities. This aligns with findings in the literature, which emphasize how the unavailability of ICT resources can deter teachers from incorporating technology into their mathematics instruction (Dhakal, P. K., 2018).

Theme 4: Mathematic Teachers TPACK development

The study's findings demonstrate that participants acquire technological knowledge (TK) as they teach mathematics. Integrating technology into mathematics instruction exposes teachers to various

technological tools and enhances their proficiency in technological knowledge. Within the TPACK framework, technology plays a pivotal role in supporting teaching methods, underscoring the necessity for teachers to possess technological expertise to effectively incorporate it into their instructional strategies. Teachers have expressed the need for enhanced facilities and comprehensive ICT training to further bolster their technological knowledge. In a study by Zhang & Tang (2021) on teachers' TPACK development, it was emphasized that providing ICT training is crucial for teachers to advance their proficiency in technological knowledge.

The results suggest that teachers acquire proficiency in integrating technology with subject content. This is supported by participants who reported actively selecting content and matching it with appropriate technology. For instance, some teachers expressed the use of WhatsApp to share content with learners and colleagues. Such integration of technology in mathematics instruction empowers teachers to enhance their technological content knowledge (TCK). Existing literature emphasizes the importance of providing teachers with support in selecting suitable technological tools that align with subject content. This support can be facilitated through collaborative interactions with fellow teachers within the school environment (Durdu & Dag, 2017).

The study confirms that teachers acquire Technological Pedagogical Knowledge (TPK) through the integration of technology in mathematics instruction. This is supported by participants who purposefully choose technology that aligns with their preferred teaching methods. For example, in a classroom observation, a teacher organized students into groups, tasking them with utilizing computers to illustrate various angles through drawings. The teacher guides discussions on various types of triangles, enabling students to acquire the skill of drawing different angles using the computer. Consistent use of technology in daily lessons fosters a strong understanding of technological pedagogy (Mishra and Koehler, 2008). Additionally, Hofer & Grandgenett (2012) highlight that integrating technology in teaching leads to the highest proficiency in combining technological and pedagogical knowledge. When designing lessons that involve both technology and teaching methods, it is imperative for teachers to carefully consider the intricate interplay between technology and pedagogy, as emphasized by Mishra and Koehler (2008).

The study illuminates how participants acquire a profound grasp of Technology, Pedagogy, and

Content Knowledge (TPCK). They demonstrate adeptness in melding these three components when employing technology in mathematics instruction. Actively, they select technological tools that harmonize with both the content and their teaching methods. Teachers acknowledge that technological advancements enable them to elevate their TPCK. For example, during the interview, a specific participant mentioned opting for GeoGebra to instruct on various types of angles and subsequently dividing her learners into groups. The literature indicated that GeoGebra enhanced students' understanding of geometric concepts, including angles, through dynamic visualization and exploration (Laborde, 2001). Furthermore, El Mouhayar et al. (2012) reported positive outcomes regarding the use of GeoGebra in terms of students' engagement and conceptual understanding. In the realm of teaching and learning mathematics, TPCK assumes even greater importance. With technology continually shaping the educational landscape, educators must possess the expertise to adeptly navigate this evolving terrain (Mishra & Koehler, 2006). The astute integration of technology, pedagogy, and content knowledge equips educators not only to adapt to evolving paradigms but also to seize the opportunities presented by these changes, invigorating and enriching the teaching of mathematics (Niess, 2005).

Theme 5: Challenges encountered by teachers as they integrate technologies in teaching mathematics

The study brings to light the challenges encountered by teachers when attempting to integrate technology into their mathematics instruction. Notably, a considerable number of teachers expressed reservations and apprehensions regarding the incorporation of technology in their mathematics teaching practices. Participants consistently emphasized the difficulties they faced in the process of integrating technology, with a major hurdle being the inadequate ICT infrastructure within their school settings. This dearth of technological facilities emerged as a significant impediment, hindering their capacity to seamlessly integrate technology into the teaching of mathematics. Consequently, this limitation resulted in a constrained development of their Technological Pedagogical Content Knowledge (TPACK). The findings align with Hechter and Vermette's (2013) study, which underscores the detrimental impact of a lack of ICT facilities on the successful integration of technology into educational practices. This reaffirms the notion that the absence of essential technological infrastructure poses a substantial barrier to harnessing the benefits of technology in teaching and learning environments. Furthermore, a parallel study conducted in rural parts of Namibia echoes similar concerns, revealing that many schools in

these areas face challenges due to a shortage of ICT facilities. This consistency in findings across different contexts emphasizes the widespread nature of the issue, indicating a need for targeted interventions to address the deficiencies in ICT infrastructure and support teachers in overcoming obstacles to effective technology integration in mathematics education.

Participants also encountered challenges in adapting to the advancements in modern technology and displayed resistance to change. They clung to their traditional educational beliefs and teaching practices related to mathematics. Adarkwah (2021) and Aceto (2019) have both underscored that this reluctance to adapt poses a significant obstacle for teachers in embracing information and communication technology (ICT). Gurer (2022) characterizes these concerns as intangible barriers that teachers face when trying to incorporate ICT into their teaching methodologies. Keengwe, Onchwari, and Wachira (2008) stress the importance of providing schools with ICT tools to facilitate participation in technology integration. Some participants expressed reservations about the continuous integration of Information and Communication Technology (ICT) in their mathematics classrooms. They pointed out issues such as inadequate training for teachers in technology, a shortage of advanced technology resources, a sense that ICT was being hurriedly imposed on their teaching practices, and concerns about the diminishing role of teachers due to increased reliance on ICT. Similar concerns about teacher training were discussed by Shambare & Simuja (2022), while Resien et al. (2020) noted various negative consequences, including the standardization of educational practices, potential social isolation, and the risk of students becoming overly dependent on ICT.

