Assessing Rural Senior Primary School Natural Science Teachers' TPACK: A Case Study

by

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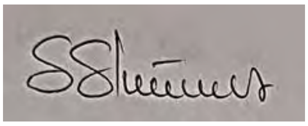
DECLARATION

I, Secilia Silvanus, declare that the contents of this thesis represent my unaided work and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Rhodes University.



ABSTRACT

In today's world, technology has changed how people live and behave. The influence of technology contemplates a similar change in the education processes of teaching and learning. Many governments worldwide invest hugely in providing technological tools and facilities and training teachers to improve teaching and learning. The availability and access to technologies in schools seem to offer teachers opportunities to develop technological knowledge and integrate technology into teaching. Literature indicates that teachers must possess technological pedagogical content knowledge (TPACK) to integrate technology into teaching and learning processes effectively. However, other scholars have also suggested that teachers' TPACK develops and is shaped by many contexts. This study, therefore, sought to assess the rural senior primary Natural science teachers' TPACK. This qualitative case study was conducted with senior primary Natural science teachers in the educational circuit of Endola. An interpretive paradigm underpinned the study. The study employed semi-structured questionnaires, semi-structured interviews, focus group interviews, and observation to collect the data. The study used the TPACK as a theoretical and analytical framework. The study results showed that participants had a firmer grasp of subject content (CK) and traditional teaching methods (Pedagogical Knowledge - PK and Pedagogical Content Knowledge - PCK) compared to technological knowledge (TK) and technology-based pedagogies (Technological Pedagogical Knowledge - TPK, Technological Content Knowledge - TCK, and Technological Pedagogical Content Knowledge (TPCK). Findings support that the participants draw upon sources of Technological Pedagogical Content Knowledge (TPACK) closely aligned with Content Knowledge (CK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK) to integrate technology. The study included inadequate professional development, teachers' attitudes, insufficient hardware and internet connectivity, limited technological knowledge, time constraints, and restricted access to technology tools and resources as obstacles for teachers attempting to incorporate technology into their classrooms effectively. Furthermore, the data highlights ICT training and teachers' interest as enablers that motivated participants to integrate technology into their teaching practices. Therefore, the study recommends professional development programs focusing on providing science teachers with practical skills to utilise different technologies and address common technical issues.

Keywords: Natural Science teachers' TPACK, technology integration in teaching, TPACK and teaching context, measuring TPACK.

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DEDICATION

I dedicate this work to the Almighty God, my savior, to my late mother Marth Ndapewoshali Hamunyela, I wish she was still alive to see my work, and to my children: Ndalinoshisho, Ngondjodi, Tulinawa, Mekeliwa, Pandulo, and Pendapala. I neglected you many times to complete this project. Let my hard work be your source of inspiration.

LIST OF ACRONYMS AND MEANINGS

ACRONYMS MEANING

CK: Content Knowledge

DSF: Digital Skills Foundation

FGI: Focus Group Interviewer

SP: Senior Primary

ICDL: International Computer Driving Licence

ICT: Information Communication Technology

MoE: Ministry of Education

MoEAC: Ministry of Education, Arts and Culture

PCK: Pedagogical Content Knowledge

PDP: Professional Development Programs

PK: Pedagogical Knowledge

QP: Questionnaire Participant

RQ: Research Questions

SAARMSTE: Southern Africa Association for Researchers in Mathematics, Science and Technology Education

SSI: Semi-structured interviewers

TCK: Technological Content Knowledge

TK: Technological Knowledge

TPACK: Technological Pedagogical Content Knowledge

TPK: Technological Pedagogical Knowledge

OB: Observation

OB-P1: Observation Participant 1

OB-P2: Observation Participant 2

OB-P3: Observation Participant 3

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CHAPTER 1: INTRODUCTION

1.1 Introduction

The 21st century has seen technology assume a significant role in many people's lives (Alismail & McGuire, 2015), with technological devices now a crucial aspect of our daily existence (Farisi, 2016). Technology encompasses a wide range of concepts, with this study focusing on emerging digital technologies, including commonly used digital devices and tools in schools such as computers, laptops, handhelds (tablets/cell phones), data projectors, interactive whiteboards, document viewers/ document cameras, software programs, mobile applications, simulations, and Internet services. This study interchangeably uses the terms technology and Information Communication Technology (ICT).

The impact of technology on human life, work, and education has been the focus of many studies (Raja & Nagasubramani, 2018; Saladino et al., 2020; Guribye & Nyre, 2017), and interest in how technology is used in education teaching and learning processes has been on the rise (Mishra & Koehler, 2009). Debates and discussions on the dynamic influence of technology in education have taken place, with some researchers reporting its benefits and suggesting that technology improves the teaching and learning process (Hechter & Vermette, 2014; Jaggars & Xu, 2016; Turugare & Rudhumbu, 2020). Other scholars have acknowledged the potential of technology in promoting learner-centered approaches (Kelley & Knowles, 2016; Dasgupta et al., 2019; Dlamini & Nkambule, 2020).

Technology integration advocates in education believe it has affordance in teaching (Valanides, 2018; Backfisch et al., 2021). For instance, Herro and Quigley (2017) urged that technology integration in the classroom offers numerous potential benefits, including aligning teaching and learning processes with the curriculum requirements and providing teachers with new opportunities to communicate with their students. In their research handbook on teaching, Fishman, Dede, and Means (2016) claimed that technology can empower teachers with innovative tools and opportunities for enhancing education. These scholars in the educational technology discipline recommend technology integration in teaching and learning processes.

Although technology has been widely recognised and accepted as a means to support effective pedagogies, it has its challenges. These include attitudes, beliefs, resistance to technology in the classroom, availability of technological devices and facilities, trained teachers, adaptability, technical maintenance, and support (Johnson et al., 2016; Dhawan, 2020). However, despite these challenges, many governments and education stakeholders are investing heavily in providing technological training to teachers, as well as providing specialised tools and facilities (Mutie, 2016; Naidu & Laxman, 2019; Altae, 2021), with the hope that technology can improve teaching and learning.

The impact of integrating technology into education has also been acknowledged and recommended in the context of science education. Numerous studies in the existing literature emphasise technology's myriad opportunities for teaching and learning science (Kelley & Knowles, 2016; Raja & Nagasubramani, 2018; Williamson et al., 2020). For instance, Potkonjak et al. (2016), in their systematic review paper about virtual laboratories for education in science, technology, and engineering, have revealed that new emerging technologies can overcome some of the potential difficulties in science teaching. They point out that using virtual labs for teaching shares many science learning processes, such as simulations and creating a realistic ambiance. Papanastasiou et al. (2019) asserted that virtual reality and argument technologies do extensive experiments, allowing students to explore the virtual environment and engage in hands-on learning activities, enhancing their understanding of complex concepts. Furthermore, Ünlü and Dökme (2020) stressed that information and communication technology (ICT) can enhance inquiry-based learning in science. All these authors highlighted the affordance of technology to improve both the investigative and practical aspects of science teaching and learning.

In addition, technology integration in science teaching has also been recognised and acknowledged by international education bodies, such as the National Science Foundation (NSF) and the Association of Science Teacher Educators (AMSTE) (Czerniak & Johnson, 2014; National Research Council, 2011). Developing countries in Africa, such as South Africa, Kenya, Ghana, and Nigeria, have also adopted technology in education, believing it can add value to teaching and learning in general and in a science classroom (Harrison & Wamakote, 2020;Simuja,2018).

Furthermore, despite efforts to advocate technology integration in education, teachers report significant gaps in knowledge and skills when effectively integrating technology into their teaching methods and content (Yang & Chen, 2021). Most teachers, including those in rural schools, need more technological knowledge to integrate technology into pedagogies and content.

Generally, schools in rural areas, particularly in developing nations, are situated in remote and under-developed regions (Tadesse & Muluye, 2020). Consequently, teaching and learning science in these schools encounters more formidable and distinctive challenges compared to schools in urban areas. These challenges stem from the low socioeconomic status of the communities and the inadequate provision of services, leading to a lack of fundamental school infrastructures like libraries, classrooms, and essential facilities such as science laboratories (Kalonde, 2017; Timmis et al., 2019; Parveen, & Tran, 2020). These resources are crucial for enhancing science teaching in rural primary schools. To address these challenges, teachers often turn to educational technologies. However, these teachers' limitations in effectively integrating technology into science teaching outweigh their strengths. This issue arises mainly because many teachers need more expertise to incorporate technology into their teaching methods (Voogt & McKenney, 2017).

Most scholars, such as Tondeur et al. (2016), Adnan and Tondeur (2018), and Shurygin et al. (2022), found that teacher-training programs, in general, do not provide future teachers with the kinds of experiences necessary to prepare them to use technology effectively in their classrooms. Traditionally, teachers' knowledge to cater to the learners' learning needs was considered adequate when they possessed a deep understanding of the subject matter (content knowledge) and employed suitable teaching methods (pedagogical knowledge), a combination referred to as Pedagogical Content Knowledge (PCK) by Shulman (1986). Even though Shulman's concept of Pedagogical Content Knowledge (PCK) remains essential, educational technology scholars (Mishra & Koehler, 2006) have recognised the need for an additional kind of knowledge to support the integration of content-based technology in teaching and learning context. These scholars urge that for integrating technology in the classroom, teachers ought to be able to combine technology with pedagogy and content seamlessly. This intricate knowledge necessary for teachers to effectively integrate technology in teaching is called technology, pedagogy and content knowledge (TPACK).

Essentially, TPACK refers to knowledge that aids teachers in understanding how technology can transform their pedagogical strategies and content representations and how it can impact students' understanding of specific topics (Redmond & Lock, 2019). Koehler and Mishra (2009) suggest teachers' technological pedagogical content knowledge (TPACK) as an underlying basic knowledge that teachers must acquire to integrate technology into their teaching effectively.

Moreover, Harris, Mishra and Koehler (2009) stress that teachers who possess technological pedagogical content knowledge can effectively integrate technology into their teaching, make informed decisions about the academic content they will teach, the pedagogical methods they will use to teach it, and how they will assess student learning. Carrillo Flores (2020) has also supported the idea that teachers who effectively integrate technology can make practical decisions regarding academic content, pedagogical methods, and assessment. Incorporating educational technologies effectively requires teachers to plan their instruction based on curriculum guidelines carefully, students' learning requirements, the capabilities and limitations of available technologies, and the specific conditions of the school and classroom setting (Mahzam, 2016).

Building on the insights provided by these authors regarding teachers' knowledge of technology integration in teaching, the possession of Technological Pedagogical Content Knowledge (TPACK) by rural science teachers would imply that they are capable of effectively integrating appropriate educational technologies to enhance the teaching of science content while taking into account the specific context and their learners' learning needs. Besides, Roussinos and Jimoyiannis (2019) suggest that teachers' TPACK differs from teacher to teacher based on their teaching context. There are no standardised or fixed criteria nor a 'one-size-fits-all' approach to defining the nature of Technological Pedagogical Content Knowledge (TPACK) or how it evolves in teachers (Jen et al., 2016). As a result, the inquiry into how teachers acquire, possess and use TPACK has been an ongoing exploration in the educational technology community. It continues to be a topic of recent academic research in educational technology.

1.2 Background of the study

The Ministry of Education in Namibia recognises the importance of integrating technology into teaching and learning. This recognition is acknowledged with the release of the National Policy for Information and Communication Technology (ICT) in education in 2006 (MoE, 2006). In addition to the National Policy for ICT in Education, technology literacy is firmly embedded in the National Curriculum for Basic Education (NCBE) document (MoE, 2016). These policies and frameworks outline the use of ICT in schools to be relevant, responsive and adequate to meet the challenges of 21st-century teaching and learning (MoE, 2016).

In support of ICT in education, the Namibian Ministry of Education is doing its best to ensure that teachers and learners have access to technological tools and acquire knowledge on the use of the technological tools relevant to education. As stated in the National Policy Framework for ICT in Education, the Ministry of Education took several initiatives to equip some public schools with ICT facilities and empower teachers with technological knowledge and skills (MoE, 2016). For example, the Ministry of Education provided technological infrastructure, facilities and training for teachers, including science teachers, toward achieving 21st-century teaching skills through the Millennium Challenge Account (Chirimbana &Ugwanga, 2019; Waiganjo & Paxula, 2020). Other programs include school NET, Education Training Sector Improvement Programmes (ETSIP), and International Computer Driving Licence (ICDL). These programs empower teachers to integrate technology into their classrooms to enhance teaching and learning.

Technology in teaching in Namibian classrooms is not free of problems and constraints. There are issues with adequately trained staff, adequate and appropriate devices, and funding (Zydney et al., 2019) coupled with adaptability, connectivity and compatibility issues. Despite these problems, technology is seen to have the ability to present rich science learning environments for learners and teachers in some schools in Namibia. It is observed by Gul and Akcay (2020) that technology integration in science teaching enhances learners' scientific inquiry skills, scientific reasoning skills, and other general thinking skills. Husnaini and Chen (2019) believe that emerging digital technologies, such as Virtua Lab, can help learners acquire scientific skills such as problem-solving, gathering more relevant information, carrying out investigations, and analysing and interpreting data more efficiently using digital technologies. Some science concepts are challenging to explain and present; hence, Gandhi and Patel (2018) noted that using technologies such as computers and projectors can create an image of reality through visualisation, which could make learners understand and visualise the content. These authors also believe that digital technology integration in science teaching, as in some schools in Namibia, could boost learners' interest in pursuing their careers in science.

In light of the benefits of using technology in science teaching, some teachers in Namibia, particularly teachers in the Endola education circuit, own or access technological tools installed in schools and continuously attend ICT training (Chirimbana & Ugwanga, 2019; Wanganjo & Paxula, 2020). As alluded to earlier, from 2015 to 2022, several teachers, including science teachers in the Endola circuit, have received ICT training which the Ministry of Education has offered in collaboration with the University of Namibia (UNAM), University of Science and Technology (NUST), World Vision International and UNESCO through the continuous professional development (CPD) programs. Some training were conducted at the cluster centers in the afternoon after school hours. The training covered the technical use of computers and laptops such as MS Word, MS Excel, MS Access, MS PowerPoint, the Internet, e-mailing, and digital literacy. After this training, some teachers were given laptops and certificates of attendance.

While technology training is essential in Endola Circuit, this approach to teacher development suggests that teachers should merely be trained to acquire knowledge on using specific technology (Voogt & McKenney, 2017). However, the Ministry of Education anticipates that by demonstrating technology skills to use various hardware and software, the teachers, including science teachers, can integrate technologies into their teaching effectively. The contention in this study is not that technology/ICT training workshops are not helpful. However, despite their valuable contribution, the ICT training focuses on acquiring specific technology skills without understanding the reciprocal knowledge between technology, pedagogies and content (Tanak, 2020). In other words, merely knowing how to use a specific technology differs from learning to teach with it. However, most science teachers in Namibian, including those in rural schools, are observed integrating innovative technologies in their practice from time to time and at their discretion and effort.

This study concludes that most science teachers, especially in Endola education circuit schools, are integrating various educational technologies, most likely unknowingly or without any guidelines for developing technological pedagogical content knowledge. Besides that, Mishra and Koehler (2006) believe that teachers' TPACK develops in different contexts. Therefore, the study intends to qualitatively assess the technological, content, and pedagogical knowledge senior primary natural science teachers developed as they integrate technology into their teaching in the Endola Education circuit.

1. 3 Problem statement

The potential benefit of using technology in education and, specifically, in Natural Science classrooms, is explored and commended by many scholars such as Azmi (2017), Paul and Jefferson (2019), Shambare and Simuja(2022). Education debates and discourse now focus on how best technology should be integrated into science teaching and learning (Nepo, 2017). The sole introduction of technology into science teaching will not necessarily capitulate the needed results for learners to optimise their learning needs. Instead, to integrate technology in teaching and learning, teachers, including science teachers, should know about a specific technology, the enablers and constraints of the technology, and use adaptive strategies coupled with how to use these properties of technology to enhance comprehensive learning (Mishra & Koehler, 2006). These knowledge ideas have huge implications on how science teachers regard their role as teachers and what they consider necessary to advance these education aspirations (Hew & Brush, 2007; Nepembe and Simuja,2023).

As indicated in the previous section, the Namibian education curriculum acknowledges the potential of technology in the teaching and learning process across its curriculum policies and regulations and recommends integrating technology into teaching. Even though the Namibian Ministry of Education, through the education policies and regulations, acknowledged and adopted the integration of technology in education, guidelines on how natural science teachers should integrate technology into their subjects still need to be developed. Moreover, in collaboration with other stakeholders in education, the Ministry of Education provides technological devices, facilities and training for teachers in different parts of the country, including teachers in the Endola circuit. However, technological training focuses more on training teachers to gain specific technological skills, which does not necessarily emphasise the pedagogical use of technology (Uerz et al., 2018).

Interestingly, out of their effort and without guidelines, natural science teachers in rural primary schools in the Endola education circuit and other schools in Namibia somehow integrate technologies into their teaching. As such, this study assumes that such practices and context could offer them opportunities to develop specialised knowledge of technological pedagogical content knowledge (TPACK), as suggested by Mishra and Koehler (2006). However, effective technology integration in teaching requires teachers to possess specialised content knowledge, technological knowledge, pedagogical knowledge and their relations (Mishra & Koehler, 2009).

Moreover, there is a scarcity of study findings that provide evidence to describe TPACK possessed by natural science teachers in the Endola education circuit. This study suggests a need for more empirical evidence about the uniqueness of the various constructs of the natural science teachers' TPACK and their experience shaping technology use in teaching. The studies available in Namibia are those conducted by Jackson et al. (2011), Yatileni and Yatileni (2019), Nuuyoma (2012), Shihomeka and Amadhila (2020); Haipinge (2016); Osakwe et al., (2017); Ying et al. (2021) Anyolo et al. (2018). For instance, Osakwe et al.'s (2017) research examined learners' and teachers' perceptions of mobile learning. In contrast, Yatileni and Yatileni (2019) examined teachers' perceptions of using ICT in teaching and learning. Therefore, this qualitative study is conducted to fill the knowledge gap. Hence, this case study intends to assess rural senior primary Natural science teachers' TPACK in a selected education circuit and identify the contextual development of self-reported and modeled TPACK.

1.4 Research purpose and questions

The above sections set out the background and rationale for this study, which revolves around technology adoption in education, technology integration in teaching and learning and teachers' knowledge of technological pedagogical content knowledge to integrate technology in teaching. To explain or explore the intention of a research study, research questions should be set (Harrison et al., 2017), and they should be clear and specific (Cohen et al., 2018). Hence, this section outlines the research purpose and sets out the questions for this study.

1.4.1 Purpose and Objectives

Purpose

This study aims to explore and assess the rural senior primary natural science teachers' TPACK.

Objectives

- To assess the perceptions of their understanding of TPACK constructs.
- To determine sources of TPACK rural senior primary natural science teachers draw on and experiences shaping their technology use in teaching.

1.4.2 The research questions

The research questions of the study are:

1. What are rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs in Namibia?
2. What sources of TPACK do rural senior primary natural science teachers draw on and experiences shaping technology integration in their teaching in Namibia?

1.5 Rationale for the Study

The success of technology integration in teaching lies in teachers' technological pedagogical content knowledge. The role of teachers' TPACK for technology integration is emphasised by Mishra and Koehler (2006), who argued that to integrate technology, teachers effectively bring TPACK into play any time they teach. In support of effective technology integration, Tondeuret et al. (2017) commented that teachers are the keys to the successful implementation of technology in the education system. Both authors cement the notion by Mirzajani et al. (2016), who argued that teachers have always been essential in utilising and implementing innovations.

Furthermore, Mishra and Koehler (2013) note that teaching is a context-bound activity, and teachers who possess TPACK use technology to design learning experiences tailored for specific pedagogies crafted for particular content as instantiated in certain learning contexts. This emphasises the role of context in teaching and learning. Different teaching environments pose unique in every interaction between technology, pedagogy, and content (Pareja Roblin. Hence (2018), there is no universal solution to the problem of technology integration. Often, teachers make their own decisions to inter-twin technology, pedagogy, and subject matter based on their classroom context. As such, teachers face a significant decision in their teaching context.

Teachers own and have access to technologies, and some have attended ICT training. Such opportunities offer them the chance to develop TPACK. However, Mishra and Koehler (2006) argued that approaches that develop technological knowledge in isolation, where technology literacy is the goal, fail to assist teachers in the development of the educational uses of those tools and do not capture the scope and unique flavour of knowledge needed to teach with technology effectively. In confronting the ways ICT training offers, teachers in the Endolla circuit are observed playing active roles as curriculum designers (Tondeur et al., 2017;Simuja,Kraus and Conger,2016),where they find ways to interweave technology, content, and pedagogy in their classroom contexts. Science teachers in the Endola educational circuit, being the designers of their curriculum regarding technology integration, offer a valuable contribution to education in a rural school context.

The literature indicates no empirical research reports on exploring the science teachers' TPACK in the Endola circuit and Namibia. Sustained efforts to uncover past studies have shown no pre-existing research based on teachers' TPACK except the reflections on the evaluation of ICT policy and installation of ICT classrooms in Namibia. Thus, this research aims to contribute to the field by exploring and assessing science teachers' TPACK. The findings of this exploration could inform the curriculum developers on what to focus on when they design teachers' continuous professional development programs on ICT.

1. 6 Theoretical Framework

The theoretical framework underpinning this research study is the Technological Pedagogical Content Knowledge (TPACK) framework by Koehler and Mishra (2006). These scholars argued that pedagogical uses of technology necessitate the development of a complex, situated form of knowledge, termed technological pedagogical content knowledge (TPACK). Baran and Uygun (2016) describe TPACK as a theoretical framework that facilitates the integration of educational technology into teaching methods. The framework outlines the essential knowledge domains teachers need to effectively incorporate technology in their educational settings. TPACK expands upon Shulman's Pedagogical Content Knowledge (PCK) theory (1986) by adding technological knowledge (TK).

The TPACK framework emphasises technology knowledge as a crucial component for teachers to integrate technology into their pedagogy. Mishra and Koehler (2008) described content, pedagogy and technology as the essential knowledge domains of good teaching. Teachers need the necessary content, pedagogical, and technological knowledge and skills to teach effectively with technology. Using the TPACK framework in this study could provide lenses for the researcher to gain insight into the Technological Pedagogical Content Knowledge (TPACK) that rural senior primary natural science teachers have as they integrate technology into their teaching.

1.7 The research methodology

The methodology articulates the logic and flow of the systematic process to gain knowledge about a research problem (Kivunja & Kuyini, 2017). It describes how the research study was conducted, allowing the leaders to evaluate the findings' reliability, validity, authenticity and trustworthiness.