In the evolving landscape of education, the emphasis on technology-focused professional development continues to grow. Recognizing that teachers play a pivotal role in effective technology integration, educational institutions are increasingly investing in targeted training programs. These programs cater to teachers at various stages of familiarity with technology, ensuring that the training is both accessible and relevant. Quality professional development emerges as a critical factor in the success of technology integration initiatives (Ngololo, 2010; Nuuyoma, 2012). It goes beyond mere exposure to tools, focusing on pedagogical strategies, curriculum alignment, and addressing challenges that may arise during implementation. A well-designed professional development program equips teachers with not only technical skills but also

the confidence and adaptability necessary for navigating the dynamic technological landscape. Adarkwah's (2021) insight underscores the ongoing importance of providing substantial support and training to teachers. This support is integral in cultivating a tech-savvy teaching workforce, ensuring that educators possess the skills and confidence needed to effectively integrate ICT into their teaching methods. The synergy between quality professional development and ongoing support lays the foundation for a transformative educational experience, where technology becomes an empowering tool for both teachers and students alike (Gorder, 2008) .

5.3 Conclusion of the chapter

The study's results were compared to the earlier literature discussed in Chapter Two, revealing a heartening alignment with several previous studies. This study delved into the exploration of teachers' utilization of technology to develop Technological Pedagogical Content Knowledge (TPACK) in the context of teaching mathematics at the primary level. The findings reflected the teachers' recognition of the benefits associated with integrating technology into mathematics instruction, showcasing their enthusiasm and positive attitude toward its incorporation. Despite participating in various training programs offered by the Ministry of Education, teachers expressed dissatisfaction with the effectiveness of these initiatives in enhancing their skills for subject-specific technology integration. The discrepancy emerged as the training primarily focused on the general use of technology rather than its application in specific subjects. Additionally, the study highlighted that some teachers, even when provided with technological resources, faced challenges in their utilization due to insufficient knowledge. This emphasizes the need for more targeted and subject-specific professional development to effectively cultivate teachers' Technological Pedagogical Content Knowledge and ensure the successful integration of technology in mathematics education at the primary level.

The findings exemplify a nuanced understanding of how teachers deliberately select and employ technological tools, aligning them seamlessly with both content and pedagogy to enhance their Technological Pedagogical Content Knowledge (TPACK). Teachers showcase their adeptness in navigating this dynamic intersection through various instances, such as organizing collaborative computer-based activities or utilizing platforms like WhatsApp for content sharing. The study underscores the crucial need for targeted professional development and support to

strengthen teachers' technological expertise, aligning with broader literature that emphasizes the pivotal role of ongoing training in Technological Pedagogical Content Knowledge (TPACK) development. As technology continues to shape the educational landscape, the study reinforces the importance of skillfully integrating technology, pedagogy, and content knowledge to empower educators in effectively navigating and leveraging these advancements. This, in turn, enriches the teaching and learning experience in mathematics. The upcoming Chapter Six encapsulates the study's conclusion, its implications, and constraints, and offers recommendations for future research in the domain of integrating technology into mathematics instruction for TPACK advancement.

CHAPTER 6: CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

6.1 Introduction

The previous chapter offered a discussion of this study's findings. This final chapter presents an overall summary of this study. It begins with the introduction (6.1), (6.2) overview of the study, followed by (6.3) conclusion of the study findings, and (6.4) recommendation for TPACK practices. Next are (6.5) recommendations for future study and this chapter concludes with (6.6) limitations of the study.

6.2 Overview of the study

Chapter One: The purpose and aim of the study were to investigate the development of Technological Pedagogical Content Knowledge (TPACK) among senior primary mathematics teachers through the integration of technology in teaching within the Okahao educational circuit. The chapter identified three objectives to support the purpose of the study; to investigate how senior primary school mathematics teachers describe their ways of integrating technology in the classroom in Okahao education circuit, to investigate how senior primary school mathematics teachers in Okahao education circuit describe their technological pedagogical content knowledge and to understand how integrating technology in the classroom support and/or constrain mathematics teacher's technological pedagogical content knowledge development in Okahao education circuit. To achieve the purpose of this study, the following main research question were taken into consideration, How do senior primary school mathematics teachers in Okahao education circuit develop their TPACK as they integrate technology in the mathematics classroom? To address the main research question, the following sub-questions were used; **(a)** How do senior primary school mathematics teachers describe their ways of integrating technology in Okahao education circuit? **(b)** How do senior primary school mathematics teachers describe their technological pedagogical content knowledge Okahao education circuit? And **(c)** What challenges do mathematics teachers have as they try to integrate technology and develop technological pedagogical content knowledge Okahao education circuit?

Chapter Two: The study delves into the most current and pertinent literature related to the subject matter. The literature review was conducted to gain an understanding of how senior

primary mathematics teachers integrate technology into their teaching. The review encompassed topics such as technology integration in the curriculum, the role of technology in teaching mathematics, challenges associated with integrating technology in teaching mathematics, perceptions of mathematics teachers regarding technology integration, and the development of Technological Pedagogical Content Knowledge (TPACK) among mathematics teachers. Additionally, the study explored the concepts of sociocultural theory and the TPACK framework.

Chapter Three: In this chapter, the research methodology and design employed in the study are expounded upon. The study embraced an interpretive philosophy, employing a mixed research approach. It adopted a case study design supplemented by a multi-method qualitative approach, employing four distinct data collection techniques: semi-structured questionnaires, semistructured interviews, classroom observations, and focus group interviews. Participants were selected through purposive sampling based on predetermined criteria. Thematic analysis, facilitated by colour coding, was the chosen method for data collection. Measures were put in place to guarantee trustworthiness, and the chapter also delves into the researchers' position and ethical considerations.

Chapter Four: The study took place in a specific educational circuit, involving twenty-five senior primary mathematics teachers from that circuit. Data gathered from these participants were meticulously analyzed using the TPACK framework and sociocultural theory, forming the foundation of the empirical findings from which conclusions were drawn. The presentation of the findings in this chapter aligns seamlessly with the chosen methodology. They are organized in accordance with the themes that surfaced during the data analysis, directly addressing the research questions. In light of the significance of dependability, considerable attention is devoted to conveying the teachers' responses in their own words. This approach aims to establish confidence among readers that the data collected unequivocally contributed to the results presented by the researcher.

Chapter Five: In this section, the study delves into a comprehensive discussion of its findings. The analysis is underpinned by a thorough examination of relevant literature, which substantiates the results. The significance of these findings is also expounded upon five overarching themes

that surfaced during the analysis, forming the basis for the discussion of the findings. Each of these themes is contextualized within the pertinent literature. The conclusions drawn in this study are firmly grounded in the chosen methodology and the results presented and discussed in this chapter. They are substantiated by the robust analysis of the data and the integration of existing knowledge in the field.

Chapter Six: This is the final chapter of this study. The chapter provides an overview of the whole study. It also presents the summary of the major research findings from which conclusions is drawn, recommendations suggested and highlights the gaps which would serve as possible focus areas for future studies.

6.3 Conclusions of the study finding

The key findings for this study are presented in relation to the research questions and the themes that emerged during data analysis.

RQ1: How do senior primary school mathematics teachers describe their ways of integrating technology in Okahao education circuit?

In relation to this research question, the study revealed that some schools in the Okahao circuit are equipped with various technological facilities and devices. This provides mathematics teachers with an opportunity to integrate technology into their teaching. The study indicated that teachers made use of these technologies in their instruction of mathematics. Additionally, some teachers had their own personal technologies such as laptops, tablets, and smartphones, which they employed in teaching and learning mathematics. The most frequently used technological tools during the study for teaching mathematics were WhatsApp groups, Facebook groups, smart TVs, radios, internet connectivity, and blackboards. However, teachers encountered challenges in integrating these technological devices into the teaching and learning of mathematics. These challenges included difficulties related to advanced technology and a lack of proficiency in employing ICT tools for teaching and learning mathematics. The study findings were derived from primary sources of data and were analyzed both quantitatively and qualitatively through the use of questionnaires, semi-structured interviews, focus group interviews, and observations."

RQ2: How do senior primary school mathematics teachers describe their technological pedagogical content knowledge Okahao education circuit?

In this study, it was observed that participants demonstrated proficiency in Technological Pedagogical Content Knowledge (TPACK) when teaching and learning mathematics. Teachers exhibited a keen understanding of how to seamlessly integrate technology into their mathematics instruction. They accomplished this by thoughtfully selecting technologies that aligned with both the subject matter and their teaching approach, thereby contributing to the advancement of their TPACK proficiency.

The integration of technology in mathematics instruction provided teachers with valuable opportunities to deepen their subject knowledge and enhance their grasp of the content. This progress, in turn, played a pivotal role in the development of their pedagogical expertise. Engaging in teaching practices that incorporate technological tools enhances teachers' abilities to utilize a diverse array of resources in math instruction. They demonstrated adeptness in selecting and effectively incorporating available technological tools into their subject matter, ensuring a seamless alignment with their teaching methods. This demonstrated a holistic comprehension of the interplay between technology, pedagogy, and content, a testament to their overall proficiency in TPACK development for teaching and learning mathematics.

RQ3: What challenges do mathematics teachers have as they try to integrate technology and develop technological pedagogical content knowledge Okahao education circuit?

During this research, the findings indicated that teachers were keenly interested in incorporating integrated technology into their mathematics instruction. However, they encountered several challenges in effectively integrating technology into their teaching and learning of mathematics. One prominent obstacle identified by teachers was the lack of adequate facilities in and around their schools. They emphasized that the integration of technology was significantly hampered by the poor infrastructure in their schools. In particular, they faced difficulties due to a scarcity of advanced technological tools.