An interpretive paradigm will underpin the study to gain an in-depth understanding of rural senior primary natural science teachers' TPACK. Cohen, Manion and Marrison (2018) assert that an interpretive paradigm is appropriate when a researcher intends to narrate and make meaning of how people make meaning of the world by interpreting events and situations. The interpretive paradigm is adopted to provide an understanding of how rural senior primary natural science teachers perceive their sense of technological pedagogical content knowledge (TPACK) constructs as well as to get an insight into sources of TPACK they draw on to use technology in teaching and the experiences shaping their use of technology in education.

1.7.1 Site and Participant Selection

The sites of choice for this research study will be the public senior primary schools in the Endola Education Circuit, Ohangwena region, in northern Namibia. The senior primary schools will be purposively selected as they are located in a rural area and are connected to electricity. Furthermore, these schools are equipped with some technologies offered by the government and non-government organisations. The site selection is further justified as teachers, including science teachers, own technology devices and receive ICT training through continuous professional programs. This background provides insight into how rural science teachers model and self-report their technological knowledge into pedagogies and content.

1.7. 2 Data collection and analysis

Four data collection strategies will be employed. These included semi-structured questionnaires, observation, individual semi-structured interviews and focus group interviews. The printed questionnaire copies will be distributed to the teachers during the science circuit meetings. The questionnaire will include biographical and background information, technology access and use, the teachers' understanding of technological pedagogical and content knowledge, and the teacher's pedagogical content knowledge to integrate technology. Biographical and background information was included to establish the teachers' age, gender, teaching experience, teaching qualifications and the grades they teach. Technological access and use items sourced information about the availability of teaching and learning technology devices at their school and how they use them. The teacher's understanding of the technological pedagogical and content knowledge section requires the participants to describe TPACK constructs. Science teachers' TPACK to integrate technology section forms a significant component, and it sourced information about the teachers' perception of their understanding of each TPACK construct, TK, CK, PK, PCK, TCK, TPK, and TPCK.

The study purposely intends to select eight teachers for interviews and focus groups based on their indication in the questionnaire that they use technology in their teaching and provided consent. The eight selected teachers will be interviewed individually, and semi-structured questions will guide the conversation. Three of the eight teachers chosen for interviews will be selected for classroom observation after their informed consent is obtained. After the observation sessions, a focus group interview will be conducted with all eight teachers interviewed individually. The individual interviews, observation, and focus groups focus more on sourcing information about teachers' technology access and use, teachers' understanding of TPACK constructs, TPACK constructs valued when integrating technology and experiences shaping the use of technology in teaching.

1.8 The Significance of the Study

The study findings could lead to educational advancements in rural regions, especially in teaching natural science. It intends to uncover how rural science teachers perceive their understanding of the TPACK constructs. By focusing on these teachers' Technological Pedagogical Content Knowledge, the study aims to understand the connection between teachers' technology use, pedagogical strategies, and subject matter content knowledge. Secondly, the study opens up insights into rural senior primary science teachers' experiences and orientations towards technology, which can be utilized in designing teacher training programs and educational policies.

The study uses a qualitative approach and analysis of teacher perception of their TPACK constructs, the sources of TPACK they draw on and experiences shaping technology use in their teaching. Such multifaceted data could provide rich insights into the barriers and facilitators of technology integration in rural education contexts.

The findings from this study might also provide recommendations to the Ministry of Education and stakeholders in Namibia education. These recommendations could address the need for teacher ICT training and professional development programs. Significantly, the study might identify several gaps in the existing research, which could set the stage for future research, especially concerning rural elementary science teachers' technological, pedagogical, and content knowledge.

1.9 Definition of terms

For clarification purposes, the researcher chose to offer a brief explanation of the following critical terminologies used in the research purpose, objectives and main question and sub-questions:

ICTs: ICT refers to various technological devices, facilities, and resources to enhance and support the teaching and learning process. ICT is an umbrella term that includes any communication device or application, encompassing radio, television, cellular phones, personal digital assistants, computer and network hardware and software, satellite systems, and so on, as well as the various services and applications associated with them, such as video conferencing and distance learning.

Technology is the collection of techniques, methods, processes, and tools used to create, modify, and utilise goods and services to solve problems, enhance efficiency, and achieve specific goals. It encompasses a wide range of concepts, such as communication devices and applications, emerging digital technologies and various services and applications associated with digital devices and tools used in schools. Technology and ICT are used interchangeably in this study.

Continuous professional development: Refer to the learning programs offered to in-service teachers to help them develop and improve their professional practice.

Rural schools – refer to schools located significant distances away from urban centers that are often geographically isolated. Rural schools often serve a large population of poor learners and are characterised by a lack of adequate essential school facilities and resources.

Technological pedagogical content knowledge - refers to knowledge, skills and understanding teachers need to integrate technology into their teaching effectively. It is a knowledge underlying significant and profoundly skilled teaching with technology.

TPACK constructs/ domains - the knowledge constructs teachers need to integrate technology in education processes effectively.

Technological Pedagogical Content Knowledge Framework outlines the essential knowledge domains teachers need to effectively incorporate technology in their teaching.

Natural science - is the subject within the natural scientific area of learning. The issue aims to equip learners to understand scientific processes and be able to apply scientific thinking and skills. Natural Science is a compulsory subject offered in the senior primary phase (grades 4 to 7) of the Namibian curriculum for primary education.

Senior primary teachers - Senior primary school teachers work with learners at the senior primary education level, which typically encompasses grades 4 to 7 in the Namibian context.

Educational circuit - In the Namibian context, it refers to the department responsible for advising and supporting schools. Each educational circuit has an office and schools allocated under its jurisdiction.

1.10 Structure of the Research Study

The research structure outlines the flow of components/ chapters that form part of the study. This thesis is organised into six comprehensive chapters that collectively examine the complex viewpoint of the senior primary natural science teachers' technological pedagogical content knowledge in the Endola education circuit. Each chapter offers a distinct perspective and contributes uniquely to the thesis.

For this study, the structure is firstly outlined with a diagram showing the chapters/components of the research. Figure 1.1 provides a flow diagram representing the structure of the thesis.

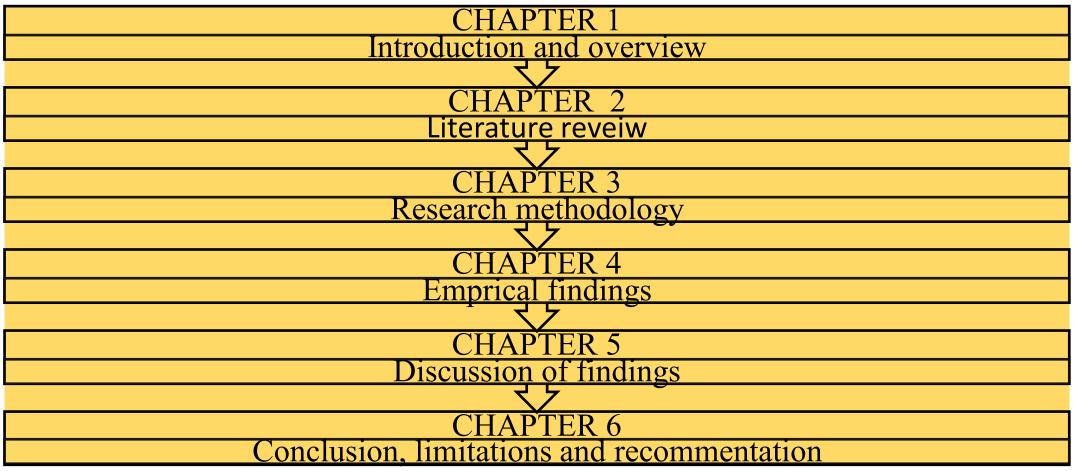

Figure 1.1: Structure of the thesis

The structure of the rest of the thesis is as follows:

- Chapter One**,** the preface of this thesis, mainly established the fundamental framework for the entire research endeavor. It presents the introduction, background, problem statement and the rationale of this research study. The chapter carefully clarifies the research objectives and questions that will guide the research journey, providing a clear sense of purpose and direction for the study. The concise yet comprehensive preview of the subsequent chapters is meaningfully woven, offering readers a valuable road map to navigate through the following complex content. The chapter ended with the outline of definitions of the key terminologies used in the research and the flow diagram representing the structure of this research study.

- Chapter two entails an in-depth examination and critical assessment of literature relevant to this research study. This section mainly reviewed the existing body of literature, explaining the research conducted by prior scholars on integrating technology in education, highlighting the areas where consensus exists and pointing out the gaps in knowledge that require further exploration. Combining this wealth of literature sets the stage for the distinctive contribution this thesis aims to make in the field**.** This study is concerned with unpacking the rural senior primary natural science teachers' perspective of their understanding of technological pedagogical content knowledge constructs, the sources of technological pedagogical content knowledge they draw on, and experiences shaping their technology use in teaching. They have these objectives in mind, describing the chosen theoretical framework of the study (TPACK) and with reasons why and how it suits the study, which forms the conclusion part of the chapter.

- **Chapter three** provides an overview of the research methodology employed in this study, utilising the Research Onion metaphor developed by Saunders, Lewis, and Thornhill (2009). This metaphor acts as a guide, mapping out the stages necessary for the researcher to formulate an effective methodology. It covers various aspects, including research philosophies, paradigms, approaches, strategies, choices, time horizons, techniques and procedures. The chapter details the study's methodology, discussing the design strategy for data acquisition, research choices, and the study's time horizon. Additionally, it explains the research techniques, focusing on site selection, sampling methods, participant selection, data collection instruments, and the data collection process. The chapter concludes by discussing the data analysis method, ensuring trustworthiness, addressing the researcher's position, and outlining the ethical considerations in the study.

- **Chapter four** presents the thematically analysed empirical findings derived from the study. Information acquired through rigorous data collection methods undergoes thorough examination, leading to the identification of patterns, trends, and correlations. These findings shed light on insights from qualitative and quantitative data sources. The presentation of results is organised into distinct components in line with the research questions and objectives. The knowledge extracted from the analysis serves as the basis for the subsequent discussions and conclusions.

- **Chapter Five** interprets and describes the significance of the findings about the literature, theoretical framework and the broader context of the study. This chapter delves into the research questions and objectives, thoroughly examining their relevance and implications. It explains the insights and new understanding from the study's findings. This is the section where the meaning, importance and relevance of this research study are provided.

- **Chapter six** presents a synthesis conclusion of the research study. This chapter presents the summary of the study findings, the valuable contribution to the decisions and implications of the study. The chapter also highlights this study's limitations, points out where there seem to be gaps and makes recommendations for the following research.

CHAPTER 2: LITERATURE REVIEW

2.1	• Introduction
2. 2	• Adoption of technology in education
2.3	• The of ICT in teaching and learning
2.4	• Technology pedagogical content knowledge
2.5	• TPACK use in integrating technology into science teaching
2.6	• Assessing TPACK
2.7	• Critique of existing literature
2.8	• Theorectical Framework
2.9	• Summary of the chapter

Figure 2. 1: Chapter 2-Literature review structure

2.1 Introduction

In the preceding chapter, the groundwork for this study was laid. The chapter included a concise exploration of the study’s background, the chosen theoretical framework, the study's rationale, the problem statement, a brief overview of research questions and objectives, the philosophical standpoint and the research methodology and design. The aspects such as the research site, participant selection, data gathering tools, procedures, and data analysis methods are also briefly discussed. The chapter concludes by explaining the study's contribution, an outline of the key terminologies used in the study, and a presentation of the structure of this research study.

The aim of this research, as stated in Chapter 1, was to investigate and gain a deep understanding of how technology is integrated into the teaching practices of rural science teachers by exploring their Technological Pedagogical Content Knowledge (TPACK). Several other studies have been conducted in the field of technology in education. To ensure that my research adds value to this existing body of knowledge, it was necessary to situate it within the broader context of the literature. Hence, the recent chapter presents the literature review for the study.

A literature review comprehensively examines scholarly sources, offering insights into theories, concepts, key findings, and methodologies pertinent to a research topic or question (Snyder, 2019). It involves a critical analysis and summary of existing research, publications, and scholarly articles within a particular study area (Durach et al., 2017). This process goes beyond merely listing existing works, as Munn et al. (2018) explained that it entails evaluating, comparing, and contrasting the ideas presented in these works. By doing so, researchers can identify gaps in existing knowledge, build upon established theories, and design studies that contribute valuable insights to the academic community. Literature reviews can be compiled in different types, such as traditional (narrative) (Templier & Pare, 2018), scooping reviews, systematic literature reviews, or annotated bibliographies (Synder, 2019). This study employed the narrative review, which refers to interpreting what other researchers found in the same field (Siddaway et al., 2019).

Conducting a literature review within this study enabled the researcher to critically examine, analyse and synthesise information from various sources. This examination encompassed an array of literature sources such as journal articles, dissertations/theses, e-books, conference papers, and multiple publications. The rigorous review process allowed for the exploration and assessment of arguments and perspectives from a diverse group of authors, enriching the understanding of the topic under study. It facilitated the identification of recurring patterns, prevailing trends, and common themes across various studies within the existing body of knowledge. This synthesis contributed to a comprehensive and well-rounded perspective on technology in education.

A well-executed literature review serves as a vital framework for a research study, showcasing the researcher's grasp of the subject matter and acknowledging the valuable contributions made by previous scholars in the field (Mukherjee et al., 2022). In this study, understanding the significant contributions of prior researchers is highlighted as a thematic discussion within the literature review. This discussion consists of recent and pertinent literature, focusing on critical aspects such as the adoption of technology in education, the utilisation of ICT in teaching and learning, the nuanced concept of Technological Pedagogical Content Knowledge (TPACK), TPACK application in integrating technology into instruction, methods of assessing TPACK, and a critical analysis of existing literature reviews about technology integration in education. By thematically organising this body of literature, the study ensures a comprehensive exploration of these essential aspects, forming a solid foundation for the research.

The Literature reviewed for this study is presented in the following: 2.2. shows the adoption of technology in education, 2.3 dispenses the use of ICT in teaching and learning, 2.4 discusses the concept of Technological Pedagogical Content Knowledge, section 2.5 explains TPACK use in integrating technology into science teaching, section 2.6 presents an assessment of TPACK from pre-exist studies, section 2.7 gives the critique analysis of the existing literature reviews, and the last section 2.8 discussed the details about the theoretical framework informing this study.

2.2 Adoption of technology in education

The advent of technology has significantly impacted various aspects of human life, including teaching and learning. Raja and Nagasubramani (2018) express that technology has transformed how people live and think, influencing the teaching and learning processes. Vallor (2016) also agrees that technology has become essential to human life since the Industrial Revolution. Ugur and Koç (2019) pointed out that technology is transforming the teaching approaches of educators, enabling them to cater to the demands of 21st-century learners who have grown up in a technology-driven environment featuring computers, the internet, and smartphones as integral parts of their daily lives. As such, educators must embrace fresh teaching approaches because the traditional methods are no longer adequate for the digital generation. Hence, schools and teachers are encouraged to explore and embrace the diverse and innovative ways of learning and teaching facilitated by technology.

Several scholars and researchers have noted the potential benefits of integrating technology in teaching and learning, including Starkey (2020), Shahid et al. (2019), Lawrence and Tar (2018), Ghavifekr and Rosdy (2015), McKnight et al. (2016), and Gilakjani (2017). In their study, Popenici and Kerr (2017) assert that technology can enhance learning interactions among students and teachers, creating more effective teaching and learning experiences. Lawrence and Tar (2018) suggest that using technology in classrooms can improve the quality of teaching and learning experiences. Others claim that technology can empower students to foster innovative thinking and achieve previously unattainable tasks for their predecessors (Thomas, 2016; Wiggan & Watson-Vandiver, 2019;Kraus,Simuja & Conger,2017).

In addition, Mishra and Koehler (2006) posit that new technologies drive forces and unavoidable change throughout the educational prospect. Similarly, Xie et al. (2019) stressed that technology offers enhanced learning experiences, broader access to educational resources, personalised learning opportunities and global collaboration.

Many governments in developing and developed countries have heeded the call for ICT in education (Serdyukov, 2017; Collins & Halverson, 2018; Morgan, 2020). They are investing more in technology tools, facilities, and policies to improve their countries' teaching and learning processes. However, Kopcha et al. (2020) note that most schools must fully adopt technology integration in teaching and learning processes. Even with technology available in schools, teachers must be observed integrating it.

Through the study about teachers' perception of barriers to technology integration in education, Emre (2019) noted that the availability of these technologies does not necessarily mean that teachers possess the necessary technological knowledge to integrate technology into their teaching. Zhang (2021) posits that the predominant use of technology among teachers is for delivering information. Incorporating technology to facilitate student-centered teaching and learning remains uncommon in classrooms, rather than being the standard practice. This highlights the need to effectively explore teachers' knowledge and ability to integrate technology into their teaching and learning processes.

2.3 Use of ICT in teaching and learning

ICT encompasses many tools and applications that facilitate the educational process (Lawrence & Tar (2018). Some scholar postulates the affordance of integrating ICTs into teaching and learning that it can transform education by meeting the needs of all learners (Umugiraneza et al. (2018). However, others pointed out the gap between integrating ICTs and their effective pedagogical use in teaching (Tallvid, (2016; Buabeng-Andoh, 2019).

Reports about ICT in education have indicated that most schools, including those in rural communities, now have the technology teachers need to effectively use at least some instructional applications (Gibson et al., 2018; Selvaraj, 2021). This indicates that the availability and accessibility of ICT tools in schools are no more a challenge than they were before. However, Ghavifekr et al. (2016) suggested that even when surrounded by ICTs, novice

ICT users may need help to select and use the appropriate technology for a lesson. Therefore, teachers need to view ICT tools as replacements for non-technology tasks and instrumental tools in teaching and learning.

Padayachee (2017) suggests that the integration of ICTs should be meaningful and relevant for teachers, and there should be a relationship between their attitudes towards ICT and their use of it. However, Jääskelä (2017) found that teachers mainly use technology for teaching and preparation purposes and view ICTs as passive content delivery tools rather than pedagogical tools. It is, therefore, essential to educate Namibian teachers on integrating ICTs as pedagogical tools into the curriculum. Samaradiwakara and Gunawardena (2014) noted that technology has minimal value unless its use and acceptance have significant theoretical and practical implications. Hence, teachers must know how ICTs should be integrated into teaching and learning.

2.4 Technological Pedagogical Content Knowledge

The discourse about technology in education has shifted from how technology is used in the classroom to how it should be effectively integrated into teaching and learning (Angeli, 2005; Sutherland et al., 2000). Earlier attempts to use technology in teaching and learning focused on equipping pre-service teachers with technological knowledge and skills (Angeli & Valanides, 2005; Thompson & Mishra, 2007), hoping they could use technological knowledge for pedagogy and content. However, research has noted that more than technology skills is needed to equip teachers with the required understanding to merge technology, pedagogy and content (Angeli & Valanides, 2009; Chai et al., 2010; Graham et al., 2009) and in their study about exploring pre-service teachers' justifications for one-to-one technology use in schools, McGarr and Ó Gallchóir (2020) asserted that both pre-service and in-service teachers agreed that technological skills alone are insufficient to prepare and enable them to teach with technology effectively.

There has been the realisation that "technology in and of itself is not a transformative mechanism, rather a tool invoked by its users to reconstruct the subject matter from the knowledge of the teacher into the content of instruction" (Angeli & Valanides, 2009, p. 157). Mishra and Koehler (2009) stressed that the effective use of technology in teaching and learning depends on teachers' ability to use their technological knowledge to deliver the curriculum content and the processes they provide.

Koehler and Mishra (2008) argued that “at the heart of good teaching with technology are content, pedagogy, and technology and the relationships between them” (pp. 11–12). They posited that teachers must possess technological pedagogical content knowledge (TPACK) for effective technology integration in teaching and learning. Santos and Castro (2021) describe TPACK as the knowledge of the effective use of technology to deliver lessons.

Scholars and researchers have observed the dynamic development of teachers' Technological Pedagogical Content Knowledge (TPACK) in various educational settings. Notable studies by Jang and Tsai (2013), Pamuk (2015), and Wang, Schmidt-Crawford, and Jin (2018) have shed light on this phenomenon. Kartal and Afacan (2017) also examined Turkish pre-service science teachers' TPACK, considering factors such as gender, computer ownership, computer usage, and grade level. Their findings emphasised that technology usage and teaching experiences contribute positively to the development of TPACK.

In a related study, Aktaş and Özmen (2020) explored the impact of a TPACK development course on pre-service science teachers' performance. Their finding revealed that the TPACK Development Course (TPACK-DC) enhanced teachers' comprehension of TPACK and equipped them with the knowledge necessary to select appropriate teaching methods using technology for specific subjects. Likewise, Chaipidech et al. (2022) investigated the TPACK development of in-service teachers. They implemented a voluntary teacher professional development program involving 92 in-service science secondary school teachers. Their findings demonstrated that the teacher professional development program effectively equipped teachers with the skills to apply technology pedagogically soundly, enriching students' learning experiences in science.

Learning the diverse contexts in which teachers' TPACK develops, it is imperative to explore the technological knowledge of rural science teachers and the contextual factors that influence their utilisation of technology in the teaching process.

2.5 Technological pedagogical content knowledge used in integrating technology into science teaching.

A comprehensive analysis of various studies on integrating technology in education has been conducted. Several researchers, including Ratheeswari (2018), Farjon et al. (2019), and Lai and Jin (2021), have conducted studies on this topic. Some researchers, such as Tondeur et al. (2017) and Lawrence and Tar (2018), have noted that the focus on technology in teaching and learning has been more on using various technologies. However, it is essential to note that more than technological skills are required for teachers to integrate technology into their teaching.

Angela and Valanides (2009) argue that technology is simply a tool that teachers use to reconstruct subject matter from their knowledge into instructional content. Technology integration in teaching and learning has revolutionised education philosophy and expertise. This has led to the development of technological pedagogical content knowledge (TPACK), which refers to the knowledge teachers should possess to integrate technology into their teaching process.

Mishra and Koehler (2009) argued that applying TPACK to teaching with technology requires a context-bound understanding of technology, where technologies may be chosen and repurposed to fit the specific pedagogical and content-related needs of diverse educational contexts. In addition, Hamilton (2022), in the book *Integrating Technology in the Classroom*, describes technology integration in teaching as a conscious decision requiring teachers to thoughtfully select the technological tools that suit the content to teach. This implies that thoughtfully determining technologies and pedagogies for science content requires teachers to develop TPACK.

Commenting on the effective integration of technology, Mishra and Koehler (2006) emphasised that good teaching with technology requires a shift in existing pedagogical and content knowledge. They further stressed that teachers must develop TPACK to successfully integrate technology into their teaching and thoughtfully select the tools best suited for their teaching content. This suggests that technology integration in science teaching is a complex process that requires a deep understanding of the technologies suitable to enhance content.