Additionally, teachers pointed out that while schools were equipped with technological facilities

and tools, they often lacked the necessary knowledge and skills to seamlessly integrate them into their subject content and teaching methods. This knowledge gap posed a significant hurdle and led to a waning interest in utilizing technology in their mathematics instruction. Furthermore, teachers expressed a sense of neglect in terms of receiving Information and Communication Technology (ICT) training and professional development, both at the school and circuit levels. This dearth of training opportunities further compounded their challenges in effectively leveraging technology in their teaching practices.

6.4 Recommendations for TPACK Practices

Premised on the findings of this study, the researcher wishes to make the following recommendations:

- Teachers should be given continuous professional development training on the integration of technology into their teaching practices. These courses should be specifically designed to enhance teachers' TPACK and must incorporate the latest technology applicable to the classroom context. These programs should cover how to integrate technology into teaching, pedagogical strategies for various types of content, and the effective use of specific technological tools in the context of teaching mathematics.
- Encourage collaborative learning and sharing of best practices among teachers. They can learn a lot from each other's experiences and effective TPACK development strategies. As identified in this study, social interactions among teachers play an instrumental role in enhancing TPACK development. Teachers can learn from each other, and share practical experiences and innovative strategies about integrating technology into mathematics instruction.
- Ensure teachers have access to various types of advanced technology and allow them enough time to interact with these tools. Familiarization with different technological tools will enable teachers to select those that best align with their subject matter and pedagogical styles. Schools should ensure teachers have access to diverse and reliable technological tools. Appropriate investment in technology infrastructure can support teachers in integrating technology into their classrooms efficiently as evident in this study.
- Teachers should constantly self-reflect on their TPACK skills and adapt their teaching

practices accordingly. They should critically assess how well they are integrating technology into their classes and whether their pedagogical strategies are effectively utilizing the available technology.

- Technology should be integrated in a way that aligns with the pedagogical approach of teachers. This means that the use of technology should support not replace or hinder established teaching methods and should be used to enhance teaching and learning. Teachers must learn to balance effectively between their teaching methods, the subjects they are teaching, and the technology they are using.

6.5 New Knowledge Contribution by the Study

The study makes a significant contribution to the understanding of Technological Pedagogical Content Knowledge (TPACK) development among senior primary mathematics teachers. By employing various data collection methods such as questionnaires, semi-structured interviews, observations, and focus group interviews, the research aimed to capture a holistic understanding of the multifaceted facets of TPACK. This diverse approach shed light on the intricate interplay between technological knowledge, pedagogical expertise, and content knowledge within the context of mathematics education .

The findings of the study provide insights into the impact of technology integration on the intricate dynamics of TPACK development among the participating senior primary school mathematics teachers. The study emphasizes the importance of teachers having access to diverse and reliable technological tools, as well as the need for appropriate investment in technology infrastructure to support teachers in integrating technology into their classrooms efficiently. It also highlights the significance of teachers constantly self-reflecting on their TPACK skills and adapting their teaching practices accordingly. The integration of technology should align with the pedagogical approach of teachers, supporting and enhancing established teaching methods rather than replacing or hindering them.

The study reflect into the development of Technological Pedagogical Content Knowledge (TPACK) among senior primary mathematics teachers through the integration of technology in teaching within the Okahao educational circuit. It uncovers the intricate interplay between

technological knowledge, pedagogical expertise, and content knowledge within the context of mathematics education. The findings reveal that while participants demonstrate a high level of proficiency in certain TPACK components such as CK, TK, PK, TPK, and PCK, they display a moderate level of expertise in TCK and TPACK. This suggests that there is a need for further support and training in these specific areas to enhance TPACK development .

The study emphasizes the pivotal role of technology in enhancing educators' proficiency, highlighting the significance of investing in professional development in ICT to nurture TPACK. It underscores the importance of access to various technologies, as it enables teachers to seamlessly integrate technology into their practices and address diverse learning styles.

6.6 Recommendation for Future Studies

This study was investigatory, without interventions or technology training. Future research should focus on designing and implementing such programs to improve TPACK development. Evaluation should include pre- and post-assessments of TPACK knowledge and classroom practices to measure effectiveness. The study also recommends that future research could consider a larger sample size, encompassing various educational circuits, to provide rich and diverse perspectives. This could help in understanding a broad range of experiences with technology integration and TPACK development among mathematics teachers.

This study was conducted within a limited timeframe. For a comprehensive understanding of TPACK development, it may be beneficial for future studies to adopt a longitudinal approach. This would permit researchers to monitor the progress and challenges of TPACK development over an extended period. A possible addition to future research might be to include a reflective session with participants after their lessons on technology integration. This could provide a deeper understanding of their experiences, challenges, and successes in using technology. The study has found that teachers face challenges due to a lack of adequate training in technology integration. Therefore, future studies could evaluate the impact of professional development programs focused on enhancing teachers' ICT skills and how it influences their TPACK development. However, the TPACK model used in this study was conceptual by nature. Future studies could consider conducting empirical research to validate and further refine the model,

enriching the theoretical underpinnings of TPACK.

6.7 Limitations of the study

Firstly, this study's findings provide a limited perspective on the development of TPACK for teaching mathematics with technology. Although participants reported using technological tools and devices, the study offers limited insight into the specific methods employed and their effectiveness in integrating technology into math instruction. Additionally, the findings indicate that teachers acquired new skills related to technology integration, but the study does not incorporate the teachers' own reflective input following their lessons on technology integration in the classroom.