Over the years, investigating teachers' TPACK has interested many scholars. However, statistics showed few studies focusing on science teachers' TPACK. For example, Setiawan et al. (2019) conducted a systematic review of research published between 2011 and 2017 on current trends in TPACK. Their study indicates that fewer TPACK studies focus on specific subject fields such as Physics (6%), biology (13%), and Chemistry (19%). This brings to the fore that little research has been done to establish how science teachers integrate technology to enhance and support teaching and learning. By contributing to TPACK research within a specific science domain, the present study demonstrated how natural science teachers in rural primary schools use technological knowledge in their pedagogies and content.

2.6 Assessing Technological Pedagogical Content Knowledge

Interest in assessing and measuring teachers' TPACK has been noted since the inception of the TPACK framework by Mishra and Koehler (2006). Some studies focused on measuring or exploring in-service teachers' TPACK or pre-service teachers' TPACK. A review of the literature by Wang et al. (2017) indicated several articles, papers, and dissertations that used, mentioned, and measured teachers' TPACK. In support, Zou's et al. (2022) bibliometric analysis of 1608 empirical TPACK studies from 2000 to 2022 shows that academic interest in TPACK is rising.

The literature search revealed that most studies on assessing teachers' TPACK were conducted outside the African continent, such as in the United States of America, Australia, New Zealand, and the United Kingdom. For example, Durdu and Dag (2017) used a mixed-method approach to examine pre-service teachers' technological pedagogical content knowledge in a computer computer-based mathematics course in Australia. They analysed the data to establish how the course influences the in-service teachers' TPACK development. Their study finding revealed that the course helped the in-service teachers develop TPACK, as significant differences existed before and after the course implementation.

In other studies, Kartal and Afacan (2017) investigated the technological pedagogical content knowledge (TPACK) among pre-service science teachers undergoing a course in the concluding phase of their four-year teacher education program in Turkey. The findings suggested that the Science Methods course, with a specific emphasis on TPACK, exerted varying impacts on the TPACK competencies of pre-service teachers. The results demonstrated that these prospective science educators acquired knowledge regarding the effective utilization of educational technology tools to different extents.

Additionally, Redmond and Lock (2019) delved into the perceptions of technological pedagogical content knowledge (TPACK) held by pre-service teachers in secondary education in Australia. The research aimed to scrutinize how secondary pre-service teachers (PSTs) described TPACK and its components, along with exploring their encounters in both teacher education programs and professional experience placements. The study uncovered that secondary PSTs acknowledged the intricacies involved in integrating technology into teaching and expressed a desire for increased guidance and modeling in Technological Pedagogical Content Knowledge (TPACK). The results of this investigation suggest that PSTs often feel inadequately prepared to seamlessly incorporate technology into their classrooms.

Furthermore, Saganda, Riandi, and Purwianingsih (2021) evaluated Indonesian teachers' TPACK perceptions in the context of 21st-century learning. The study delved into teachers' perspectives on creativity, critical thinking, communication, and collaboration within this framework. It also explored the correlation between teaching experience and TPACK perceptions, particularly concerning contemporary learning technology. Biology teachers with diverse teaching backgrounds, ranging from less than 5 years to over 15 years, participated. The findings indicated that the majority of biology teachers demonstrated a positive TPACK perception, signifying a robust understanding of integrating technology, pedagogy, and content knowledge in their teaching. However, limitations were observed in teachers' perceptions of 21st-century learning, especially in terms of students' abilities in creativity and critical thinking. Teachers with less experience exhibited a lower understanding of the latest learning technology, emphasizing the necessity for professional development in this area.

However, there are also several studies measuring teachers' TPACK conducted in some developing countries in Africa, such as those undertaken by Kihoza, Zlontnikova and Banda (2016), Gyaase, Gyamfi and Kuranchie (2019), Ramnarian, Pieters and Wu (2021). To give some examples, Gyaase et al. (2019) conducted an assessment of Teachers' Technological Pedagogical Content Knowledge (TPACK) among pre-university educators. The study focused on gauging the readiness of these teachers to employ ICT in teaching various subjects. The results indicated a lack of correlation between teachers' ICT literacy and their TPACK. Despite a high level of ICT literacy among pre-university teachers in Ghana, the findings highlighted challenges in effectively utilizing ICT for designing and delivering subject content

In the same vein, Ramnarian et al., (2021) used a mixed-method approach to examine pre-service teachers' technological pedagogical content knowledge in a computer computer-based mathematics course in Turkey. They investigate pre-service science teachers' proficiency levels regarding their practical knowledge of technological pedagogical content knowledge (TPACK-P). They used the TPACK questionnaire to survey students' TPACK-P proficiency levels. The findings revealed that most pre-service teachers have a proficiency level of 3 for their knowledge of TPACK-P.

Furthermore, through a personalised learning system design approach, Chaipidech et al. (2022) assessed the development of in-service teachers TPACK in Thailand. They used a voluntary teacher professional development program in which 92 in-service science secondary school teachers participated. Their finding revealed that the TPD program taught teachers to apply technology to students' learning experience in science pedagogically. These researchers (in both developed and developing countries) and several others who studied teachers' TPACK development, such as Mishra and Koehler (2007), Angeli and Valanides (2009), Nwaozuzu (2017), Luik et al. (2018), Muhaimin, et al., (2019), Prasojo, et al., (2020), agree that technology training/ courses offer teachers' opportunities to develop TPACK.

Besides, most of these studies revealed by the literature focused more on assessing pre-service teachers' TPACK compared to those focused on assessing in-service teachers' TPACK. This indicates to the educational technology researchers that more research needs to be conducted to understand in-service teachers' technological pedagogical content knowledge. Aiming to contribute to the literature in the field, the current study focused on assessing the in-service rural science teachers' TPACK.

2.7 Critique of existing literature

The existing literature offers a historical understanding of the adoption of technology in education and the use of ICT in education. It also provides a holistic experience of teachers' expertise in effectively using technology in their teaching and learning processes. This comprehensive approach ensures that teachers can effectively integrate technology into their teaching practices (Mishra & Koehler, 2006). Several studies acknowledge the importance of contextual factors, such as demographics, technology access and teaching environments, in shaping teachers' TPACK (Swallow & Olofson, 2017; Anagün, 2018; Yurtseven, 2020). This recognition of context provides a nuanced understanding of how TPACK develops in diverse educational settings.

Several studies provide practical implications for technology training programs and professional development initiatives (Durdu & Dag, 2017; Prasojo et al., 2020; Ramnarian et al., 2021; Chaipidech et al., 2022). By identifying the factors that influence TPACK development, governments, through the ministries of education and policymakers, can design targeted interventions to enhance teachers' technological pedagogical skills. However, as indicated earlier, many studies about teachers' TPACK are conducted in developed countries, limiting the generalisation of the findings. The confined teaching contexts make drawing universal conclusions about teachers' TPACK development challenging.

Moreover, the rapid evolution of technology poses a challenge (Atzori et al., 2017;Conger,Kraus & Simuja,2016). Some literature might need to be updated quickly due to the constant emergence of new tools and platforms. This makes it essential for future research to keep pace with technological advancements. While many studies highlight the positive aspects of TPACK development, there needs to be more literature addressing the challenges teachers face (Mseleku, 2020). Understanding these challenges is crucial for designing effective support systems.

While the existing literature on teachers' TPACK provides valuable insights into the integration of technology in education, there are still gaps that future research can contribute to such as understanding of teachers' perceptions of educational technologies and understanding of teachers' perceptions of TPACK. The recent case study aims to contribute significantly to the ongoing discourse on assessing teachers' pedagogical content knowledge and contextural factors shaping their technology integration in teaching in Namibia.

2. 8 Theoretical Framework

This section presents the theoretical framework of the study. Adom, Hussein and Agyem (2018) define a theoretical framework as a blueprint often 'borrowed' by the researcher to build their research inquiry. It forms a reference point for interpreting the research findings (Mpofu et al., 2013). This study aims to explore and assess the rural senior primary natural science teachers' TPACK. Therefore, this study used the Technological Pedagogical and Content Knowledge (TPACK) framework by Mishra and Koehler (2006).

Technological Pedagogical Content Knowledge (TPACK) framework

Technological Pedagogical and Content Knowledge (TPACK) is a conceptual framework for integrating educational technology into pedagogy. This framework was introduced by Mishra and Koehler (2006) to present the knowledge domains required for teachers to incorporate technology into their teaching and learning environment effectively. TPACK framework builds on Shulman's Pedagogical Content Knowledge (PCK) theory (1986), which identifies the knowledge domains or features of knowledge for teaching.

This framework adds technology knowledge as a critical component of what teachers should know for integrating technology into their pedagogy. TPACK has seven constructs, namely: Technological Knowledge (TK), Pedagogical Knowledge (PC), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), Technological Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2006).

Mishra and Koehler (2006) adjusted the TPACK diagram to demonstrate the framework within the subject context, as indicated in Figure 1.

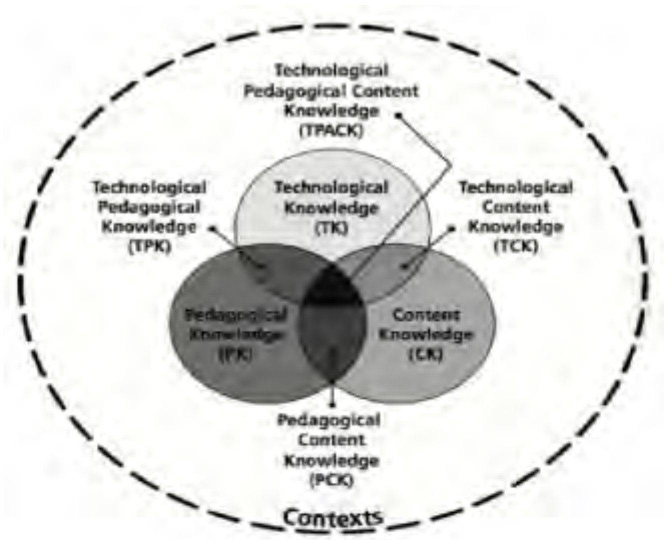

Figure 2.2 Graphic representation of the TPACK framework (as adapted from HTTPS://www.researchgate.net)

Figure 1 and the constructs of TPACK above suggest that the constructs of the framework are intricately interconnected to form an amalgam of a unique body of knowledge (Koehler & Mishra, 2008; Cohen, 2020). Tseng et al. (2020) emphasise TPACK as a dynamic framework for examining teachers' knowledge required for teaching with technology. The TPACK framework allowed the researcher in this study to explore rural science teachers who effectively teach with technology and suitably select and draw on these constructs as the foundation for their technological skills, content knowledge, and pedagogical knowledge. This study has applied all seven TPACK constructs for data analysis.

To understand the seven TPACK constructs, Mishra and Koehler (2006) have defined them as: *Technological Knowledge (TK)* refers to teachers' comprehension and ability to use various technologies, including emerging and digital technology. It includes the knowledge that teachers have about how to operate, select the available technologies and applications, thinking methods and cooperation with technology, practical tools, and teaching resources that can continuously adapt to changes in information technology (Mishra & Koehler, 2009). This construct is necessary to this study because it aids in establishing the science teachers' evolving knowledge base of using different digital and emerging educational technologies in various settings.

Pedagogical Knowledge (PK) refers to teachers' deep understanding of teaching and learning processes, practices, methods, and educational goals, values, and objectives. This kind of knowledge involves understanding how technology and content influence related to each other (Mishra & Koehler, 2007). This knowledge construct was necessary to establish the teachers' teaching methods to meet the requirements and foster effective learning in Natural science.

Content Knowledge (CK) refers to the knowledge about the subject matter to be learned/taught (Mishra & Koehler, 2007). The science subject content involves terms, processes and theories. The CK construct is essential to this study as it aids in unpacking the knowledge of science matters/content that the teachers possess.

Technological Content Knowledge (TCK) concerns teachers' understanding of the interrelationship between technology and content, including how technology and content influence and constrain each other. This knowledge encompasses teachers' understanding of how technology and content are reciprocally related (Mishram et al., 2014). In this study, TCK provides lenses to view and unpack the science teachers' knowledge and understanding of how the subject matter they teach is transformed by technology and how content dictates or shapes their selection and use of specific technologies.

Technological Pedagogical Knowledge (TPK) refers to teachers' awareness of how teaching and learning change when specific technologies are employed and vice versa. This knowledge involves teachers' ability to recognise how technology impacts teaching methods and strategies and achieve effective teaching and learning through technology (Mishra & Koehler, 2008). In this study, TPK aids in unpacking the science teachers' use of technology to enhance teaching and learning methods and how their teaching methods dictate or shape their selection and use of specific technologies.

Pedagogical Content Knowledge (PCK) refers to the knowledge of teaching methods tailored to different subject matters. This knowledge consists of teachers' ability to present content that is understandable to students (Koh et al., 2010). In this study, PCK aids in unpacking the science teachers' understanding and ability to employ different teaching methods without using technology.

Technological Pedagogical Content Knowledge (TPCK) represents the intersection of technological, pedagogical, and content knowledge (Mishra & Koehler, 2006). It requires the understanding of how technology is used to present different concepts, pedagogies that use technology to teach content, the knowledge of how technology can be used to address easy or complex ideas, knowledge of students' prior knowledge and theories of epistemology and understanding how technology is used to build on existing knowledge and creating new knowledge (Mishra & Koehler, 2007).

In this study, TPCK aids in unpacking the science teachers' understanding that emerges from the interactions and interplay between and among technology, content and pedagogical knowledge that underlies their meaningful teaching with technology. The science teachers' knowledge and understanding of complex relationships among content, pedagogy, technology, and context are engaging in this study. Natural science teachers possess technological pedagogical content knowledge and know how to use it to integrate technology into teaching and learning effectively (Mishra & Koehler, 2006).

Although TPACK is grounded in context, it has limitations as well. The framework offers scanty guidance about the content to teach, which methodologies to use and the kinds of technologies to use. The TPACK framework offers a broad overview of the kinds of knowledge teachers need to integrate technology effectively, but it does not offer specific guidance. This lack of specificity can leave researchers uncertain about how to apply the framework in practice. The TPACK framework's focus on the teacher may overlook the role of learners. Today's learners often have significant technology skills and knowledge, which may affect the way technology should be integrated into teaching.

Despite its limitations, the TPACK framework is relevant in this study as it offers a lens for the researcher to explore and assess teachers' knowledge to integrate technology and the ability to describe it. The TPACK framework provides several opportunities for researching teacher education, teacher professional development, and teachers' technology use (Koehler & Mishra, 2009). Hence, the TPACK framework is adopted in this study to help the researcher select teachers, describe the participants' technology integration, and provide the potential constructs to classify them using a framework diagram.

2.9 Summary of Chapter two

This chapter has presented a comprehensive overview of relevant literature within the study's field. It has loosely examined previous works conducted by other scholars, encompassing a diverse range of research from various theoretical and analytical perspectives. The initial focus is on widely accepted viewpoints regarding integrating technology into educational settings, laying the groundwork for further exploration. Understanding the integration of technology in education is crucial, given that technology has transformed the dynamics of teaching and learning, including in the realm of science education. This review has allowed for an examination of literature related to the adoption of technology in education, the utilisation of information and communication technology (ICT) in teaching and learning, technological pedagogical content knowledge, the application of technological pedagogical content knowledge in integrating technology into science teaching, and the assessment of teachers' Technological Pedagogical Content Knowledge.

Establishing a strong basis for this study, the chapter delves into TPACK as the theoretical framework, providing readers with the essential context for the research. The subsequent chapter details the methodology utilised to generate and analyse the data related to TPACK development among science teachers in rural areas.

CHAPTER 3: RESEARCH METHODOLOGY

3.1	• Introduction
3.2	• Methodology design
3.3	• Research paradgim
3.4	• Research approach
3.5	• Research strategies
3.6	• Research choices
3.7	• Time horizons
3.8	• Research techniques
3.9	• Trustworthiness, Validity and Reliability
3.10	• Positionality
3.11	• Research ethics
3.12	• Summary of the chapter

Figure 3. 1: Chapter 3- Research methodology structure

3.1 Introduction

Chapter 2 presented the literature review of the study. The literature review of this study contained a discussion about other studies conducted in the field of technology in education and the theoretical framework of TPACK underpinning the study. Chapter three presents the research methodology of the study.

The research methodology is described as a general research strategy articulating the logic and flow of the systematic process to gain knowledge about a research problem (Kivunja & Kuyini, 2017). The methodology outlines the specific procedures or techniques used to identify, select, process, and analyse information about the research questions. It includes a system of beliefs and philosophical perspectives shaping the understanding of the research questions.

Methodology plays a massive role in a research study as it offers insight to the researcher to critically evaluate its overall validity and reliability (Turnnidge & Côté, 2018). This chapter presents the research methodology employed to address the research objectives of the study, which are:

- ➢ To assess the rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs.

- To determine sources of TPACK, the rural senior primary natural science teachers draw on experiences shaping technology use in their teaching.

Therefore, the study assessed the natural science teachers' technological pedagogical content knowledge teaching in rural primary schools. The researcher evaluated the rural senior primary natural science teachers' perceptions of their understanding of technological pedagogical content knowledge constructs, the sources of technological pedagogical content knowledge they draw on, and experiences shaping their technology in teaching.

This chapter is structured into eleven sections outlined below: Section 3.1 Introduction and the chapter's layout. Section 3.2 discusses the research methodology design, encompassing 'The Research Onion' metaphorical illustration outlining the elements of research methodology adopted in this study to help the researcher organise the research and develop a practical research methodology. Section 3.3 explains the research paradigm and the use of the interpretive paradigm. The research approach describing the plans and the procedures for research are detailed in Section 3.4. Section 3, explains the research strategies and the essential methodological choices that apply to conducting a research study. Section 3.5 discussed the research strategies; a qualitative case study approach was used in this study. Section 3.6 discussed the research choices and the mixed method approach used in the study. 3.7 Explained the time horizon of the study, cross-sectional. 3.8 Explained the research site, sampling techniques, participants, and data collection methods employed: questionnaires, interviews, focus group interviews, observation, and the data analysis process are elaborated. Section 3.9 delves into aspects of trustworthiness, validity, and reliability. Section 3.10 addresses ethical considerations in the study, and Section 3.11 forms the summary of the chapter.

3.2 Methodology Design

Saunders, Lewis and Thornhill (2007) developed the 'Research Onions' (Figure 3.1) model to describe the decisions and stages a researcher makes and passes to develop a research methodology. The Research Onion is a metaphorical illustration outlining the elements of research methodology (Saunders & Tosey, 2012). It represents the various decisions and reasoning a researcher should take from the onset of developing a research methodology (Phair & Warren, 2021). Describing the research onion approach metaphor, Sahay (2016) urges that outer layers must be "peeled away" before dealing with the inner layers.

The notion of taking stages that must be covered when developing research relates to peeling the layers of an onion. Research Onion helps researchers organise the research and develop practical research methodology following the layers portrayed in the metaphor (Sinha et al., 2018). Figure 3.1 shows the Research Onion model.

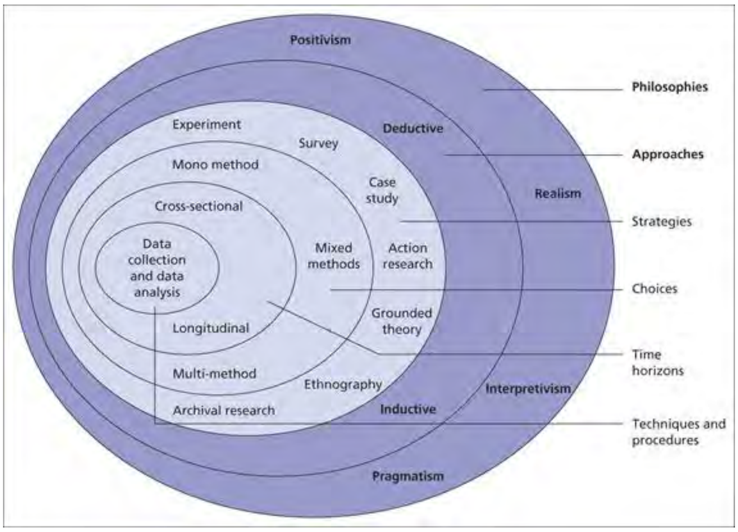

Figure 3.2: The Research Onion, Adopted from Kock (2022)

The Research Onion metaphor, adopted from Kock (2022), elucidates the research methodology design model developed by Saunders et al., (2007). The Research Onion metaphor offers a comprehensive framework for delineating the critical stages to formulate an effective methodology (Rauthatha, 2017). The outer layers of the onion symbolise the diverse conceptual and logical choices that steer the research processes in specific studies. This Research Onion model comprises six core stages: research philosophy, research approaches, research choices, research strategies, time horizons, and techniques and procedures. Sahay (2016), in his explanation of how researchers should navigate these layers or stages of the Research Onion, emphasises the peeling process, starting from the outermost layer and progressing toward the inner layers of the research methodology. He categorises the outer layers as the foundational elements and the middle layers as the fundamental building blocks of the research.

Melnikovas (2018) examined the research onion model. Despite its initial plan for business applications, they discovered its utility as a valuable tool for researchers to structure their research and formulate designs by its layers. However, he warned that researchers should exercise caution when adopting the model. They should modify it and make essential logical adjustments to ensure its suitability for their study. In the context of this study, the Research Onion model is employed to outline the stages involved in the planning and development of the research. Figure 3.2 illustrates the design choices made for this research study, guided by the principles of the research onion model.

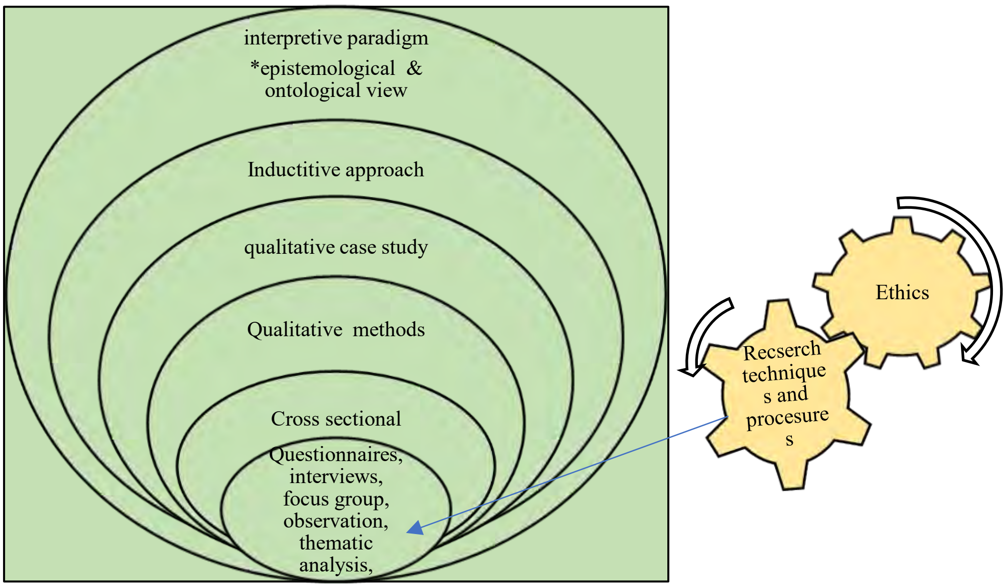

Figure 3. 3 The research design choices for this study

3. 3 Research paradigm

The initial layer of the 'research onion' metaphor, known as the research philosophy, encompasses the fundamental assumptions about the worldview of the research. These assumptions, in turn, provide the foundation for shaping the research strategy and methods (Saunders & Tosey, 2012; Sahay, 2016;Nyirenda & Simuja,2023). The research philosophies delineated by Saunders et al. (2007) in the Research Onion metaphor include positivism, realism, pragmatism, and interpretivism.