Secondly, this study was conducted within a limited timeframe. I recommend that future researchers undertake a longitudinal study to monitor the progression of TPACK in teachers over an extended duration. This could yield invaluable insights into the factors shaping the evolution of TPACK and its long-term impact on teaching practices.

Lastly, in this study, the number of participants was limited. It started with a substantial group of 35 participants, but some individuals faced constraints in their ability to continue with the interview and observation sessions. This limitation hindered the researcher's ability to gather findings from all participants regarding their development of TPACK.

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APPENDICES

 RHODES UNIVERSITY <i>Where leaders learn</i>	Rhodes University, Education Faculty Research Ethics Committee PO Box 94, Makhanda, 6140, South Africa Tel: +27 (0) 46 603 8393 Fax: +27 (0) 46 603 8026 email: e.rosenberg@ru.ac.za https://www.ru.ac.za/researchgateway/ethics/
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16 February 2023

Dr Clement Simujsa
Education Department
C.Simujsa@ru.ac.za

Dear Dr Clement Simujsa and Ms Hilya Shikesho

Re: TPACK: investigating Senior Primary Mathematics Teachers' integration of technology in the classroom in Okahao educational Circuit

APPLICATION NUMBER: 2023-5914-7374

This letter confirms that your research ethics application has been reviewed and **APPROVED** by the Education Faculty Research Ethics Committee (EF-REC). Your permission letter(s) where applicable have been received and you are free to proceed with your study.

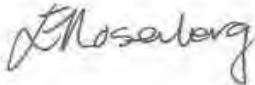
Approval is granted for 1 year. An annual progress report is required in order to renew approval for an additional period. You will receive an email notifying you when the progress report is due.

Should any substantive change(s) be made during the research process, that may have ethical implications, you should notify the Education Faculty REC Chair via email. This includes changes in investigators. The REC Chair will advise as to whether a new application is necessary.

Do keep this clearance letter secure and accessible throughout your study and after its completion. It will be needed when a thesis is examined and when publications are submitted to journals.

Please also submit a brief report to the REC Chair on the completion of the research. This can be done via email. The purpose of this report is to indicate whether the research was conducted successfully and whether any ethics-related matters arose that the committee should be aware of, in order to guide future studies.

Sincerely,



Prof Eureka Rosenberg
Chair: Education Faculty Research Ethics Committee

Page 1 of 1

APPENDIX A: RHODES CLEARANCE CERTIFICATE



REPUBLIC OF NAMIBIA



OMUSATI REGIONAL COUNCIL
DIRECTORATE OF EDUCATION, ARTS AND CULTURE
Team Work and Dedication for Quality Education

Tel: +264 65 251700
Fax: +264 65 251722

Private Bag 529
OUTAPI

Enq: Apollonia Hango
Ref: 13/2/9/1

02 February 2023

To: Ms. Hilya Shikesho
P.O. Box 129
Okahao

Re: Request for Permission to Conduct Research in the Omusati Region Department of Education.

1. This letter serves to notify you (**Ms. Hilya Shikesho**) that permission has been granted to conduct a research focusing on **"Technological Pedagogical Content Knowledge (TPACK): investigating Senior Primary Mathematics Teachers, integration of technology in the classroom"** at a selected senior primary school in Okahao Circuit.
2. In addition, the information to be collected should be for the sole purpose of completing the research study only.
3. You are further informed that although permission is granted, please ensure that teaching, learning and staff members' normal working hours is not disrupted during your study and participation is voluntary.
4. You are further urged to ensure that your investigation methodologies are in compliance with Covid 19 preventative protocols put in place.
5. We hope and trust this exercise will enhance quality education in the Region.

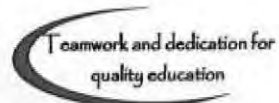
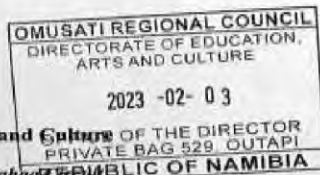
Thank you for your understanding.

Yours faithfully


Mr. Benjamin N. Eiseb

Director of Education, Arts and Culture

Cc: Inspector of Education; Okahao Circuit



APPENDIX B: APPROVAL LETTER FROM OMUSATI DIRECTORATE OF EDUCATION

Hilya Shikesho
P O Box 129
Okahao
Cell: 0813086523
Email:hilyandahambelela@gmail.com
13/02/2023

The inspector of education
Okahao circuit
Private Bag 527
Okahao

COVER LETTER: REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN OKAHAO EDUCATION CIRCUIT

Dear Sir

My name is Hilya Shikesho, and I am presently studying for a Master's degree at Rhodes University. As part of my Masters programme, I am required to conduct research on an aspect of interest to contribute to the knowledge and understanding of the issues under study. I hereby humbly request your permission to conduct a research in your schools and teachers in the Okahao Educational Circuit. This research is titled: Technological Pedagogical Content Knowledge (TPACK): investigating Senior Primary Mathematics Teachers' integration of technology in the classroom in Okahao educational Circuit. The purpose of the study is understand how the senior primary school mathematics teachers develop their TPACK as they integrate technology in mathematics classroom

The study will involve myself administering a survey to the senior primary Mathematic teachers in the circuit; conducting semi-questionnaires with 35 teachers; conducting semi-structured interview with seven teachers; conducting lesson observation with 3 teachers; and focus group interview with seven teachers. I wish to assure your good office that should permission be granted; I will strictly uphold all the ethical standards as required by the Omusati region Department of Education.

This research has been approved by the Rhodes University Ethical Standards Committee, and the Rhodes University Education Department Higher Degrees Committee. During the research, any concerns may be directed to Rhodes University ethics committee, ethics-committee@ru.ac.za and Dr C. Simuja (Supervisor), c.simuja@ru.ac.za.

Thanks in advance for offering me with this professional development opportunity

Yours Sincerely
.....
Hilya Shikesho

Approved by *E. Kauna* 4/10/23
Name of the education inspector *E. Kauna*
Signature *E. Kauna*

OMUSATI EDUCATION COUNCIL
DIRECTORATE OF EDUCATION
THE INSPECTOR OF EDUCATION
14 FEB 2023
OKAHAO CIRCUIT OFFICE
P.O. BOX 580 OKAHAO
TEL: 942 583 252004
REPUBLIC OF TONGA

APPENDIX D: CONSONANT FORMS SAMPLE

SCHOOL PRINCIPAL'S CONSENT FORM

- I understand the aims and purposes of the research study being undertaken by Hilya Shikesho
- Participation in this study by the Mathematics teacher is voluntary, and he or she will have all questions answered to his or her satisfaction.
- The Mathematics teacher is aware that he or she can withdraw from the study at any time without penalty and understands his or her involvement in the project.
- I understand that all information will be treated in the strictest confidence. I understand that all data from this research will be securely stored in password-protected facilities.
- Within these restrictions, the findings may be submitted for publication in national or international journals or presented at educational conferences
- Based on the above understandings, I allow you to conduct your study with the teacher in this school.

DECLARATION BY SCHOOL PRINCIPAL
I Johannes Nampila (full name and surname of Principal) hereby confirm that I give permission to the researcher to conduct the study with a teacher in our school.

Signature of Principal [Signature] Date 14/02/2023

SCHOOL STAMP
2023-02-14
PG 508 128
OK 2-30
OKAHAD CIRCUIT

Appendix E: Semi questionnaire

Introduction

This is an M Ed research questionnaire designed to obtain your views on the **integration of technology in teaching mathematics at your school**. Kindly be open and free as possible. Be assured that absolute confidentiality will be adhered to, and under no circumstances will your details be revealed to a third party. Please answer all questions and to the best of your knowledge. Your responses will be kept completely confidential. Thank you for your participation.

Instruction

Read each question carefully. The questions are followed by possible answers. For each question you read, there are indications on the number of possible choices. Tick in the appropriate box(es) next to the answer of your choice. Kindly respond to **ALL QUESTIONS** to the best of your ability. Your honesty will be appreciated.

SECTION A: TECHNOLOGIES INTEGRATED IN MATHEMATICS CLASSROOM

Respond by putting an (X) under the appropriate heading.

1. Are the following facilities available at the school you are teaching?

Available teaching and learning technologies	Y e s	N o
Computer Laboratory		
Computers/laptops for teachers' use		
Internet connectivity		
Tablets for teachers' use		

2. Which devices did you use in teaching and assessment of learning in mathematics subject?

Devices	Y	N
---------	---	---

used	e s	o
Smartphone		
Tablet		
Laptop		
Desktop		
Ipad		

3. Which of the following technologies/technological means did you use to present your content to the learners in mathematics subject?

Technologies	A I w a y s	O f t e n	Som etim es	L e s s e r e x t e n t	N o t a t a i l
Blackboard collaborate					

Zoom					
WhatsApp groups					
Facebook groups					
SMS					
Radio					
Telephone					
Television programs					
Telegram					
Instagram					
Email					
Skype					
Google Meet					
Ms Team					
Twitter					
Tiktok					
WeChat					

4. Any brief description of how you have been teaching and communicating using technologies or not with learners during the teaching of mathematics?

—

SECTION B: DEVELOPMENT OF TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE DURING TECHNOLOGY INTEGRATION IN MATHEMATIC CLASSROOM

Technology is a broad concept that can mean a lot of different things. For the purposes of this questionnaire, technology is referring to digital technology/technologies. That is, the digital tools we use such as tablets, computers, the internet, ipods, laptops, software programs, and data projectors. for educational purposes. *Please answer all the questions and if you are uncertain of or neutral about your response you may always select neither “Neither Agree nor Disagree”.*

Technological knowledge	S tr o n g l y A g r e e	A g r e e	Nei the r A g r ee norD i s a g r e e	D i s a g r e e	S tr o n g l y D i s a g r e e
I know how to solve my own technical problems.					
I can learn technology easily.					
I keep up with important new technologies.					
I frequently play around the technology.					
I know about a lot of different technologies.					
I have the technical skills I need to use technology.					
	S		Nei the		S

Content knowledge	tr o n gl y A g r e e	A g r e e	r Agr ee	D is a g r e e	tr o n gl y D is a g r e e
I have sufficient knowledge about the mathematics subject I teach					
I can use content in mathematics subject.					
Pedagogical knowledge	S tr o n gl y A g r e e	A g r e e	Nei the r Agr ee	D is a g r e e	S tr o n gl y D is a g r e e
I know how to assess student performance in a classroom.					
I can adapt my teaching based upon what students currently understand or do not understand.					
I can adapt my teaching style to different learners.					
I can assess student learning in multiple ways					