Positivism philosophy maintains that knowledge exists independently of the subject under study (Gray, 2013). In adhering to the positivist perspective, the researcher refrains from considering personal opinions or viewpoints. Conversely, interpretivism philosophy asserts that knowledge is socially constructed, suggesting that societal factors and attitudes shape it.

In research, pragmatism subscribes to the belief that ability is not static but is continuously subject to questioning and interpretation (Gray, 2013). Furthermore, realism philosophy posits that an object or entity exists with specific attributes, irrespective of individuals' perceptions or beliefs (Gray, 2013).

Research philosophy encompasses three critical paradigms: ontology, epistemology, and axiology. Kamal (2019) defined a paradigm as a viewpoint that provides insights and explanations. According to Durach, Kembro, and Wieland (2017), a paradigm is a shared set of beliefs and agreements among scientists regarding how problems should be comprehended and resolved. Gray (2013) further delineates these paradigms, explaining that ontology delves into questions about the nature of reality, epistemology investigates the nature and sources of knowledge or facts (determining what constitutes acceptable knowledge), and while axiology is concerned with the values, beliefs, and ethics within the study field.

This study was rooted in an interpretive paradigm. As Cohen et al. (2018) suggest, the interpretive paradigm is well-suited when the researcher aims to depict and grasp how individuals construct meaning from their experiences and the world by interpreting events and situations. Crotty (1998) further explains that in an interpretive philosophy, there is no singular, objective reality; instead, the truth is shaped by individuals, specifically the participants, and then subjectively interpreted. Expanding upon the interpretivist philosophical standpoint, Cohen et al. (2018) contend that truths are context-dependent, and there are no absolute, universally applicable truths. Since each participant's experience is highly unique, and there is no one-size-fits-all reality for all participants, the interpretive paradigm is a valuable approach because its primary objective is to fathom the subjective world of human experience (Cohen et al., 2018). Therefore, for this study, an interpretive philosophy was deemed appropriate as it enables the researcher to gain an in-depth understanding of rural senior primary natural science teachers' technological pedagogical content knowledge (TPACK) by examining the nature of reality from ontological and epistemological perspectives.

3.4 The research approach

The research approach, situated as the second layer of the 'research onion' metaphor, outlines the plans and procedures for conducting research. This approach can be inductive or deductive, depending on how research data is collected and analysed. According to Saunders et al. (2007), an inductive research study involves collecting data and developing a theory based on data analysis. Conversely, a deductive research study starts with developing an idea and hypothesis, followed by designing a research strategy to test that theory (Pearse, 2019; Shambare et al.,2022). Melnikovas (2018) further distinguishes between the two approaches, stating that the deductive approach tests existing ideas. In contrast, the inductive approach is commonly used for theory development, especially in fields with limited prior research.

In the inductive research approach, empirical data is collected, and patterns within the data are identified, leading to the formulation of theories (Smith, 2009). This study aimed to contribute to TPACK theory development with the view of science teachers' TPACK development in the context of rural schools. Therefore, it adopted an inductive research approach, seeking patterns within the collected data to contribute to the existing body of knowledge.

3. 5 Research Strategies

The third layer of the research onion metaphor corresponds to research strategies. In his book entitled "Interpretive Description: Qualitative Research for Applied Practice," Thorne (2016) defines research strategies as the guiding framework that informs researchers about the crucial methodological choices necessary to conduct a research study. According to Saunders et al. (2012), research strategies, as outlined in the research onion metaphor, include experiments, surveys, case studies, ethnography, grounded theory, and action research. These strategies play a vital role in determining the research choices made by researchers based on the data needed and the study's purpose.

This study employed a qualitative case study approach to explore participants' understanding and experiences. This approach allowed the use of primary instruments for data collection, enabling the generation of a detailed description (Merriam & Grenier, 2019). Kothari (2011) characterises a case study as a method in which researchers aim to gain an in-depth understanding of a specific and bounded subject unit, which can be either highly representative or highly atypical. The case study approach was fitting for this research because of its holistic nature, enabling participatory social engagement, particularly within the context of rural schools' senior primary natural science teachers.

The qualitative approach was chosen over the quantitative approach for this study, as it offers a deeper exploration of concepts and experiences. While quantitative methods are valuable for systematically measuring variables and testing hypotheses, qualitative methods allow for exploring these concepts and experiences in greater detail. Unlike quantitative research, which focuses on numeric data collection and analysis, qualitative research gathers and studies non-numeric data to comprehend individual social realities (Moalusi, 2020; Shambare et al.,2022). The qualitative research approach also acknowledges the socially constructed nature of 'multiple realities' (McMillan & Schumacher, 2014;Simuja,2028). This perspective aligns with the aim of this study to capture the nuanced and diverse experiences and perceptions of the participants

This research study aimed to assess and comprehend rural natural science teachers' technological pedagogical content knowledge (TPACK). This goal was pursued by gauging the teachers' perceptions of their understanding of TPACK constructs, investigating the sources from which they derived their TPACK knowledge, and exploring the experiences that influenced their use of technology in teaching. Employing a qualitative approach facilitated assessing and understanding the participants' TPACK within their teaching practices at the chosen research sites, effectively addressing the research questions. The focus of the analysis was the TPACK of the selected teachers. Each participant in the study held unique perspectives on the phenomena under investigation, and their viewpoints provided a comprehensive insight into the overall phenomena.

3. 6 Research choices

According to Saunders et al. (2007) research onion metaphor, the fourth layer encompasses the choice, which delineates the decisions and approach regarding the types of data a researcher selects for the study. The metaphor categorises these choices into three main options: mono-method, mixed-method, and multi-method. The mono-method involves employing only one research method, while the mixed method involves integrating two or more ways, often referring to the combination of qualitative and quantitative methodologies (Gray, 2013). Conversely, multi-method employs diverse blends of qualitative and quantitative approaches in the research study (Göttfert, 2015;Conger,Krauss & Simuja,2017).

The research choices are pivotal in determining the research approach, data collection, and analysis techniques. This study used a mixed-method approach, integrating quantitative and qualitative data collection techniques. These techniques included semi-structured questionnaires, interviews, focus group discussions, and observations. These four distinct data collection methods enabled the researcher to triangulate the data. Triangulation involves using multiple sources or methods to validate or cross-verify research findings (Shen et al., 2020;Shambare et al.,2022). By employing these varied methods, the study aimed to enhance its findings' validity, reliability, and trustworthiness, contributing to a more robust research outcome.

3. 7 Time horizons

Time horizons, represented as the fifth layer of the research onion metaphor, determine the time frame of the research (Melnikovas, 2018). The metaphor distinguishes between two types of time horizons: cross-sectional and longitudinal. A cross-sectional study is a short-term research approach that involves collecting data at a single point in time, providing a "snapshot" of a population at that specific moment (Cohen et al., 2018; Saunders & Tosey, 2012). In contrast, a longitudinal study entails collecting data repeatedly over an extended period, spanning weeks, months, or even years. This approach allows researchers to monitor a population over time, gaining insights into changes and developments (Phair & Warren, 2021).

In a cross-sectional study, the researcher measures both the outcome and the exposure of the study participants simultaneously (Wang & Cheng, 2020;Simuja & Silvanus,2023). On the other hand, longitudinal studies involve data collection at multiple points in time, enabling a comprehensive analysis of trends and patterns over the study period (Ryan & D'Angelo, 2018). The choice of time horizon dictates how the research data is collected, providing researchers with a framework to determine the appropriate techniques and procedures for their study (Schoch, 2020). Longitudinal studies, with their extended time frame and multiple data collection points, offer a more in-depth understanding of how phenomena evolve. In contrast, cross-sectional studies provide a snapshot view, capturing a specific moment in the research subjects' experiences.

In this study, a cross-sectional case study strategy was employed. Saunders and Tosey (2012) stressed that a case study can be classified as cross-sectional if it allows the researcher to address a problem at a specific time. However, Collier and Thomas (2017) posit that a longitudinal study would be appropriate if addressing the issue requires collecting data over an extended period.

Saunders (2012) emphasised that the nature of the research study, the research question, aims and objectives, and research constraints are pivotal factors in determining the time horizon of the study. In this case, the specific research question and objectives, along with the constraints of the study, led to the decision to adopt a cross-sectional case study approach.

3. 8 Research Techniques and Procedures

The central core of the research onion metaphor encompasses techniques and procedures for data collection, sample selection, questionnaire development, and interview preparation, addressing the practical "how" of the research study (Cohen et al., 2018). Educational research planning involves designing appropriate data collection instruments such as surveys, questionnaires, interviews, focus groups, and tests (Cohen et al., 2018). In this study, the data collection process includes selecting the research site, choosing the study population, determining sampling procedures, specifying data types, designing collection instruments, and outlining data analysis methods to address research questions. Together, these components constitute the core techniques guiding the practical aspects of the research process.

3.8.1 The research site

This research study is based on the senior primary schools within Namibia's Endola educational circuit, a rural area in the northern part of the country, specifically in the Ohangwena region. This location was chosen deliberately because all the schools there have access to electricity, mobile phone networks, and the Internet. They also have standard technology tools like computers, laptops, projectors, copy machines, whiteboards, and printers. Some teachers in this circuit have received ICT training, which provided them with technical knowledge in specific technologies like MS Word, MS Excel, MS PowerPoint, MS Access and the Internet. This training was part of the continuous professional development programs offered to in-service teachers by the Ministry of Education in collaboration with other educational stakeholders. As a result, teachers who completed these ICT programs were given laptops and certificates of completion, meaning that many of the school teachers in this circuit now have access to technologies such as laptops, computers, the internet, smartphones, and others.

By the time of this study, the Endola educational circuit comprised 29 public schools and four private schools. Only public schools were included in the study due to differences in teaching resources and facilities observed informally between public and private schools. Convenience sampling was employed, selecting public schools for their proximity to the researcher's location, ensuring easy access for the researcher, participants, circuit inspector, and school principals (gatekeepers). This approach facilitated the study's practicality and accessibility.

3.8.2 Sampling and Participants

In this study, a purposive sampling methodology was employed. Purposive sampling involves deliberately selecting participants from an existing population, with individuals either included or excluded based on specific criteria (Grays, 2013; McMillan & Schumacher, 2014; Cohen et al., 2018). In this research, 30 senior primary Natural Science teachers from the Endola educational circuit were purposefully chosen as participants. These teachers were explicitly those who utilised technology in their teaching methods. They were identified through subject meetings and activities conducted at the circuit level, organised by the circuit office. Purposive sampling was deemed appropriate as it enabled the researcher to group participants according to predetermined criteria relevant to the research questions.

To assess the Natural Science teachers' perceptions of their Technological Pedagogical Content Knowledge (TPACK) constructs and understand the sources influencing their TPACK and technology utilisation in teaching, semi-structured questionnaires were distributed to thirty senior primary teachers in the Endola circuit. In addition to the questionnaires, individual interview sessions were conducted with seven participants, all of whom were also reached and participated in a focus group interview. This selective choice of participants aimed to gain deeper insights into their TPACK sources and their experiences related to technology use in teaching.

A total of eight participants were selected for interviews in this study. This specific number was chosen to uphold the quality and reliability of the data, anticipating the possibility of participant withdrawals. However, out of the initially chosen eight participants for interviews, only seven could be reached and successfully engaged. Unfortunately, the eighth participant remained unresponsive and could not be contacted, despite committing to respond to the researchers.

Furthermore, classroom observations were conducted for three out of the seven participants. The selection of participants for the study was deliberate, with the researcher exercising discretion to identify individuals possessing specific characteristics relevant to the research (Maestripieri et al., 2019;Conger,Krauss & Simuja,2016). The researcher considered multiple criteria in the selection process, including experience in teaching and integrating technology, availability, willingness to participate, completion of ICT training, and ownership of laptops and smartphones. These criteria guided the selection of participants for both interviews and observations. Given their teaching experience, proficiency in integrating technology, access to ICT training, and possession of technological tools, these chosen participants are well-positioned to provide valuable insights into their grasp of Technological Pedagogical Content Knowledge (TPACK), the factors influencing their TPACK and their encounters with integrating technology into their teaching approaches.

While all 23 participants met the established criteria for inclusion in the study, not all of them provided consent for participation in interviews or classroom observations. Consequently, the researcher was only able to engage with those candidates who granted their consent. Additionally, the researcher also took into account the accessibility of the research sites.

3. 8. 3 Data gathering Techniques

This study utilised multiple qualitative data-gathering techniques to collect information, allowing for data triangulation, as described by Bertram and Christiansen (2018). Triangulation involves cross-verifying data from different sources to identify consistencies or discrepancies. The data collection tools employed included semi-structured questionnaires, semi-structured interviews, focus group sessions, and classroom observations. Before the data collection, necessary permissions were obtained from the gatekeepers, including the Regional Director of Education, Arts, and Culture of Ohangwena region, the Inspector of Education of Endola Circuit, and school principals (See Appendices B and C). Parents, learners, and teachers also obtained informed consent for classroom observations (See Appendices E, F, and G). The study received ethical approval from the Ethics Department at Rhodes University (See Appendix A). The data collection process began with distributed semi-structured questionnaires, interviews, observations, and focus group sessions.

3.8.3.1Semi-structured questionnaire (See Appendix H)

Kumar (2011) defines a semi-structured questionnaire as a systematically prepared form or document with open and closed questions designed to elicit responses from research participants to collect quantitative and qualitative data. This study used a semi-structured questionnaire to get qualitative and less quantitative data on teachers' perceptions of their understanding of TPACK constructs. The questionnaire used in this study was adapted and revised from a study examining elementary school teachers' integration of technology and the enactment of TPACK in Mathematics by Urbina and Polly (2017).

In the TPACK questionnaire of this study, all sections were revised to suit the purpose of the study. The questionnaire consisted of four areas: A) Biographical and background information; B) Technological access and use; C) Science teachers' understanding of TPACK; and D) Teachers' TPACK to integrate technology in teaching. The teachers' TPACK section consisted of all TPACK constructs: D1) 12 items for TK; D2) 10 items for CK; D3) 8 items for PK; D4) 8 items for PCK; D5) 7 items for TCK; D6) 8 items for TPK and eight items for TPCK.

The items were rated for the participants to tick in a column of their choice based on how they weight their knowledge for each TPCK construct. Each item was placed under the description: strongly disagree = when the participant is in total disagreement about the ability; disagree = When the participant is in a dispute about the knowledge; neither agree nor disagree = when the participant could not approve or deny the knowledge, agree = when the participant agrees about the knowledge and strongly agree = when the participant is in total agreement about the ability.

The questionnaires were delivered to the participants during circuit subject meetings and activities. Before answering the questionnaire, participants were informed of their right to participate in the study and asked to sign the informed consent papers attached to the questionnaires. A total of 30 semi-questionnaires were distributed among these teachers, and 23 were completed and returned. As participating in the study was voluntary, the number of complete questionnaires varied, ranging from two to three from the eight schools involved.

During the questionnaire distribution, the researcher picked up some exciting participant reactions. For instance, some participants complained that the questionnaire was too long and would take time. Some of these participants requested that the researcher read the questions while answering. Hence, they opted to answer the questionnaire orally, with the researcher reading the questions or instructions. These participants completed the questionnaire and handed it back to the researcher at that moment.

Furthermore, while collecting questionnaires, some participants raised concerns about a statement in the consent letter stating that their participation in the study is voluntary and that they can withdraw from the study should they feel no more willing to do so. To this statement, participants said that it discourages people from taking exercise as seriously. They pointed out that in their culture (Oshiwambo culture), such talk shows disrespect and can prevent the participants from taking the exercise as necessary. They further emphasise that in their culture, such words demotivate a person to do the work willingly and diligently. They indicated that a questionnaire accompanied by permission letters from the director and the inspector makes the study valuable and essential and suggested such statements be avoided. This input means a review of research ethics from an African perspective, recognising Namiban Oshiwambo's cultural context as a contribution to the research process. It also shows how research ethics can shape the research procedures and techniques as suggested in Figure 3.2. The data from questionnaires responded to both research questions 1 and 2.

3.8.3.2 Semi-structured interview (See Appendix J)

Semi-structured interviews are the researcher's discussions with individual participants (Roulston & Choi, 2018). A semi-structured interview was used to ensure the uniformity of the data in this study. This interview was conducted with seven participants based on their responses to a semi-structured questionnaire and consent to be interviewed. In this study, semi-structured interviews sourced more insight into teachers' perceptions of their understanding of TPACK, the sources of TPACK they draw on, and their experiences shaping the use of technology in their teaching.

Seven participants selected and consented to be interviewed were conducted for the interview. As indicated earlier, the eighth participant could not be reached and did not form part of the data collected. Three of the participants out of the participants opted for a face-to-face interview at their schools after school hours were reached. The school principals were duly informed of the arrangement and granted their permission. The other four participants opted for a telephonic interview. All the interview participants requested the interview question guide before the exercise. The interview question guide (Appendix J) was shared via email, and each participant was asked to indicate a reply upon receiving the email. The interviews lasted between 30 to 45 minutes.

Before the interview commenced, participants were reminded about the audio recording of the interview session and asked if they were comfortable with it. For each interview, the session started with the introduction, where the researcher greeted the participant and introduced herself. The highlights of the purpose and focus of the study were provided, as well as information about confidentiality, anonymity, and the rights of the participants.

All interviews were conducted in English, the official language and the medium of instruction in Namibian schools from grade 4 upward. Endola Circuit schools are in a community where Oshiwambo is the local language. However, conducting the interviews in English was necessary as not all teachers in these schools were Oshiwambo-speaking groups. The multi-lingual and multi-cultural disposition of the participants were taken into consideration. However, participants were informed to indicate when they find it challenging to respond in English. Hence, code-switching was allowed.

Through the interviews, I observed that language is one of the barriers and challenges in the data-collecting process. Language challenge became a challenge to both the participant and researcher, which could compromise the meaning or interpretation. I observed that translating the local language to English adds a layer of understanding as words or phrases may be directly translated and so lose their meaning or nuance. For fairness, reliability of the research findings, and not to disadvantage a participant whose home language falls outside of the researcher's capabilities, the decision was thus made to conduct the interviews in a language the participants and the researcher are familiar with and as previously mentioned, is the official communication language of these schools.

All interviews were audio recorded. The audio records were transcribed verbatim into written texts. Interview transcripts were emailed to the participants to verify if what they said was transcribed. Participants were informed that they might add, remove, or request edits if they need information that needs to be added, clarified, or further elaboration. None of the participants edited the data. The interview transcripts were also shared with the supervisor. The data from the interview responded to both research questions one and two

3.8.3.3.Observation (See Appendix L)

Observation is defined as a purposeful, systematic and selected way of watching and listening to an interaction or phenomenon as it takes place (Oksattridywi, 2017). In this study, observation was conducted with three participants from the seven teachers who participated in a semi-structured interview and consented to be observed. Observation provided more insight into the sources of TPACK teachers draw on and experiences shaping the sources of TPACK and their use of technology in their teaching. The researcher used an observation guide (See Appendix L) to observe issues with research objectives and respond to research question two.

Informed consent was sourced from the participants, parents, and learners for the researchers to observe in one of the science lessons for each participant. The selected teachers surveyed were informed in advance, so their lesson planning and presentation on technology use should be precise. No video recording nor audio recording was done for observation schedules. All the observation data were recorded using an observation record sheet.

During the classroom observation, I noticed that two participants used laptops and data projectors to present the science content, showing videos they downloaded from the internet. The third teacher used the cellphone to show some pictures of science content she had taken when she visited the coastal area of Namibia. Each lesson lasted for 40 minutes only. Before the lesson started, each participant introduced the researcher to the learners and highlighted the purpose of the study. Since the focus was not on the learners, their reaction to the content was not part of the observation record data.

Exciting events and activities were noted during the observation process. For instance, four teachers who consented to be interviewed and observed were selected for observation; however, only three could be reached. Unfortunately, the fourth teacher could not participate in the observation process due to unforeseen circumstances. She fell sick and went on sick leave for a certain period. However, the fourth teacher, who was not part of the observation process, did not compromise the data quality because the minimum number of the three participants targeted for this exercise in this study still needed to be reached.

3.8.3.4 Focus group interview (See Appendix K)

Creswell and Creswell (2018) describe a focus group interview as a stimulating discussion among group members. Seven participants who were individually interviewed were reached for a focus group interview. These participants were selected based on their responses to the semi-structured questionnaires, willingness, and accessibility.

An interview with a focus group intended to source more insight into perceptions of their understanding of TPACK, the sources of TPACK they draw on, and experiences shaping the selection or prioritising of the sources of TPACK in teaching. The reason for choosing focus group interviews is that the researcher intends to stimulate reflective discussion among the participants and promote the relevance and validity of the data. The interview question guide (Appendix K) was used and the researcher's role in the focus group interviews was to initiate thoughtful recall interview questions that all participants could answer and tape-record the responses. Informed consent for tape recording was requested from the participants before the record.

Due to some duties and responsibilities after school, getting the participants to one center for a focus group interview took much work. To respond to the challenge, participants indicated and agreed to meet virtually for a focus group interview using Zoom, an online service. Before the focus group interview commenced, the researcher ensured that all participants knew how to install and use Zoom on their gadgets and noted the possible internet challenges.

Firstly, the researchers set the 30-minute Zoom meeting and sent the link to the participants for trial. This exercise allowed the participants to familiarise themselves with the Zoom app. Some participants were senior teachers over 50 who needed Zoom assistance. Fortunately, all seven participants managed to log in during the trial, and those unfamiliar with it were assisted.