I can use a wide range of teaching approaches in a classroom setting.					
I am familiar with common student understandings and misconceptions.					
I know how to organize and maintain classroom management.					
Pedagogical content knowledge	S tr o n gl y A g r e e	A g r e e	Nei the r Agr ee norD	D is a g r e e	S tr o n gl y D is a g re e
I can select effective teaching approaches to guide student thinking and learning in mathematics subject.					
I have various ways and strategies for developing mathematics subject content.					
Technological content knowledge	S tr o n gl y A g r e e	A g r e e	Nei the r Agr ee norD	D is a g r e e	S tr o n gl y D is a g re e

I know about technologies that I can use for understanding and presenting subject content.					
Technological Pedagogical knowledge	S tr o n g l y A g r e e	A g r e e	Nei the r Agr ee	norD is a g r e e	S tr o n g l y D is a g r e e

I can choose technologies that enhance the teaching approaches for a lesson.					
I can choose technologies that enhance students' learning for a lesson.					
Access to technologies at my school and home has caused me to think more deeply about how technology could influence the teaching approaches I use in my teaching.					
I am thinking critically about how to use technology in my teaching.					
I can adapt the use of the technologies that I am learning about to different teaching activities.					
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.					
I can use strategies that combine content, technologies, and teaching approaches that I learned about in my coursework in my classroom.					
I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/or district.					
I can choose technologies that enhance the content of a lesson.					
Technological and Pedagogical content knowledge	Strongly	Agree	Neither Agree nor Disagree	Disagree	Strongly

	A g r e e	e		r e e	D i s a g r e e
I can teach lessons that appropriately combinesubject content, technologies, and teaching approaches					

Appendix F: Semi-Structured Interview

1. What are your views on the integration of technology in teaching mathematic lessons?

.....
.....

2. What were your first experiences teaching with technology in mathematics lessons?

- Tell me about how you have used technology in your classes?
- Tell me about assignments you have designed that require technology

4. Has your teaching with technology changed over the years?

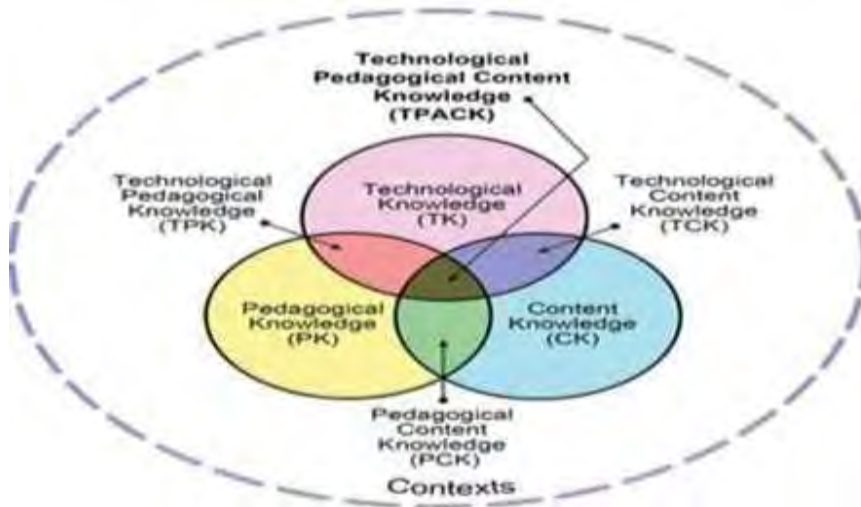
- Give example of the things you have worked on since you integrated technologies in your classroom

5. Has teaching with technology gotten easier or more difficult?

- What are some challenges you have experiences teaching with technology?
- What are some challenges you anticipate to experience in the future using technology for teaching mathematics?

7. What have you learned about your ability to teach mathematics with technology?

- How would you describe your experiences learning to use technology for teaching?



8. Identify based on the picture, the knowledges (construct) that resonate with ways you have integrate technology in teaching
9. How would you describe your own TPACK?
10. Have you had experiences teaching with technology that you would not repeat?
11. How has teaching with technology factored in your work outside of the classroom?

Appendix G: Observation tool

Observation Schedule Form

1. Name of observer	
3. Name of school	
5. Grade and class	
8. Observation Date	
9. Observation Time	

1. WHAT IS THE TEACHER'S LESSON OBJECTIVES IN THE LESSON?

(If possible, I will speak with the teacher before the observation begins and complete this section with the following information: What is the teacher planning to do? Are there particular outcomes the teacher is hoping for? Is there evidence of pedagogical intention to integrate technologies in the lesson plans? How does the teacher plan to integrate technology in the lesson?)

2. WHAT TECHNOLOGY RESOURCES ARE PRESENT IN THE CLASSROOM? (Describe the technology resources present in the classroom and include the number of each)

PART 2: LESSON OBSERVATION GUIDE

In this section, I will take detailed notes in real time as I observe classroom activities. The following questions serve as guidelines for what I will document during the classroom observation.