The Zoom meeting was set for 45 minutes, and the link was shared with the participants on WhatsApp and email. Unfortunately, the 45-minute Zoom set was insufficient because the discussion took longer than expected. To respond to that challenge, the researchers quickly set another Zoom meeting and shared the link with the participants. All the two Zoom meetings were charged with the automatic recording activated, but an extra device was also used as a backup. An issue of internet trapping occurred once with one participant during the Zoom meeting but was minimal as a candidate was assisted and managed to join back. The focus group discussion was transcribed verbatim into text and shared with the participants for validation.

3.8.4 Data Analysis Process

Data analysis is when researchers reduce data to a story and interpret it to derive insights. It helps reduce a large chunk of data into smaller fragments, which makes sense (Elliot, 2018; Opie, 2019). The data collected using questionnaires, interviews, focus groups, and observation was analysed inductively, allowing themes to emerge from the raw data. Molnár, Greiff, and Csapó (2013) state that inductive reasoning shifts from the specific to the general, from particular observations to discovering patterns, whereas deductive reasoning shifts from the general to the clear, from expected marks to observations that test if a pattern occurs. The questionnaires, interview records, focus group, and observation records yielded pages of transcripts and notes, which had to be purposefully, systematically, and carefully studied, analysed, and interpreted to elicit empirical findings and suggest recommendations.

Thematic analysis was used in this study. The researcher used all the seven constructs of TPACK as adapted from Mishra and Koehler (2006) to serve as a lens for assessing and analysing specific knowledge elements of technological pedagogical and content knowledge possessed by the rural senior primary Natural science teachers in the Endola circuit. According to Opie (2019) and Elliott (2018), data analysis is categorised into editing, coding, and creating an electronic data file.

After the data collection process, the first step was to check the data for correctness, consistency, and legibility. For instance, the moments of laughter and pausing during interviews were highlighted in the transcripts. After the data had been edited, coding and assigning symbols to the raw data occurred. McCallum (2019) explains that data coding begins by *identifying data segments*, a text that is "comprehensible by itself", and then analysing these segments to *produce codes*. Codes are words or phrases that act as labels or tags for a text (Barman, 2014).

Various codes were used in this study, such as Q1 (questionnaire), SSI_1 (semi-structured interview), Focus group Interview (FGI), and observation (OB) to refer to the data source while P (participant) refers to the participants. The Q, SSI, FGI, and OB codes were used to refer to the data as per the data gathering tool to make it easy for triangulation, while P1 and P2 codes were used to ensure the anonymity of the participants. This study analysed the data collected from questionnaires partly quantitatively and more qualitatively. Quantitative analysis of the data was used as descriptive statistics to transform or summarise the data into a single or a few numbers that summarise the data (Bertram & Christiansen, 2018).

The quantitative data obtained from the questionnaire was analysed using the cross-tabulation method. Cross-tabulation is regarded as the solution for quantitative analysis (Macia, 2015). Denscombe (2017) describes cross tabulations as the tables presenting the results from survey respondent subgroups. Moreover, Monsen (2018) defined cross-tabulation as a two or more-dimensional table that records the number (frequency) of the respondents with the specific characteristics described in the cells of the tables according to the selection criterion and then analysed.

Cross-tabulation provides a wealth of information about the relationship between the variables (Rao & Yip, (2018). With cross-tabulations, a researcher can examine relationships within the data that might not be readily apparent when only looking at the total survey (Gheyle & Jacobs, 2017). This study used cross-tabulation to determine the natural science teachers' perception of their understanding of TPACK constructs by analysing how they rated themselves per construct. Hence, cross-tabulation allowed the researcher to draw inferences between data sets recorded in tables.

The qualitative data from questionnaires and the raw data obtained from the semi-structured interviews, focus group, and observation were organised, transcribed verbatim into written text, and thematically analysed. The researcher used different color highlighters to group the coded data into categories, sub-themes, and themes. The qualitative analysis commenced by initially coding the data according to the research questions and then according to the questions on the interview schedule, focus group, and observation record sheet by assigning codes. Initial codes, such as: *I use the internet to download, use technology for my teaching, use the laptop, curriculum content, the syllabus guides, download videos for education, use computers to type, learners' context, technology knowledge, technical support, time, interest, motivation, lack of technologies, attitudes or feelings (positive, negative), interest perception, lack of teaching materials, technological know-how, teaching method, approaches to sciences teaching*, were generated from the data by focusing on the key concepts that evolved from the transcripts for questionnaire interviews, focus group, and observation sheet.

Similar codes were identified and grouped under one primary code during the coding process, which evolved into categories and sub-categories. Vague principles were re-looked; some were deleted while some were re-coded, which was continually done to refine the coding process. After coding, recording and code grouping, thematic analysis was implemented to develop themes that categorise data per research question. The data was further analysed to identify relevant quotations.

Saunders (2018) described themes as patterns that create relationships between data. Korstjens Moser (2017) further emphasises that themes will emerge when corresponding findings repeatedly occur across different participants and data sources. In this study, as the code groups appeared, they were further analysed and themed, forming the research findings' starting point. All the relevant data were grouped under the themes to answer the research questions. Finally, the themes developed from the coding outlined the rural senior primary science teachers' perception of understanding TPACK constructs, the sources of TPACK they draw on, and experiences shaping the use of technology in teaching.

3. 9 Trustworthiness, Validity and Reliability

Belotto (2018) described trustworthiness in a research study as the degree of confidence in data, interpretation, and methods used to ensure the quality of a survey. Richards and Hemphill, (2018) urge that the trustworthiness of a research study should start from the preparation phase until the reporting phase. In their study about Qualitative content analysis focusing on reliability, Elos et al. (2014) compiled a checklist for researchers attempting to improve the trustworthiness of the content analysis study. They indicated that the selection of the appropriate method of data collection, sampling strategies, a unit of analysis, categorisation and abstraction, interpretation, representativeness, reporting results, and reporting analysis process is essential for credibility, dependability, conformability, transferability and authenticity, which ultimately ensure the trustworthiness of the study.

Trustworthiness is an essential element of research quality as it determines the validity and reliability of the study. Cohen et al. (2018) describe validity through various forms such as "honesty, depth, authenticity, richness, trustworthiness, dependability, credibility and scope of the data achieved, the participants approached, the extent of triangulation the disinterestedness or objectivity of the researcher (p. 246). To ensure trustworthiness, various data-gathering tools for data triangulation were employed.

Cohen et al. (2018) described triangulation as a technique in the social sciences attempting to map out or explain more fully the richness and complexity of human behaviour by studying it from more than one standpoint. Various data-gathering tools, such as semi-structured questionnaires, interviews (individual and focus group), and observation, were used to ensure that the strengths of the others compensate for the shortcomings of one instrument.

During data collection, the interviews were conducted where the participants felt comfortable and considered their schedules, unforeseen circumstances and backgrounds to avoid the possibility of some participants withholding relevant information. (Nowell et al. (2017) state that researchers should ensure that data is accepted as trustworthy if the data analysis was “conducted precisely, consistently, and exhaustively. The data presentation contains individual quotations from the interview transcripts to ensure the study's trustworthiness.

Korstjens and Moser (2018) state that triangulation and member checking are some elements that ensure a research study's credibility. In this study, the supervisor validated the questionnaires, and the researcher processed the semi-structured interview and piloted the questions with fellow masters and honours students. Furthermore, trustworthiness was also ensured by transcribing transcripts verbatim.

Member checking strategy was also employed as a means to ensure trustworthiness. The member check strategy involves data feedback, analytical categories, interpretations, and conclusions to members (participants) (Korstjens & Moser, 2018). The interview transcripts were shared with the participants. This exercise was done for the participants to see if what they said was transcribed, which ultimately ensured the accuracy of the data. To ensure the accuracy of the data, participants were allowed to commend and give suggestions.

3. 10 Positionality

Mahajan (2018) posits that the position of a researcher may disadvantage some research participants' participation in the study at some points if not carefully considered. Hence, Creswell and Creswell (2018) alert the researchers to be vigilant of their positionality as it can compromise the data collection and interpretation if not adequately addressed, mainly when the researcher collects data at their workplace or when they are in a superior role to participants.

For this study, the researcher and the participants are all senior primary science teachers in the circuit. The researcher is also the facilitator of the Natural Science subject for the senior primary phase at the circuit level. In such cases, the participants were likely to think the research study was related to their continuous professional development and that they were obliged to participate. This position could also influence how participants interacted with the researcher during the research process. I observed that bias and subjectivity arise in a research study due to the researcher’s position and role at the selected site.

As a teacher-researcher, I knew the uneven power relation between the participants and me. First, I acknowledged that my position as a teacher and a facilitator of Natural Science in the Endola circuit is a potential risk to the study. To neutralise the power dynamic, I fostered rapport and trust with the teachers by clarifying that my research was collaborative rather than observational, aligning with Ngcoza and Southwood (2015). I established harmony and trust with these teachers by explaining that the study data is not related to their regular school work, nor does the study intend to evaluate their professional and teaching performance. I have also emphasised that the focus of the study was on the need to hear the participants’ viewpoints, not to judge them and to affirm what the researcher thinks or knows.

Furthermore, I recognized the significance of culture in this study, noting that my cultural background mirrors that of most participants. Acknowledging this shared cultural context, I set aside my own cultural beliefs and research assumptions, emphasizing the need to learn from participants who share my cultural background. Throughout the study, I respected participants' diverse attributes, including age, language, nationality, customs, race, color, gender, and marital status. Despite not being a participant researcher, I acknowledged the impact of my experiences in technology use in teaching on the adaption of questionnaires, development of interview questions and observation sheets. My positionality played a role in interpreting the data.

3.10.1 Research Ethics

Anabo, Elexpuru-Albizuri, and Villardón-Gallego (2019) describe ethics in academic study as the moral principles governing how researchers should conduct their investigations. As indicated in section 3.8.3, ethical clearance was obtained from Rhodes University before the study commenced. Subsequently, the Director of Education, Ohangwena region, and the inspector of education, Endola circuit, granted permission to conduct research (cross reference 3.8.3)

Permission to conduct the research with the selected teachers was obtained from the principals of the selected schools (cross reference 3.8.3). Informed consent was obtained from the selected teachers, learners, and their parents (cross reference 3.8.3). It was explicitly made clear to the participants that the research study is a private study conducted by a master's student at Rhodes University, not on behalf of the school, circuit, or the region. The well-being of the research participants should be a researcher's primary priority whenever research is conducted (Bell & Waters, 2018). Due to the challenge of different duties for the teachers after school hours, all participants were offered the option of both online and in-person interviews. All participants opted for virtual communication via a Zoom meeting for the focus group interview. The participants' needs were respected and observed.

All participants were informed of their rights to participate in the study through informed consent papers (See Appendix E). Participants were guided through the consent form, and signed consent was obtained. They were assured that they could withdraw from the study at any time without prejudice. They were also given interview transcripts to verify the accuracy of the data. Participants were accorded time to ask questions and raise any issues regarding the study.

Confidentiality and anonymity are of the utmost importance and ethical consideration (Fleming & Zegwaard, 2018). The data generated in the study was recorded and analysed anonymously. The research data was anonymously coded and presented. Participants' names were not used anywhere in the study. Interview audio records, transcripts, and observation sheets are stored in soft copy and locked with a password to which only the researcher and supervisors can access data. Complex documents (questionnaires, observation record sheets, and handwritten transcripts) are scanned and saved in the USB, and together, all are kept in an area only known to the researcher. Any duplication of data was duly destroyed.

3.12 Summary of the chapter

The chapter presented the methodological design for this study. The research questions and aim of the research (Cohen et al., 2011; Sileyew, 2019) informed the appropriate methodology design for this study. The research aimed to explore the rural school natural science teachers' perception of their understanding of TPACK constructs and investigate the sources of TPACK they draw on and the experiences shaping their use of technology in their teaching. The research aims to fit into the interpretivism worldview "that meanings arise from the process of social interaction" (Gray, 2013). Therefore, the study used the interpretivism philosophy" design of mixed methods approach, which comprised quantitative and qualitative aspects.

The quantitative aspect of the study was achieved through a semi-structured questionnaire sent to the Natural Science teacher in the Endola educational circuit. The data generated from the questionnaire were analysed to find the science teachers' perceptions of their understanding of TPACK constructs. Some parts of the questionnaire constituted the qualitative aspects, and together with interviews, observations, and focus groups included the methods for the qualitative part of this study. Seven Natural Sciences teachers who indicated that they are regular users of technology in their teaching were purposively selected to be the cases for this study. These teachers were interviewed on their uses of technology in their teaching as individuals and in a focus group. The teaching episodes of three of the seven Natural Science teachers were observed to find out how they use technology to enhance content teaching. The last section of the chapter outlines how trustworthiness was ensured for the study, the researcher's positionality and the ethical considerations in this study.

Chapter 4: EMPIRICAL FINDINGS

4.1	• Introduction
4.2	• Technology use and access
4.3	• The evaluation of TPACK constructs
4.4	• The TPACK constructs valued by participants as they integrate technology into teaching
4.5	• Factors attributed to participants' use of technology in teaching
4.6	• Summary of the chapter

Figure 4.1: The organisation of Chapter 4

4.1 Introduction

The preceding chapter is excavated into the study's methodology. It extensively covered the study's research design, data collection, analysis, and ethical considerations. This chapter presents the findings of the study for the data as collected through questionnaires, interviews, focus group, and observation on rural science teachers' TPACK. Partly of the results from the questionnaires form the quantitative aspect of this study, while the rest of the questionnaire data, individual interviews, focus group, and classroom observations form the qualitative part.

The data provided in this chapter were obtained in two distinct phases, which are elaborated upon as follows:

• Phase One:
In the initial stage of the study, the researcher diligently collected crucial data through well-structured questionnaires. This critical step in the research process involved creating comprehensive questionnaire questions tailored to elicit specific insights. For a more detailed explanation of this data collection method, please refer to section 3.8, which thoroughly examines the methods employed.

• Phase Two:
In the subsequent phase of this research project, the researcher conducted a series of research interviews and observations following a thorough analysis of the collected questionnaires. These interviews included both semi-structured interviews and focus group discussions.

Observation was conducted once for each participant, as explained in section 3.8. This multifaceted approach allowed for a more profound exploration of the research questions, fostering a comprehensive understanding of the underlying nuances and perspectives.

The findings of this study are structured into distinct sections as follows:
Section 4.1 serves as the chapter's introduction, providing an overview of the previous chapter, detailing the study's execution phases, the research questions, and the background information about the participants. Section 4.2 discusses technology access and use. Section 4.3 covers the assessment of TPACK constructs. Section 4.4 discusses the TPACK constructs valued by the participants to integrate technology into their teaching. Section 4.5 presents the factors attributed to participants' use of technology in teaching. Section 4.4 provides a summary of the chapter, offering concluding insight.

Participants' background and information

Total number of participants	Gender	Age range	Field of expertise and field	Teaching experience (years in range)	*Teaching qualification range*
23	*11 females 12 males*	*26-59*	*Natural Science grade 4-7*	*6 – 32*	*Diploma in Education – master's in Education*

Table 4.1: Illustrates the participants' background profiles

Research questions

This study aimed to explore and assess the rural senior primary Natural Science teachers' TPACK. The following research questions were designed to drive this study, and the findings are presented respectively:

RQ1. What are rural senior primary Natural Science teachers' perceptions of their understanding of TPACK constructs?
RQ2. What sources of TPACK do rural senior primary Natural Science teachers draw on and experiences shaping technology use in their teaching?

The data generated from the questionnaires, interviews, focus group, and observation solicited the about the Natural Science teachers' TPACK to integrate technology in teaching, in rural schools in Endola circuit, Namibia. Literature indicates that no study has been conducted in Namibia focusing on exploring the Science teachers' TPACK. Therefore, the findings from the data contribute to a more precise knowledge base of the perception of rural science teachers' TPACK and the use of technology in teaching in this context.

To answer research question 1, this chapter offers findings on assessing science teachers' understanding of Technological Pedagogical Content Knowledge (TPACK) constructs. It also explores the technology facilities/resources available at schools and how teachers use them to enhance teaching and learning. Addressing research question 2, this chapter accounts for the TPACK constructs valued by science teachers for using/integrating technology into their teaching practices. It encompasses discussions on the factors influencing their decisions to incorporate technology in their teaching methodologies.

In the study, a total of 23 natural science teachers took part. To safeguard their privacy and comply with ethical guidelines, the participants were identified using numerical codes and categorised based on their involvement in various research methods, as discussed in section 3.8. All participant quotes were transcribed verbatim, preserving language issues like grammar errors, code-switching, or word repetitions. This approach was maintained to retain the original meaning of the responses.

RQ 1: What are rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs?

As indicated in the methodology section, part of the questionnaire generated the quantitative data in which the rural senior primary Natural Science teachers' perception of their understanding of TPACK constructs was solicited. The data for this research question is sourced from twenty-three Natural Science teachers (n=23) who responded to the semi-structured questionnaires. It also includes the data from interviews (semi-structured and focus group) and observation. The findings about the participants' technology access and use in teaching and learning, followed by an evaluation of the participants' understanding of TPACK constructs to integrate technologies in education, provided the answer to the research question.

4.2 Technology access and use.

4.2.1 Participants' access to technologies available at schools

Participants who completed questionnaires and interviews (individual and focus group) were asked to indicate the technology resources and facilities available in their schools. The findings revealed a variety of technological facilities/ resources present in schools. Several participants mentioned computers, laptops, whiteboards, tablets, and internet access as their schools' technology facilities/resources. Figure 4.2 below summarises the technology facilities and help in the participants' schools as surfaced from the questionnaire data.

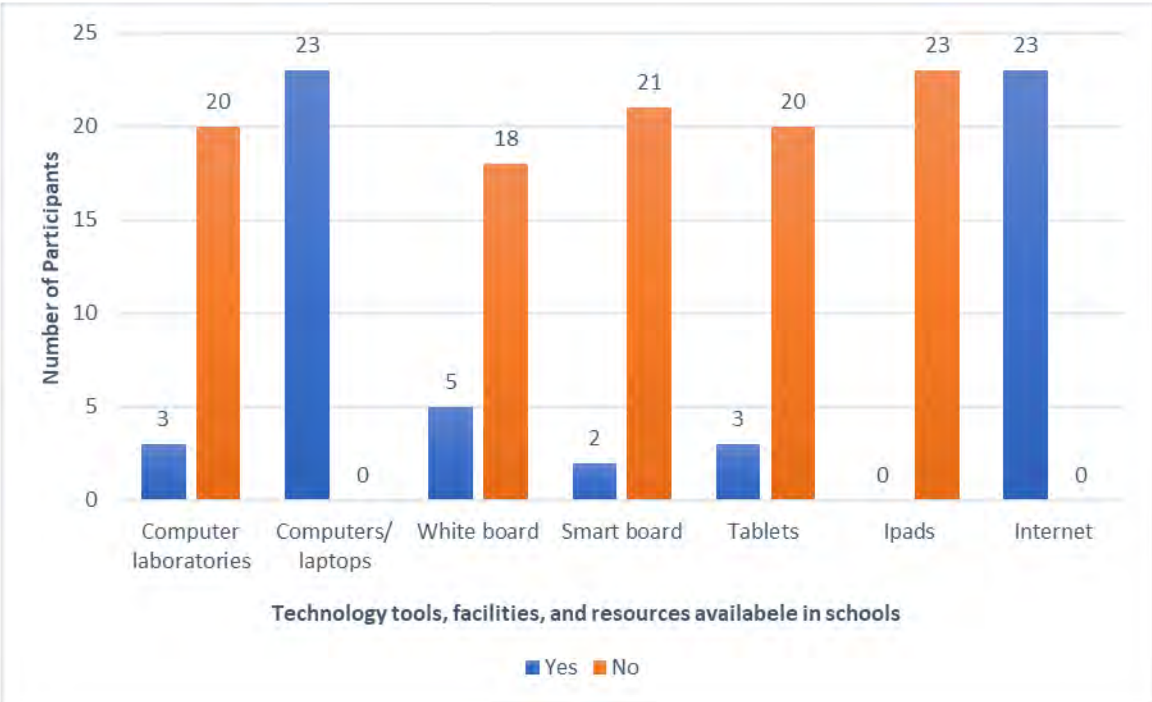

Figure 4.2: Illustrates technology facilities/ resources available at schools

The results in Figure 4.2 show that a few questionnaire participants (n=5) reported having computer laboratories, whereas the majority (n=16) stated that their schools lacked such facilities. However, all participants (n=23) affirmed having access to computers and laptops and having internet connectivity at their schools. Additionally, a few participants (n=3) indicated that tablets are available in their schools, with none indicating iPads' availability.

The data from the individual interviews and focus group discussions also revealed the technologies available in schools. One question during the interviews asked the participants to list the technological tools, devices, facilities, and services available in their schools. In their responses, participants said:

SSI-P2 expressed: "*At our school, we have one computer for the secretary, two laptops, one projector, and no computer laboratory; we use this library as our computer lab. Most teachers, I think all of them, have smartphones. Aaa…. the internet at our is not working, but I come with my pocket WIFI daily to school, which we use as a school*".

SSI-P3 responded, "*We have five laptops, five computers, a whiteboard, a computer lab, and one Tablet for the principal's office. I use the laptop to type and to download pictures and videos from the internet.*"

FGI-P1 narrated, "*There is only one laptop at my school. Our school also has some computers, but they are not working now. So, I come with my laptop to school every day.*"

SSI-P6 said, "*Of course, there are four laptops at school and one computer for the secretary, but two are not working*".

The finding shows that most technologies available in schools are laptops, computers and the Internet. Other technology devices, such as whiteboards, smart boards, and tablets, are available in a few schools, while the iPad is unavailable in all the schools that took part in this study.

Furthermore, during the interviews, participants were questioned about the acquisition of technologies in their schools. The data revealed that some schools received donations from non-governmental organisations and purchased devices from their school development budgets. For instance, during the individual interview, SSI-P5 narrated:

"*The computers available at our school were donated by the school Patron some years back, but the laptops were bought with the money raised through school fundraising activities, the bazaar. In the same vein,* SSI-P8 postulates *that all the desktop computers at our schools were donated through the Millennium Challenge Account.*

4.2.2 The technologies used in teaching

In the semi-structured questionnaire, participants were requested to list the technologies they use in their teaching. The findings on participants' technology use in teaching are presented in Figure 4.3.