STRUCTURE AND CONTENT OF THE LESSON (CK)

I will describe the structure of the lesson that I will observe:

- What is happening in the classroom? What are the teacher and the learners doing?
- Does the teacher present some kind of introduction 'hook' (story or problem or information or brainstorm to engage the learners on the topic?)
- Does the teacher provide appropriate information and clear instructions/guidelines for the class activities?
- Does the teacher have various ways and strategies of demonstrating his/her own mathematics

understanding of the content to be taught as prescribed by curriculum?

- Is the teacher able to answer most of the questions asked by the learners?

USE OF TECHNOLOGY TO SUPPORT CONTENT PRESENTATION (TCK)

- What technologies were being used in the lesson by the teacher and the learners?
- How is the technology being used by the teacher to present mathematics lesson content?
- How does technology shape the way the lesson progresses?
- Is the teacher experiencing difficulties in their use of the technology/device? Are they able to troubleshoot?

USE OF TECHNOLOGY & PEDAGOGICAL STRATEGIES (TPK)

- What specific technologies does the teacher combine with certain pedagogical strategies during lesson delivery?
- How does the technology support the teaching strategies?

APPLICATION OF TECHNOLOGY, PEDAGOGY, AND CONTENT KNOWLEDGE (TPACK)

- How do the teachers' pedagogical strategies and choice of technology fit together with the lesson content?
- How are the teachers using the technology to interact with content?

APPENDIX H: Focus group interview guide

Greetings. My name is Hilya Shikesho. I am very pleased that you have agreed to join me today. We are here to discuss a range of issues concerning developing your technological pedagogical content knowledge. Please allow me to take this opportunity to explain a little bit about focus group interview. Focus group interview are economic interviews used to gather information informally from a small group of individuals who have a common interest in a particular subject, in this instance, the development of technological pedagogical content knowledge in primary school mathematics teachers in Okahao Education circuit. In focus group interview, there are no right or wrong answers. I encourage everyone in this room to participate in the discussion. I am pleased that you can be part of this group because I think you have important ideas regarding the development of technological pedagogical content knowledge.

Don't hesitate to speak up when you have a point you would like to make. I will be moderating the session and moving us along so that we evaluate all the key subjects on our agenda. My role today is to see that we have a productive discussion and to summarise the group's feelings. I will not refer to any participant by name in the reports that I will prepare. The information will be kept confidential and used only for research purposes. You are free to withdraw from the discussion or indicate whenever you feel uncomfortable. This session will be recorded; therefore, I kindly ask you to indicate by signing on the consent forms if you agree.

INFORMED CONSENT FORM: FOCUS GROUP INTERVIEWS AUDIO RECORDINGS

I will conduct all the focus group interview with field note records and audio recordings. If you do not wish to be audio recorded, the responses will be conducted without audio. If you do not wish certain parts of the response to be audio recorded, the audio can be switched off for these parts. The response field notes will be written up for the research without identifying the speakers. Part of the response audio recording will be transcribed into written form without identifying the speakers. The field notes and audio recordings will be erased when the research dissertation has been completed, not later than six months after completion.

Please tick the following boxes to indicate whether you have read the information and understand how you will be invited to participate in the focus group interview:

- ☐ I understand that participation in the focus group interview is voluntary and that I am free to withdraw my consent at any time until the completion of the sharing circle.

- ☐ I understand that all the information gathered in the focus group interview will be kept strictly confidential and that my name and school name will not be included in any reports.
- ☐ I understand that the focus group interview can be audio recorded, and I am free to withdraw my consent to be audio recorded.
- ☐ I understand that I may ask that the recorder be turned off at any point during the focus group interview if there is something that I do not want recorded.

PLEASE TICK ONE OF THE FOLLOWING BOXES TO INDICATE WHETHER OR NOT YOU AGREE TO TAKING PART IN THE RESEARCH FOCUS GROUP INTERVIEWS:

- ☐ I AGREE to take part in the focus group interview.
- ☐ I DO NOT AGREE to take part in the focus group interview.

PLEASE TICK ONE OF THE FOLLOWING BOXES TO INDICATE WHETHER OR NOT YOU AGREE TO TAKING PART IN THE FOCUS GROUP INTERVIEW WITH AUDIO RECORDING:

- ☐ I AGREE to taking part in the focus group interview with audio recording ☐
☐ I DO NOT AGREE to taking part in the focus group interview with audio recording

SIGNATURE: _____ DATE: _____

FOCUS GROUP INTERVIEW QUESTIONS (APPENDIX E)

1. Which technologies do you use in your teaching and for what purpose(s)? Please freely explain.
2. Explain how you socially interact with your colleagues as you integrate technology in your classroom. Do you think the interaction assisted in developing your technological pedagogical content knowledge? Please elaborate with an example.
3. In your view, in what ways do access to, and your interaction with various technological tools, created opportunities for you to develop technological pedagogical content knowledge?
4. Explain some of the technological challenges you encountered during your teaching. How did you overcome these?

5. In your view, does the use of technology open new opportunities in your teaching?
6. Based on your experiences of teaching with technology, what noticeable TPACK component (s) were you able to identify in your teaching? How? Why?
7. Based on your experience of integrating technology in your classroom, how would you describe your own TPACK and what contributed to its development?
8. Based on your overall experiences of technology integration, how important (or not) is it for primary school mathematics teachers in rural schools to develop TPACK?