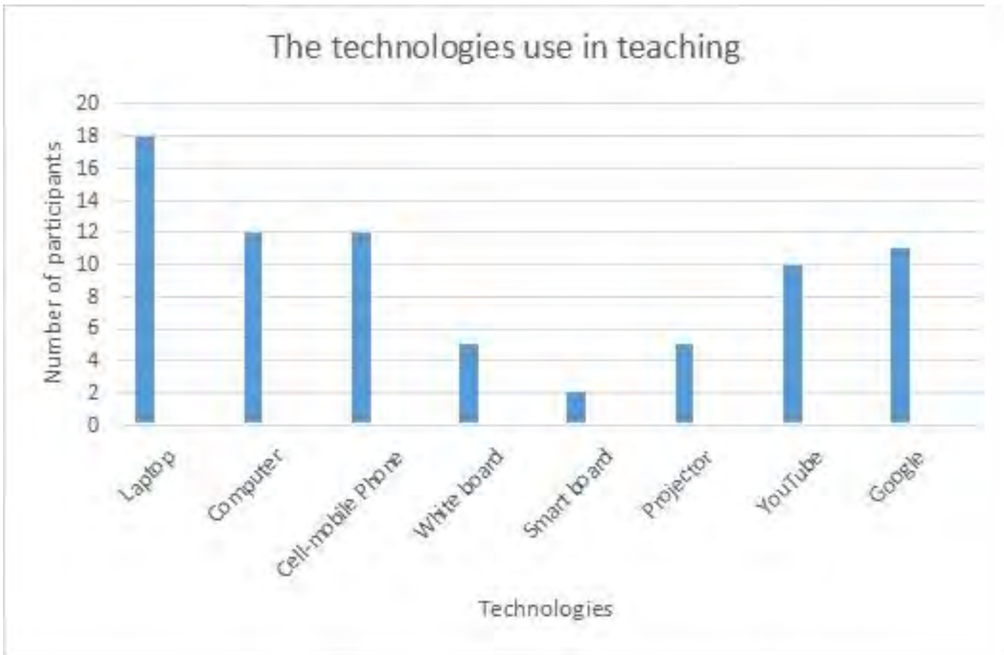

Figure 4.3 illustrates participants' use of technology in teaching.

As shown in Figure 4.3, the majority of the participants (n=18) indicated laptops as the standard devices they use for teaching. Computers and cell-mobile phones were listed by the same number of participants (n=12) as the technology tools they use in teaching. Several participants (n=11) indicated Google and YouTube (n=10) as the technology applications they use to source science content for teaching. Whiteboards and projectors were listed by a few participants (n=5). Very few participants (n=2) indicated smart boards as one of the tools they use in their teaching. The data revealed that no participants listed iPads or tablets for teaching and learning.

Furthermore, in the semi-structured questionnaire, participants were also asked to describe how they use technology for teaching. The data to this question also revealed that laptops, computers, and smartphones were used to prepare lessons, download videos/pictures, set tasks, and present their lessons. Some of the participants described as follows:

Q-P1 described: "*I use technology to get ample information about several topics that we are required to cover in Natural science, and I use videos from the internet so that learners would have pertinent information or clues about certain concepts.*"

O-P6 described. "*I use a laptop and cellphone to find the relevant teaching and learning materials that can be used in a certain topic.*"

Participants indicated the technologies they could use in natural science teaching from semi-structured interviews and focus group discussions. Laptops, projectors, internet, and cell mobile phones appeared as the standard technologies used for the teaching and learning process. The data surfaced when participants elaborated on the technological tools they utilised in teaching. For instance, SSI-P2 narrated:

"*I use the laptop to type learners' activities like the tests, projects, topic tasks, and to download pictures and videos from the internet or YouTube, and also to connect to the projector and show videos to my learners*".

In the same vein, SSI-P7 indicated that *I use the laptop and projector to present the content on the screen. I sometimes use my cellphone to search for information from the internet to enhance the subject content* ".

The questionnaire, semi-structured interview, and focus group data findings show that laptops, computers, data projectors, and cell-mobile phones are the participants' most common technology devices for their teaching. This finding aligns with Padayachee (2017), who indicated that laptops, smartphones, and data projects are the standard technology devices used in teaching.

Moreover, in the semi-structured questionnaire, participants were asked to rate their technology use for communication, teaching, study, and personal communication on the scale <1hr, 1hr, 2-3hrs, 4-6 hrs, and +7hrs. The responses were grouped and rated as: <1hr = never, 1hr = rarely, 2-3 hrs occasionally, 4-6hrs frequently, and 7+hrs most of the time. The findings on the participants' responses are presented in Table 4.3.

Technology use	How often technologies were used				
	Never	Rarely	Occasionally	Frequently	Most of the time
Use technology devices/tools for teaching purposes	n=7	n=2	n=12	n=2	n=0
Use technology devices/tools for personal purposes	n=5	n=2	n=4	n=10	n=2
Use the Internet for study purposes	n=6	n=10	n=3	n=3	n=1
Use the Internet for personal purposes	n=1	n=5	n=4	n=9	n=4

Table 4.2 illustrates the participants' rating of their use of technology.

The data in Table 4.2 revealed that the majority of participants (n=12) occasionally use technology devices for teaching, while the use of technology devices for personal purposes, the majority (n=10) rated as frequently used. The data also presents that none of the participants use technology devices most of the time for teaching; however, some participants (2) frequently use technology devices for teaching. The data further revealed that most participants (n=9) frequently used the internet for personal purposes and rarely (n=10) used it for study purposes. This implies that participants used the internet more for personal than teaching and learning purposes.

4. 3. The evaluation of TPACK constructs

The questionnaire asked participants to show their understanding of TPACK constructs. The section consisted of all seven TPACK constructs, and each construct consisted of several items, such as 12 items for TK, 10 items for CK, eight items for PK, eight items for PCK, seven items for TCK, eight items for TPK and eight items for TPCK. The items were rated for the participants to tick in a column of their choice based on how they weight their knowledge for each TPCK construct.

The participants were asked to rate their understanding of TPACK constructs using the words **strongly disagree**, **disagree**, **neither agree nor disagree**, **agree, and strongly agree**. The responses were grouped and rated as strongly disagree + disagree = disagree, neither agree nor disagree = neutral and agree + strongly agree = agree. The participants' responses were recorded using the cross-tabulation method, as discussed in Chapter 3. They are compiled to ascertain how the participants responded to the items under each construct. This was done to assess their understanding of TPACK constructs and identify specific items that needed attention. This could inform the Ministry of Education where it should target teachers' professional development on ICT in education programs. The participants' responses per TPACK construct are presented as follows:

4.3.1 Technological Knowledge

Participants were asked to rate their self-assessed technological knowledge in the semi-structured questionnaire. Table 4.4 presents the participants' ratings on technological knowledge items.

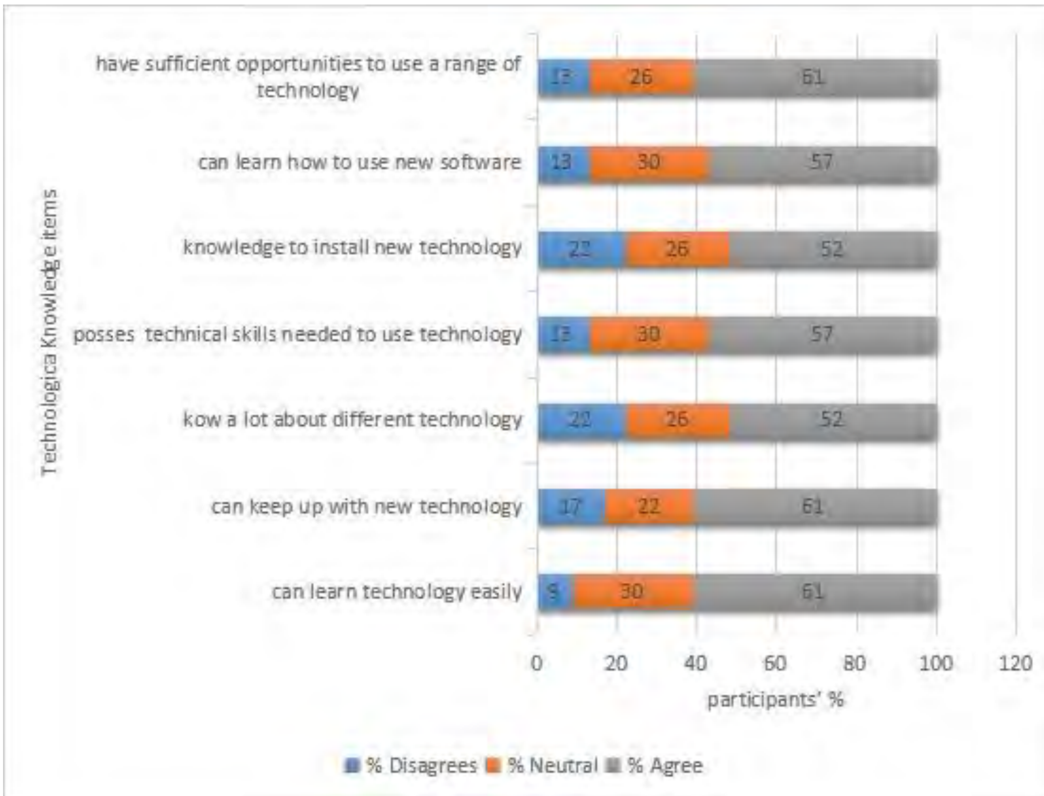

Figure 4.4 illustrates participants' responses to technological knowledge (TK) items.

The analysis of participants' responses to the items on technological knowledge (TK) revealed that 61% indicated sufficient opportunities to use various technologies and learn technology quickly. Aside from this item, 57% can easily learn to use new software and possess the technical skills needed to use technology in teaching. The data further revealed that 52% of the participants knew about many technologies. The finding provided evidence that the participants' overall rating of their technological knowledge is low. This implies that participants perceived themselves as not having enough technological knowledge.

4.3.2 Content Knowledge

In the semi-structured questionnaire, participants were also asked to indicate their self-assessed level of their content knowledge. The finding about participants' rating on content knowledge items is shown in Figure 4.5

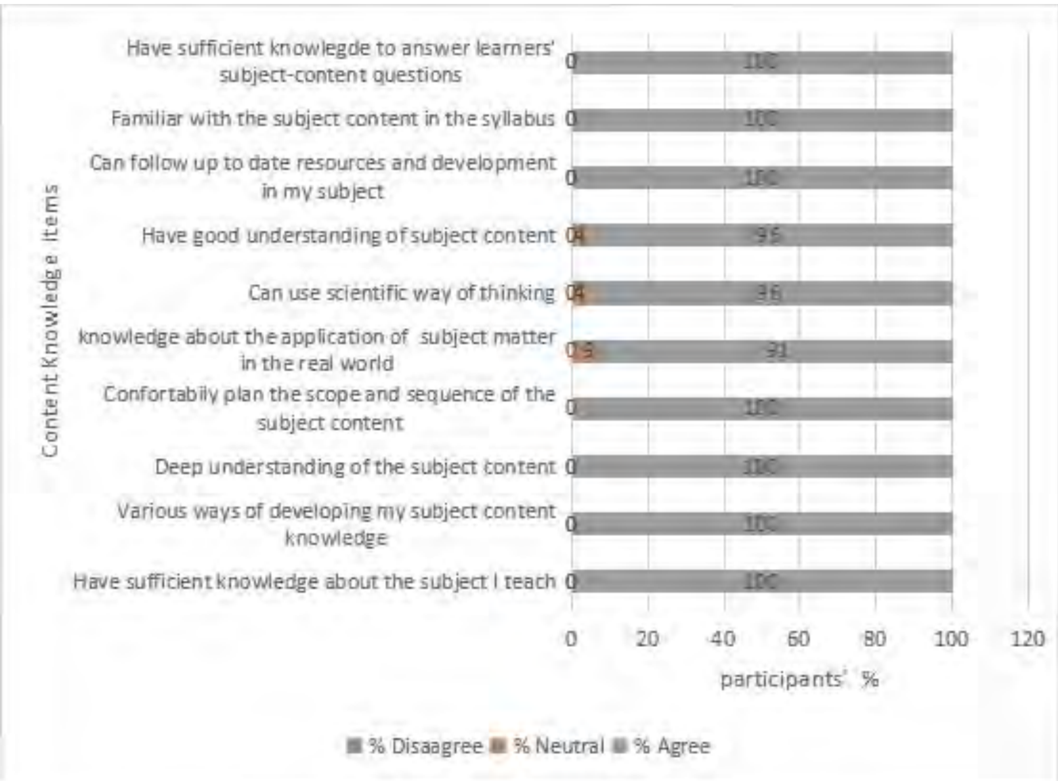

Figure 4.5 illustrates participants' responses to Content Knowledge (CK) items.

Figure 4.4 presents that 100% of the participants have sufficient subject content knowledge, are familiar with the subject content prescribed in the syllabus, have adequate content knowledge to answer learners' questions, keep up to date with resources and developments in their subject, they comfortably plan the scope and sequence of concepts in their subjects and have a deep understanding of their subject content. The data in the figure also shows that 9% of the participants were neutral about their knowledge of applying subject matter in the real world; in comparison, 4% were neutral with their scientific way of thinking and were comfortable planning the scope and sequences of the subject content. The data finding provided evidence that participants perceived themselves with high content knowledge.

4.3.3 Pedagogical Knowledge

In the semi-structured questionnaires, participants were also asked to indicate the self-assessed level of their pedagogical knowledge. Figure 4.6 presents the findings on participants' responses to pedagogical knowledge items.

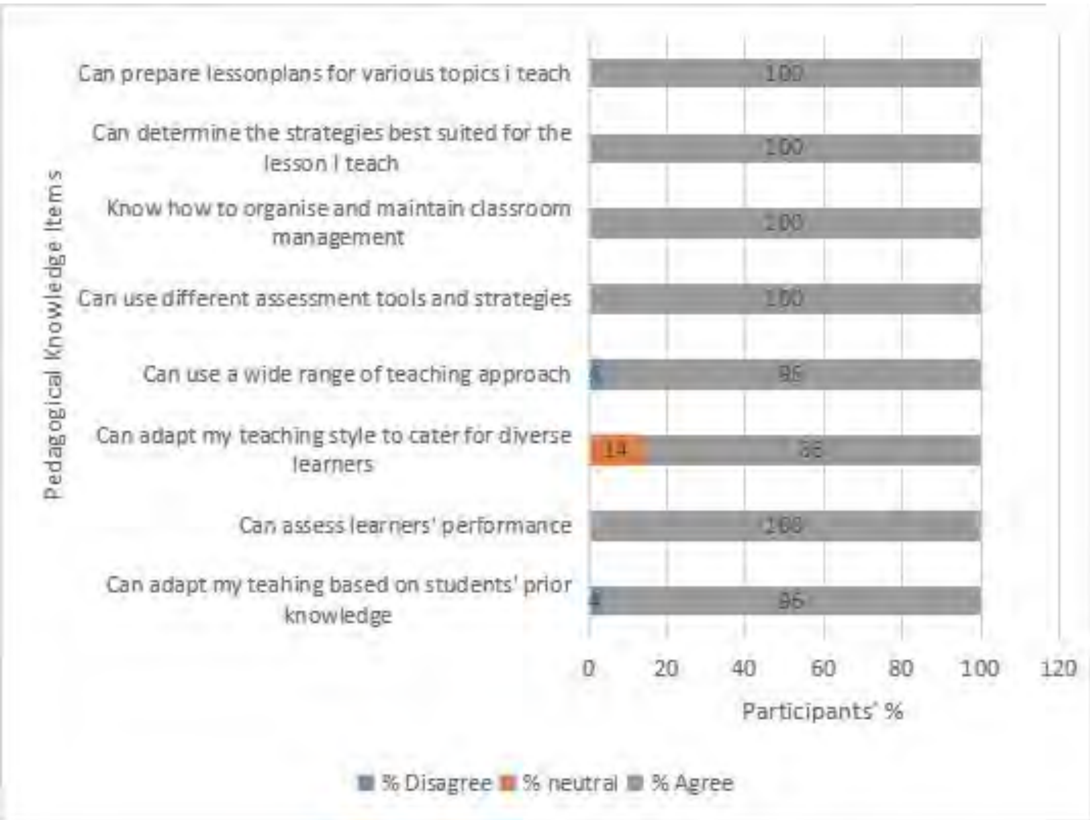

Figure 4.6 Illustrates participants' responses to Pedagogical Knowledge (PK) items.

Fig. 4.6 illustrates that 100% of the participants know how to assess student performance in a classroom, prepare lessons for various content they teach, determine the best strategies for their lessons, organise, maintain classroom management and use different assessment tools and techniques. At the same time, 96% indicated that they could adapt their teaching based on student's prior knowledge and use a wide range of teaching approaches in a classroom setting. However, 14% of the participants are neutral about their knowledge and ability to adapt different teaching strategies to cater to learners' needs.

4.3.4 Pedagogical Content Knowledge

Participants were also asked to rate their pedagogical content knowledge in the questionnaires. Figure 4.7 shows the findings.

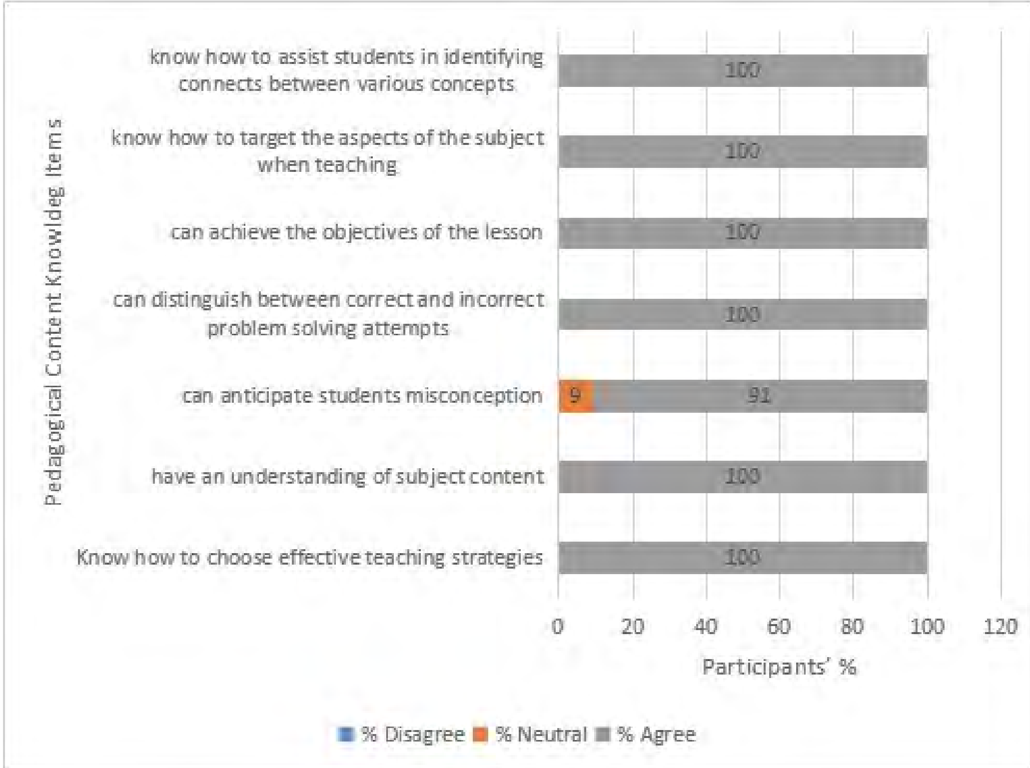

Figure 4.7 illustrates participants' responses to Pedagogic Content Knowledge (PCK) items.

As illustrated in Figure 4.7, the data shows that 100% of participants possess the knowledge and the ability to assist students in identifying links between various concepts in the subject content. They can achieve their lesson objectives, understand subject content, know the technologies they can use in understanding content, and know how to choose effective teaching strategies. However, the finding also revealed that 9% of the participants were unsure of their knowledge and ability to anticipate students' misconceptions.

4.3.5 Technological Content Knowledge

In the analysis of the participant's responses to the items under technological content knowledge, the results show low ratings compared to their content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) ratings. The finding on participants' rating of technological content knowledge is shown in Figure 4.8

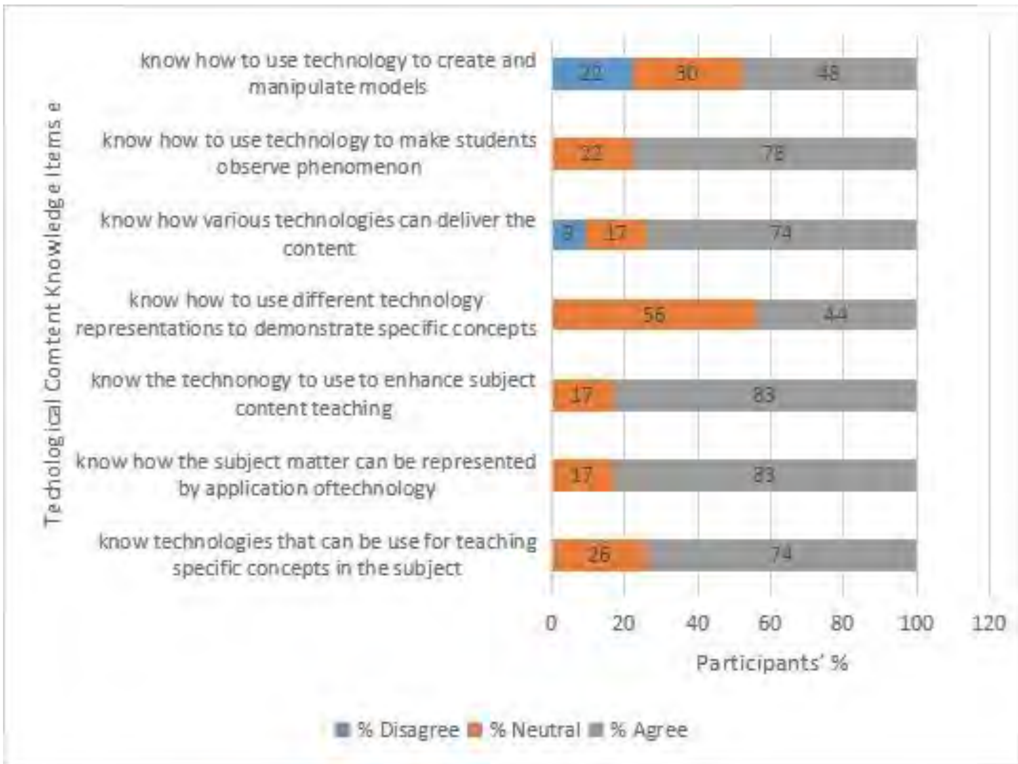

Figure 4.8 Illustrates participants' responses to Technological Content Knowledge (TCK) items.

The finding in Figure 4.8 shows that 83% of the participants indicated that they know the technology to use to enhance subject content and how the application of technology can represent matter. The data further revealed that 78% of the participants know how to use technology to make students observe phenomena, and 74% know how various technologies can enhance content delivery and understand the technologies that can be used for teaching specific subject content. On the contrary, 56% of the participants are unsure about using technology representations to demonstrate particular subject content, whereas 30% are unsure about using technology to create and manipulate models.

4.3.6 Technological Pedagogical Knowledge

In the questionnaire, participants were asked to rate their technological pedagogical knowledge. Detailed information on the participants' technological pedagogical knowledge is presented in Table 4.3 and Figure 4.9

Technological Pedagogical Knowledge (TPK) items	**Disagreed**	**Neutral**	**Agreed**
I know how to choose technologies that enhance the teaching approaches for a lesson	3	5	15

I know how to choose technologies that enhance learners' learning of a concept	3	4	16
I know how to choose technologies that are appropriate for my teaching	2	2	18
I can apply technologies to different teaching activities	2	6	15
I can effectively manage a technology-rich classroom	2	7	14
I can use technology to help assess student learning	4	5	14
I can think critically about how to use technology in my class	2	2	19
I can choose technologies that enhance the content of a lesson	2	3	18

Table 4.3 illustrates participants' responses to technological pedagogical knowledge (TPK) items.

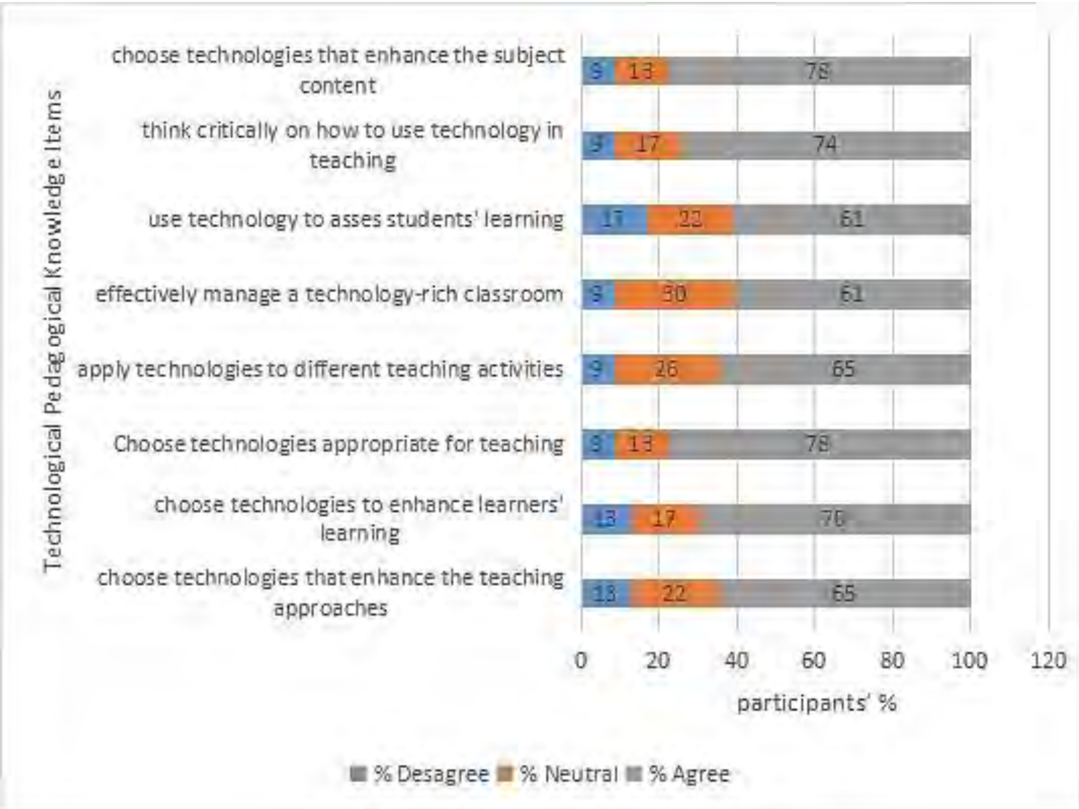

Figure 4.9 Illustrates participants' responses to Technology Pedagogical Knowledge (TPK) items.

The data presented in Table 4.3 and Figure 4.9 reveals several key findings. First, 78% of the participants are proficient in selecting technologies that improve their teaching approaches. Additionally, 74% of the participants indicated they can think critically about integrating technology into their teaching. Moreover, 70% of the participants agreed that they can choose technology that enhances the learning experience for their students. Furthermore, 65% of the participants are adept at applying technology to various teaching activities, and 61% can effectively manage a classroom with technology while using it for student assessment. However, it is worth noting that 30% of the participants need clarification about their proficiency in effectively managing a technology-rich classroom.

4.3.7 Technological Pedagogical and Content Knowledge

The participants rated their understanding of Technological Pedagogical and Content Knowledge (TPCK) higher than their understanding of Technological Knowledge (TK). The results revealed that most participants agreed with the items related to technological pedagogical content knowledge (TPCK) rather than those related to technological knowledge (TK). However, it is noteworthy that there were also individuals who expressed disagreement or remained neutral on specific aspects of technological pedagogical content knowledge (TPCK). Detailed information on the participants' TPCK is presented in Table 4.4 and Figure 4.10.

Technological Pedagogical and Content Knowledge (TPCK)	**Disagreed**	**Neutral**	**Agreed**
I can teach lessons that appropriately combine my subject matter, technologies, and teaching approaches.	2	5	16
I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn	2	6	15
I can use strategies that combine content, technologies, and teaching approaches in my classroom	0	6	17
I can provide leadership in helping others coordinate the use of the content, technologies, and teaching approaches at my school	1	6	16
I can choose technologies that enhance the understanding of the content of a lesson	0	4	19
I can find and use online materials that effectively demonstrate a specific scientific principle	0	4	19
I can use technology to create effective representations of content that depart from textbook approaches	0	5	17
I can use technology to facilitate scientific inquiry in the classroom	2	7	14

Table 4.4 Illustrates participants' technological pedagogical and content knowledge (TPCK) items.

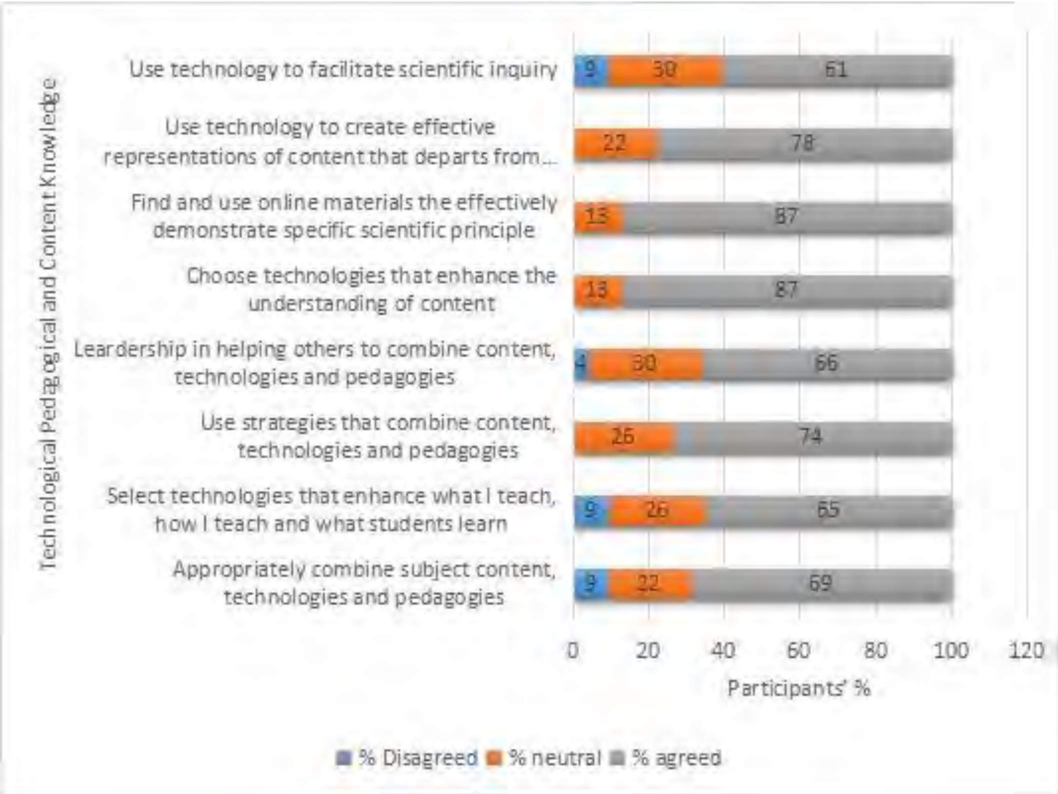

Figure 4.10 illustrates participants' responses to TPCK items.

Table 4.5 and Figure 4.10 illustrate that 87% of the participants can locate and utilise online materials effectively to demonstrate scientific concepts and choose technologies that enhance their students' understanding of the taught content. The data also indicates that 78% of the participants employ technology to create engaging content representations, deviating from traditional textbook approaches. Additionally, 74% of the participants confirmed they possess strategies to integrate subject content and technological knowledge into their teaching methods. In comparison, 69% believe they can appropriately blend subject content and technologies into their teaching practices. However, the data also reveals that 26% of the participants needed to be more specific about their knowledge and ability to assist their colleagues in integrating technology into content and teaching methods and selecting technologies that enhance what and how to teach and what students learn. Despite this uncertainty, the overall finding suggests that participants possess solid technological, pedagogical, and content knowledge (TPCK).

The descriptive analysis conducted on the data from the semi-structured questionnaire, aimed at assessing the participants' understanding of Technological Pedagogical and Content Knowledge (TPACK) constructs, yielded insightful results. The findings indicated that participants possess a theoretical knowledge of all TPACK constructs, even though they might only apply some in their teaching practices. Figure 4.11 visually represents the assessment of the participant's comprehension of TPACK constructs derived from the questionnaire data.

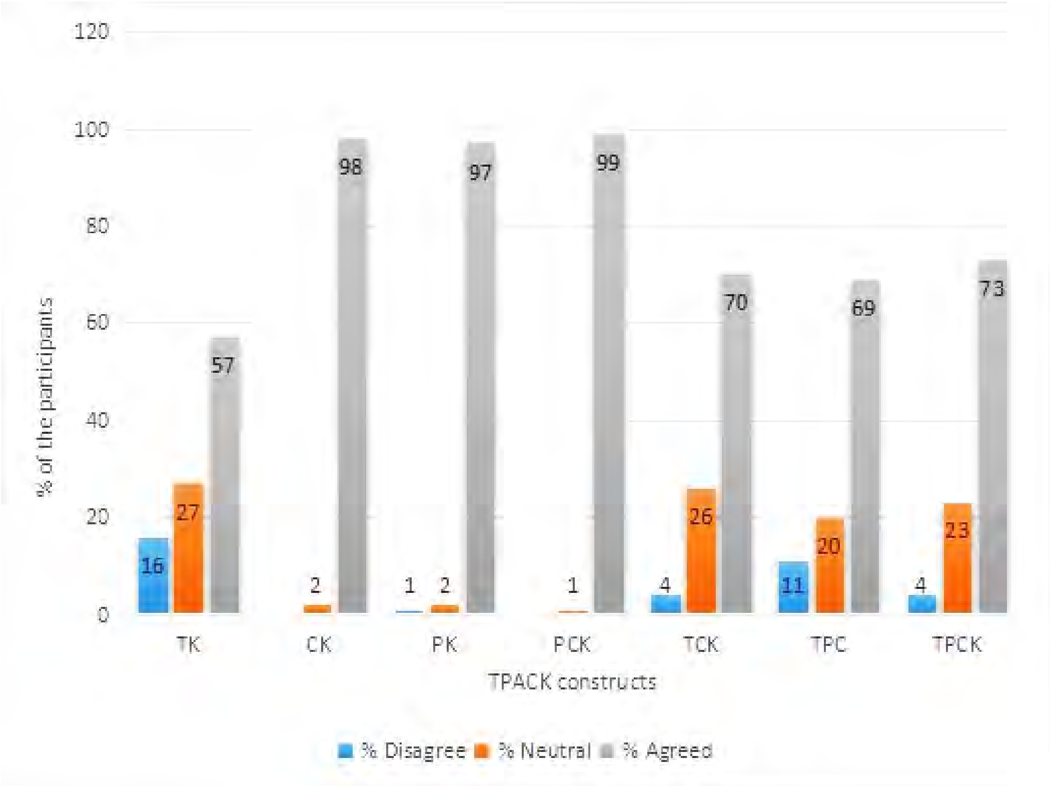

Figure 4.11 illustrates the data of participants' understanding of TPACK constructs.

As depicted in Figure 4.11, the results indicate that participants rated high (more than 90%) for certain constructs, including Content Knowledge (CK), Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK). However, their ratings were low (less than 75%) for other constructs such as Technological Knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical and Content Knowledge (TPACK). Notably, the lowest rating (57%) was observed for the items related to Technological Knowledge (TK). Additionally, Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical and Content Knowledge (TPACK) were closely rated.

Furthermore, qualitative findings from the study also revealed that participants possessed various TPACK constructs. Upon examining data from three distinct sources of observations, focus group discussions, and semi-structured interviews, it became evident that participants demonstrated diverse TPACK constructs, encompassing Content Knowledge (CK), Technological Knowledge (TK), Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical and Content Knowledge (TPCK)

For example, during the interviews (both semi-structured individual interviews and focus group discussions), participants were asked to indicate the technology facilities and resources they can use and to explain how they determine which technologies are best suited for addressing specific topics in Natural Science. According to the participants' responses, most indicated they choose and use technology resources and facilities such as computers, laptops, whiteboards, projectors and the Internet, indicating their technological knowledge (TK). For example, indicating the technology tools they are able to use for natural science teaching FGI-P1 said: "*I use the Internet to download videos related to our subject, Natural science".* Similarly, during the individual interview, SSI-P1 said: *I mostly use the laptop and the projector to show videos and pictures and prepare tasks".* The data showed that participants use technology to demonstrate science concepts, which means their technological content knowledge.

The participants indicated their ability to download videos and pictures from the internet to enhance the subject content. For instance, participant SSI-P3 explained how he use technology to improve science content through simulation. He said:
"*For example, when teaching a lesson on the water cycle, I might use the technology simulation, a technology that allows my learners to visualise the different stages of the water cycle. This can help learners to observe, ask questions, and discuss among each other."*

Similarly, the data from observation notes has revealed that various participants demonstrated TPACK constructs as they integrated technology into teaching. As surfaced from the observation notes, participants were observed employing multiple technologies such as laptops, projectors, and smartphones to enhance science teaching, indicating their application of TPACK constructs such as technological knowledge (TK), content knowledge (CK), pedagogical content knowledge (PCK) and technological content knowledge (TCK). Here are some examples from the observation notes:
Observation 1 (OB-1): "T*he teacher connected the laptop to the projector (TK) and played a YouTube video about ecosystems in Namibia (TCK). The teacher paused the video (TK) and engaged students in a discussion about the living and non-living things found in ecosystems (Pedagogical Content Knowledge)*."

Observation 2 (OB-2): "*The teacher introduced the topic of testing oxygen (CK) and asked students about their prior knowledge of oxygen gas (Pedagogical Content Knowledge). Using a smartphone, the teacher played a YouTube video demonstrating how to test for oxygen gas (Technological Pedagogical Content Knowledge).*

Observation 3 (OB-3): *"The teacher used a laptop connected to a projector (TK) to play a video about human teeth (TCK). There was difficulty connecting the speakers for sound (low TK), and the teacher sought assistance from a colleague.*"

The data findings from the observation provided evidence that, as self-reported through questionnaires and interviews, participants also demonstrated TPACK constructs in their teaching. Notably, Content Knowledge (CK), Technological Content Knowledge (TCK), and Pedagogical Content Knowledge (TPK) were particularly evident in the teaching practices of the participants and emerged frequently during classroom observations.

The overall data from questionnaires, individual interviews, focus group discussions, and observation seeking to answer research question 1 provided insightful findings. The finding revealed that participants possess some knowledge and understanding in all the TPACK constructs, even though they may need to apply them more consistently in their teaching. While participants rated themselves highly in constructs like Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK), they received low ratings in Technological Pedagogical Knowledge (TPK), technological content knowledge (TCK) and Technological Pedagogical and Content Knowledge (TPCK), with the lowest rating about technological knowledge (TK). The overall findings imply that the participants possess TPACK, both in their understanding, as self-reported and in practice.

RQ 2. What sources of TPACK do rural senior primary natural science teachers draw on and experiences shaping technology use in their teaching?

The semi-structured interview, focus group interview, and observation data were also coded for references to sources of TPACK the science teachers draw on and experiences shaping their use of technology in teaching. The findings revealed from the data analysis are presented next under surfaced themes.

4.4 TPACK constructs valued by the participants as they integrate technology into teaching.

To explore the TPACK constructs considered essential in teaching, a comprehensive analysis of data collected through individual interviews, focus groups, and observations of how participants integrate technology into their instructional practices is conducted. The analysis unveiled distinct themes that depicted the understanding of the TPACK constructs drawn upon by the participants as they incorporated technology in their classrooms. The data underscored that the utilisation of technology in teaching is influenced by factors such as curriculum content (requirements), learners' learning needs, availability of technology, technological affordance, and teaching strategies.

4.4.1 Curriculum content

A prevalent theme that emerged was the significant influence of curriculum content (CK) on teachers' choice to incorporate technology into their teaching and learning activities. In semi-structured and focus group interviews, participants were asked about the factors guiding their selection of specific technology tools for lessons. The findings indicated that participants consider the curriculum content (CK) when choosing suitable technology tools to enhance the content (TCK) according to the learners' needs. Participants emphasised that when deciding whether and how to use technology (TK), they align the technology with the nature of the content being presented. Three participants explained how the content (CK) dictates the technology choice for teaching and learning (TPK). The participants, FGI-P6, stated:

"*For me, I start with the content, the learning objectives from the syllabus, then from there I have to look at the teaching method, a method that fits the content, from the syllabus, and that is when now I have to look at the type of the technology which can enhance the teaching of content*".

Another participant FGI-P8 said:

"*what to consider first is the content that you are getting from the syllabus; basic competence of the specific subject from the syllabus should guide you. I am saying that the content from the syllabus should inform pedagogy for technology.*" Participants SSI-P5 expressed: "*I always give the theory, which is the content first, and then I will bring in technology on the latest stage.*"

The study found that participants make intentional choices based on the educational goals they want to achieve and how technology can support them (TCK). Teachers align the technology they use with the nature of the content being presented. This means they choose technology tools that enhance the specific scientific concepts or topics they teach (TPK). The findings imply that the integration of technology is purposeful and strategic.

The finding revealed that participants engage in a thoughtful selection process, considering both the content being taught (CK), the availability of technologie, (TK), and the characteristics of their learners. As expressed by SSI-P1:

"*I always refer to the syllabus when choosing technology for my lesson. First, I evaluate the content and then consider how technology can enhance it. I ensure that my technology is user-friendly for both me and my learners. The focus should be on the content, not on struggling with the tool. I test the tool beforehand to avoid any issues during the class*".

In the same vein, SSI-P4 expressed: "*Apart from content, I should also look at other things, like what technology is available for me to present that content and the level of the learners. Technology availability matters most because it is insufficient in our schools, and learners cannot access technology at home".*

This approach underscores the careful integration of technology to complement and amplify the curriculum content (TCK), ensuring a practical and seamless learning experience for the learners. It also indicates that participants consider the type of learners they are teaching. Different learners have varying learning styles, abilities, and preferences. By understanding the needs of their learners, teachers can select technology tools that cater to these diverse learning requirements. These educators' insights underscore the nuanced approach to integrating technology, balancing content, available tools, and students' learning requirements (TPCK).

During the interviews, both semi-structured and focus group sessions, participants were probed further on whether the curriculum content (CK) changes in response to the choice of technology (TK) employed in teaching and learning. Four participants staunchly asserted that the core curriculum content remains unchanged regardless of the technology used, except for supplementary material that learners explore or search for during lessons or learning activities. This perspective was clearly articulated in the focus group interview transcript.

FGI-P7 emphasised,

"*When I use technology, the content remains consistent. It aligns with the competencies outlined in the syllabus. We adhere to the curriculum guidelines, so I must teach what the syllabus requires. Technology is a tool for me, the teacher, to deliver the required content*."

Similarly, FGI-P4 stated,

"*The curriculum content remains constant. What varies are the teaching methods and the technology. The curriculum objectives and fundamental competencies guide the selection of appropriate teaching methods and relevant technology*."

Echoing this sentiment, FGP-P8 remarked,

"*The subject content remains unchanged. It is the teaching approach and technology that changes*."

FGI-P2 concurred, explaining,

"*The content remains consistent. What changes are the teaching strategies and technology, depending on how the teacher plans to present the content to the learners? Whether technology is used or not, the content remains the same*."

Owing to their teaching science subject experiences (PK and CK), the participants in this study reported increased thoughtfulness and intentionality in selecting both learning activities and the technologies to assist them (TPCK). They acknowledged the pressure from the policies that require them to incorporate technology in teaching (TCK). However, they expressed their understanding that technology is just a tool to enhance science teaching (TK, TPK), not to replace the aims of science teaching and learning (CK, PK). During the focus group discussion, one participant FGI- P8 expressed:

"*Of course, technology is good; in science, learners are expected to learn how to carry out scientific processes such as measuring, observing, estimating, analysing, experimenting, etc. However, by using technology more to teach science, learners will not be able to acquire those skills"*.

In the same vein, FG-P3 expressed: "*Science is a subject in which learners learn scientific processes, but if we rely more on using technology to demonstrate those skills to the learners, I do not think learners will fully acquire the scientific skills. Of course, technology can expose learners to scientific skills virtually, but at the same time, I feel learners should also be allowed to learn through hands-on equipment method*".

These responses highlight the participants' recognition of the importance of science content dynamic (CK) and the limitation of technology in science teaching (TPK). Their awareness of these limitations underlines the significance of technological pedagogical and content knowledge (TPCK) in their decision-making process.

The findings underscore the participants' emphasis on content knowledge (CK) being the primary factor influencing their use of technology in teaching (TCK). The data indicates that participants alter curriculum guide (CK) and learners' learning needs as the fundamental means when choosing the technology to enhance science content (TCK). Similar conclusions were drawn from a study conducted by Chai, Koh and Tsai (2013), reinforcing the significance of content knowledge in integrating technology within teaching practices.

4.4.2 Technology affordance

In the individual interviews, participants illuminated their approach to integrating technology into teaching, emphasising the importance of their technological knowledge. They underscored their understanding of how different technologies can enhance teaching and learning and influence their choices. Participant SSI-P2 emphasised,

"*My familiarity with various technologies guides my technology selection. Understanding what each technology can offer allows me to make informed decisions about which technology best suits my teaching objectives*."

Likewise, Participant SSI-P5 articulated, "*I know about the capabilities of technologies A, B, or C and how they can facilitate specific teaching objectives. For instance, when I need to teach experiments or demonstrate concepts to my students, I know that certain applications, such as YouTube, enable me to showcase these experiments*."

In these statements, participants highlight their deliberate consideration of various technologies' capabilities (TK) and how this knowledge informs their choices, ensuring that technology aligns with their teaching goals (TPK).

During both semi-structured and focus group interviews, many participants highlighted instances where technology (TK) facilitated a more authentic assessment of learners' understanding, especially in formative assessments. For example, SSI-P4 explained,

"*When assessing my learners, I first type activities using my computer or laptop. I can also source pictures, old question papers, or worksheets from the internet to create tests, topic tasks, projects, and other assignments for my learners. Technology simplifies the process of setting* *my learners' work. I use the internet to create papers with clear images, a far cry from when we had to work with poorly reproduced pictures due to manual cut-and-paste methods*."

SSI-P2 added, "*I use my laptop at home to type exercises and tests for the learners. Sometimes, I download question papers from the internet. It is so fast and easy. Technology allows me to create tasks within a very short period. It is the way to go*."

SSI-P7 elaborated, "*There are videos that serve as educational material and assessment tools. I can use technology to present the lesson and create assessment tasks for the learners. I can group learners and have them answer specific questions from the video. So, integrating technology can be for both teaching and assessment*.

These responses highlight the participants' recognition of the dynamic nature of technology and the importance of their knowledge about technology (TK) and its affordances in making informed choices that align with the content (CK) and pedagogical requirements (TPK) of their lessons. Their awareness of these relationships underlines the significance of technological pedagogical and content knowledge (TPCK) in their decision-making process.

Observation data revealed participants' "ability to use" technology or pedagogy for teaching, an indicator for their TK and PK. Participants were observed using technology to demonstrate science concepts, which indicates their TCK. The data from the observation revealed that participants used the projector, laptop, smartphone, and screen to share the science content (TCK, TPCK). They projected the video on the screen for the learners to observe (TK, TCK). These participants viewed selected technology as a way to improve their teaching practice as a teacher-centered approach instead of using technology to facilitate self-learning, a new pedagogical method (TPCK).

The finding highlights that teachers' technological knowledge (TK) plays a crucial role in their decision to use technology in the classroom (TPK). When teachers know the use of various technologies and understand how they can enhance science teaching (affordances), they are more likely to be motivated to incorporate them into their teaching methods. The findings align with the study conducted by Hughes (2005), who investigated the role of teacher knowledge and learning experiences in forming technology-integrated pedagogy. His analysis suggested that the power to develop innovative technology-supported pedagogy lies in the teacher's interpretation of the newly learned technology's value for supporting instruction.

The overall finding demonstrates evidence of TPACK sources the participants value as they integrate technology into teaching. Aspects such as teachers' knowledge and understanding of how they can enhance the science teaching curriculum content and requirement, selecting technologies that fit the content, and teaching strategies to enhance content teaching and learning align with TPACK constructs such as TK, CK, TPK, TCK, and TPCK.

4.5 Factors attributed to participants' use of technology in teaching

During the interviews (individual and focus group), participants were asked about challenges in using technology, the teaching experiences, the ICT training received, how the ICT tools changed their teaching, and factors encouraging or inhibiting them from using technology. The data analysis revealed issues such as: allocated teaching time, technological knowledge and skills, intention to use technology, technical support, attitudes and interest, ICT training, and availability of technological tools as factors influencing the participants' use of technology in teaching. Participants indicated that interest and attitudes inhibit the participants from integrating technology into their teaching. For instance, regarding what factors inhibit teachers from using technology in their teaching, SSI-P6 said:

I think it is primarily knowing how and interest. Even if we are interested in technology, we cannot do it. In college, we were not trained on how to use technology. So, we just did it on our own. So, some of our colleagues are relaxed and will tell you, "I do not know how to use technology."

The finding further revealed that lacking technological knowledge and skills inhibits the participants from incorporating technology in their teaching and learning process. Participants expressed that not all teachers received ICT training, which could be why some of them are not using technology in their teaching, and for those who received it, it is difficult for them to teach others. FGI-P8 explained:

"Sometimes, after attending an ICT training, you may wish to train your colleagues. However, upon your return, you have a laptop; the school has two laptops; one teacher possesses one, and the remaining teachers do not. In this situation, you might be uncertain about how to proceed with the training at school."

All participants involved in the study identified insufficient access to technology in schools as an impediment to its use in science teaching and learning. They linked the limited access to inadequate government funding, which negatively impacted the procurement of technologies for teachers and learners in their primary schools. Although they did not mention mobile technology, like mobile phones, as a barrier to integration, participants indicated their difficulties with incorporating mobile technology as connected to their students' limited access and the potential exclusion of those without access to technology at school or home.

For instance, in response to the question on challenges they find in their use of technology, participants FGI-P4 expressed:
"*As much as we want to use technology to teach science, schools face a challenge: the availability of computers, laptops, Tables, projectors, computer labs, and all that. We are in a rural area where most learners cannot access computers or laptops at school and home.*"

In the same vein, FGI-P4 explained: "*It is difficult to task learners to search for certain information on their own because some learners do not have access to technological devices at home and those with access to internet connection is a challenge. Therefore, it is difficult to task learners to search for information from the internet, for example,*"

The study's data indicated that the participants could not demonstrate a learner-centered approach to instruction. Insufficient technology devices in schools and learners' learning needs compromise teachers' ability to use technology not only to present lessons but also for the learners to facilitate their learning. The participants also revealed the issue of limited technology facilities through the comments under the technological knowledge construct (TK) in the questionnaire. One participant (Q-P2) commented,
"*Using the Internet is not easy because we live in a remote area with no proper network connection in our environment*".
Similarly, during the semi-structured interview, participant SSI-P3 indicated internet connection as one of the challenges and said, "*Sometimes internet connection can be a problem. Let us say you want to download something like videos for your lesson, but the internet is very low*".

Participants mentioned the challenge of consistently using technology in their science teaching due to the constraints of allocated teaching time and the availability of technology facilities at schools. They also pointed out that presenting the lesson using technology requires more time than traditional teaching methods. During the group discussion, participants FGI-P3 said that "*Using technology in teaching is more convenient, but you need enough time to prepare the venue and set up the devices, and forty minutes allocated for each lesson are not enough*". Similarly, participant FGI-P5 expressed: "*Sometimes you plan to use the laptop and the projector for your lesson, but you might find another teacher who also plans to use it. Therefore, insufficient technology devices make using technology in every lesson very difficult.* In the same vein, participants expressed disappointment with the internet connection as another factor limiting their technology integration. FGI-P7 said*:*

"Internet connection can be a disappointment sometimes. Our internet connection can go off for one to two weeks, and you want to download videos, pictures, and other teaching materials."

The data further revealed how participants feel receiving technology training contributes to technology integration in teaching and learning. During the individual interview, participant SSI-P1 narrated:

"*I attended an ICT training, which is the ICDL program. I also attended another computer program offered to the teachers and administrators at the regional level, where I acquired some computer skills. Such training offered me adequate knowledge and skills to use technology in teaching.*"

In support of ICT training, SSI-P2 expressed: "*I wish all teachers could have received computer training to be motivated to use technology in their teaching. Imagine if all teachers could receive computer training, then many could incorporate it in their teaching*".

The participants believed that gaining experience in computer skills and related programs improved their teaching. They explained how they are now more aware of the diverse options for science-technology-enhanced learning activities. As a result, they anticipate incorporating a wider variety of learning activities and technologies into their lesson and learning activity planning. Participants expressed how technology makes their science planning, assessment, and teaching easier. For instance, SSI-P5 said:

"*Using technology is more convenient, especially when setting assessment tasks. There are plenty of science activities on the Internet. So, all you do is download and edit it to your learners' level".*

SSI-P6 explained, "*There are many science learning activities on YouTube. However, the problem with us here is that most learners are not exposed to it. We do not have enough computers at school; even at home, most learners cannot access laptops or smartphones. So, these learners only see these videos when a teacher plays them*".

The findings provided insightful information describing the experiences shaping the participants' use of technology in teaching. The result provided evidence that technological knowledge, learners' needs, allocated teaching time, availability of technology facilities/resources, interests and attitudes, and ICT training are the experiences shaping the participants as they use technology in their teaching.

4.6 Summary of the chapter

In this chapter, the researcher has presented the outcomes of the data collection process, employing a variety of methodologies such as semi-structured questionnaires, interviews, focus group sessions, and observational techniques. The data is organised in alignment with the research questions, utilising a mix of textual exposition, tables, and charts. Furthermore, direct in-text quotations have been included whenever applicable to add depth to the interpretation.

Moving forward to the subsequent chapter, the research will delve into a comprehensive discussion of these findings in comparison with existing data findings from other scholars within the same field. This comparative analysis will be framed against the backdrop of the analytical and theoretical frameworks elucidated in the second chapter. By juxtaposing the current research findings with established data and theoretical perspectives, the ensuing chapter aims to draw meaningful conclusions and contribute to the broader understanding of the subject matter.

CHAPTER 5: DISCUSSION OF FINDINGS

5.1	• Introduction
5.2	• Summary of the finding
5.3	• Discussion of findings
5.4	• Summary of the chapter

Figure 5.1: The structure of chapter 5

5.1 Introduction

The previous chapter presented the empirical findings gathered in response to the research questions. Responses to the research questions transpired from the data sourced using the four data gathering tools: questionnaire, individual interview, focus group, and observation. The data findings are systematically presented in alignment with the underlying research questions, each finding elaborately interlaced into the study's objectives. The data findings are presented logically to offer elucidated insight, contributing to a broader understanding of the research's aim and objectives.

As the study aims to assess the rural senior primary Natural Science teacher' TPACK, the data provided insight and understanding of the science teachers' TPACK through thematic analysis. The current chapter discusses the data findings as presented in the previous chapter. The results concern the existing literature and the theoretical framework in alignment with the two main research questions. The two main research questions answered are:

RQ1: What are the rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs?

RQ1: What sources of TPACK do the senior primary natural science teachers draw on and the experiences shaping their use of technology in teaching?

Firstly, the research delved into several aspects concerning the participants, including their technological backgrounds, the availability of technology facilities and resources in schools, and the utilisation of these resources in teaching. The participants' technological pedagogical content knowledge (TPACK) was then evaluated. This study enlisted the participation of 23 Natual Science teachers from rural senior primary schools who completed semi-structured questionnaires, providing valuable insights that addressed the two research questions.

Secondly, the study explored the sources of TPACK drawn on by the participants to integrate technology and the experiences that shape their use of technology in teaching. A subset of seven teachers was selected for semi-structured interviews, and a focus group discussion involving the same seven individuals was conducted. Furthermore, observations were made on three participants from this group, providing insights that provided answers to research questions one and two. Data descriptions in this study were primarily colour-coded, and the resulting themes were identified to facilitate analysis.

This chapter has been organised into four distinct sections. The first section, 5.1, serves as the chapter's introduction, outlining its objectives and research questions. Section 5.2 summarises the overall findings for research questions one and two. Meanwhile, 5.3 shows a comprehensive discussion of results based on research questions about the existing literature and the study's theoretical framework. The last section, 5.4, presented the concluding remarks of the chapter.

5.2 Summary of the data findings

The comprehensive findings obtained from the semi-structured questionnaires, complemented by semi-structured interviews, focus group discussion, and observations, have provided a thorough assessment of rural senior primary natural science teachers' perception of their understanding of the Technological Pedagogical Content Knowledge (TPACK) constructs for integrating technology into teaching. The data reveal a promising level of comprehension among these teachers regarding integrating technology into their teaching practices.

Research question 1: What are rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs?

5. 2.1 The assessment of participants' understanding of TPACK constructs

The study initially examined teachers' access to and utilisation of technology facilities and resources in teaching and their understanding of TPACK constructs. The findings indicated adequate availability of technological facilities and resources within these schools. The most prevalent technologies accessible in these schools include laptops, computers, and internet access. The data suggest that teachers commonly employ laptops, computers, smartphones, and the internet to create learning materials and download videos, effectively enhancing the learning experiences in science. This access to technology tools and their active utilisation underscores the potential for technology integration within the teaching practices of these rural science educators.

The teacher participants' Technological Pedagogical Content Knowledge (TPACK) was assessed by evaluating their skills against TPACK constructs through questionnaires, semi-structured interviews, focus group discussions and observations, providing a comprehensive perspective. The collected data revealed that participants exhibited a limited understanding of technology-based pedagogies (Technological Pedagogical Knowledge - TPK, Technological Content Knowledge - TCK, and Technological Pedagogical Content Knowledge - TPCK) when compared to non-technology-based pedagogies (Pedagogical Knowledge - PK and Pedagogical Content Knowledge - PCK). Interestingly, the participants demonstrated a very high perception of their subject content knowledge (Content Knowledge - CK). However, the results indicated that most participants scored the lowest in technological knowledge (TK).

The participants’ low ratings on technology-based pedagogies implied disagreement with most items related to these constructs, suggesting a need for more awareness and understanding. Conversely, their high ratings on non-technology-based pedagogies indicated agreement with most items within these constructs, indicating more heightened awareness and knowledge in these non-technology-related domains. These findings emphasise that the participants need more awareness and understanding of technology-based pedagogies, even as they utilise technology in their teaching practices. Addressing this gap in technological pedagogical knowledge is crucial to enhancing teaching methods and optimising technology integration in science education.

The data showed that participants' low perception of technological knowledge was more attributed to possessing the technological knowledge necessary to work with various technologies, solve technical issues, and install new technologies. Despite participants' low perception of their technical skills, they believed they could use technology in their teaching to enhance science content. Observational data indicated that participants sought assistance from colleagues with the necessary technological knowledge to incorporate technology into their teaching. This evidence suggests that integrating technology into science teaching for the participants does not necessarily require them to be technology experts. Instead, their ability to collaborate and seek support from colleagues with technological expertise allows them to effectively integrate technology into their pedagogical practices.

Research question two: What sources of TPACK do rural senior primary natural science teachers draw on and experiences shaping technology use in their teaching?

5.2.2 TPACK constructs valued by the participants as they integrate technology into teaching.

The qualitative findings obtained from the semi-structured questionnaires, complemented by interviews, focus group discussions, and observations, have shed light on the sources of Technological Pedagogical Content Knowledge (TPACK) drawn upon by the rural Natural Science teachers and the experiences that shape their use of technology in teaching. The results indicate that the participants primarily consider curriculum requirements, learners' learning needs, and technological affordances when integrating technology into their teaching practices.

The results indicate that teachers' choice of technology is predominantly driven by the curriculum content (CK). This content knowledge guides their selection of technology to be incorporated into teaching and learning activities, encompassing both Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). Additionally, participants highlighted their consideration of learners' learning needs when choosing technologies to use in teaching. Teachers' knowledge and understanding of how specific technologies enhance science learning also influenced their choices regarding technology integration.

The overall findings provide compelling evidence that the sources of TPACK drawn upon by the participants align closely with TPACK constructs such as Content Knowledge (CK), Technological Knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPCK). Among these constructs, Content Knowledge (CK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK) emerged as the most valued TPACK components among the participants. This insight highlights where teachers find the most value and relevance in integrating technology into their science teaching practices.

5. 2. 3 Factors attributed to participants use of technology in teaching

The data findings unveiled various conditions that have the potential to influence the integration of technology in teaching and learning processes. Factors such as inadequate professional development, teachers' attitudes, lack of hardware and internet connectivity, insufficient technological knowledge, time constraints, and limited access to technology tools and resources were identified as barriers hindering participants from effectively integrating technology into their teaching practices. These challenges create obstacles for teachers seeking to incorporate technology into their classrooms.

Conversely, factors such as ICT training and teachers' interest were identified as enablers that encouraged participants to integrate technology into their teaching. When teachers receive appropriate training and exhibit a genuine interest in utilising technology, they are more likely to overcome barriers and successfully integrate technology into their instructional methods. These positive factors play a crucial role in facilitating the effective integration of technology into teaching and learning processes.

5.3 Discussion of Findings

5.3.1 Assessment of rural the Natural Science teachers' understanding of TPACK constructs

The findings of this study revealed that participants expressed lower agreement levels for Technological Knowledge (TK) compared to technology-related constructs such as Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPCK). Despite their lower ratings on TK, these teachers still believed they could incorporate technology into their teaching methods. This indicates confidence in their ability to integrate technology despite a perceived lack of in-depth technological knowledge.

However, these findings contradict those of a study conducted by Kaplon-Schilis and Lyublinskaya (2020), who assessed the relationship between the five domains of the TPACK framework (TK, PK, CK maths, CK science, and TPCK) among pre-service Special Education Teachers in Turkey. In their study, science teachers who scored high on TPCK also exhibited a high level of TK. Unlike the teachers in the current study, those participants rated their TK higher, aligning with their confidence in integrating technology effectively into their teaching practices.

The disparity in findings between the two studies highlights the complexity of teachers' perceptions and confidence levels in using technology. It underscores the need for further research to explore the factors influencing teachers' confidence in their technological abilities and how these factors relate to their actual integration of technology in the classroom. Such insights are crucial for designing targeted training programs that address teachers' specific needs and concerns, ultimately promoting effective technology integration in education.

Furthermore, even though the participants rated their Technological Knowledge (TK) relatively low compared to the technology-related pedagogical constructs, they still exhibited confidence in teaching with limited technological knowledge. This suggests that these teachers may not require advanced technical expertise to utilise technology in their teaching methods effectively. The findings indicate that participants seek assistance from their colleagues in using technology tools in their teaching, as highlighted in section 4.7. This implies that these teachers often rely on knowledgeable peers, aligning with Vygotsky's social development theory (1978), emphasising the role of social interaction and collaboration in learning.

The ratings of the participants on Pedagogical Knowledge (PK), Content Knowledge (CK), and Pedagogical Content Knowledge (PCK), as depicted in Figure 4.11, suggest that these teachers are more familiar and experienced with constructs associated with traditional teaching methods. This observation is not unexpected and could be attributed to the emphasis placed on subject content and teaching methods in teachers' training institutions and continuous professional development programs, a point highlighted by noted scholars in the field. A similar finding was reported in a study conducted by Kihoza et al. (2016), which assessed the technological knowledge, competencies, skills, attitudes, beliefs, and readiness of tutors and teacher trainees to integrate classroom technology. In their study, teacher trainees rated CK and PK highly.

To explain the high scores on the constructs of CK and PK, the researchers noted that teacher trainees might have been well-acquainted with content knowledge and pedagogical skills from their training. This reasoning could also apply to Namibian science teachers, given that a science teaching qualification is the entry requirement for such positions. As indicated in Table 4.1 regarding the participants' backgrounds, all participants in this study are qualified teachers, holding qualifications ranging from diplomas to master's degrees and possess experience in teaching science. Therefore, they are expected to possess substantial and pedagogical content knowledge acquired during their education at teachers' training universities.

The findings of this study indicate that the knowledge of the participants regarding Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPCK) falls within a moderate range. The average levels of technology-based pedagogical values suggest that many In-service Teacher Training programs in Namibia must sufficiently address the crucial interaction between content, pedagogy, and technology, as noted by previous research (Turgut, 2017; Tseng et al., 2022). This deficiency may be attributed to a need for subject and context-specific ICT training focused on technology integration, which fails to provide teachers with the necessary knowledge, skills, and competencies for effective teaching.

Consequently, the responsibility of integrating technological knowledge into pedagogy and content is placed upon the teachers themselves. This situation forces teachers to navigate the complex relationship between these three knowledge domains independently, highlighting the need for more targeted and comprehensive training programs. Addressing this gap in training is crucial to empower teachers with the skills and understanding necessary for the seamless integration of technology into their teaching methods, ultimately enhancing the quality of education in Namibian schools.

The data from the questionnaires and interviews indicate that most participants have access to technological tools such as computers, laptops, and smartphones, as depicted in Figure 4.1. These teachers can utilise these tools to enhance their lessons, suggesting a genuine interest in integrating technology into their teaching practices. Existing literature supports the idea that teachers, when provided with access to technology tools and resources, develop technological knowledge (TK) essential for integrating technology effectively in their classrooms, leading to the development of technological pedagogical knowledge (TPK). This connection is highlighted in a study conducted by Santos and Castro (2021), which focused on evaluating the application of Technological Pedagogical Content Knowledge (TPACK) among pre-service teachers in various public schools in Bulacan. Santos and Castro's study revealed a significant correlation between TPACK and educational technology tools. Therefore, the fact that these science teachers have access to technology tools in their schools likely contributes to their ability to incorporate technology in teaching.

Consequently, it is unsurprising that these teachers perceive themselves as capable of using technology to enhance the understanding of specific science concepts (TCK) and are adept at selecting technologies that improve their teaching approaches (TPK). This suggests that there is still untapped potential among rural school science teachers to further develop their skills in effectively integrating technology with their content and pedagogy knowledge in science teaching (TPCK). With continued support and training, these teachers can harness technology to enrich their teaching methods and enhance the overall learning experience for their learners.

The study's findings show that certain teachers have acquired the essential skills to operate various technological tools and resources in their schools. However, they may need to consistently integrate these tools into their teaching methods. Existing literature supports the idea that teachers' technological knowledge significantly influences their attitudes toward incorporating technology in the classroom, as Semerci and Aydin (2018) discussed. Their study, which focused on the impact of Technological Pedagogical Content Knowledge (TPACK) development courses on pre-service science teachers' performances, concluded that teachers' active use of technology aids in developing TPACK and fosters a genuine interest in utilising it in their teaching practices. This suggests that encouraging teachers to engage with technology actively can enhance their pedagogical skills, ultimately enriching the learning experiences of their learners.

5.3.2 TPACK constructs valued by the rural Natural Science teachers as they integrate technology into teaching

The results of this study indicate that the participants often focus on curriculum requirements and technological knowledge when integrating technology into their teaching. The finding provided evidence that the sources of TPACK drawn on by these science teachers to incorporate technology are more aligned with the TPACK constructs such as Content knowledge (CK), technological knowledge (TK), Technological Content Knowledge (TCK), Technological Pedagogical knowledge (TPK) and Technological Pedagogical Content Knowledge (TPCK) with Content Knowledge (CK), Technological Content Knowledge (TCK) and Technological pedagogical knowledge (TPK) being the most valued TPACK constructs.

Harris and Hofer (2011) noted that TCK definitions must be more consistent across research studies. In this study, TCK refers to understanding how technology can aid in presenting content. Past research has suggested that TCK typically scores the lowest on surveys examining teacher knowledge (Mouza, 2016; Cheng, 2017; Debbagh & Jones, 2018), and other studies found minimal evidence or emphasis on teachers applying TCK in the classroom (Turgut, 2017, & Venkestasamy, 2022). However, this study identified several instances of TCK utilised in observations and interview data, such as SSI-P3 using a YouTube video to help learners visualise the water cycle.

Additionally, the findings show that the participants appreciate TPK, suggesting they can employ the necessary pedagogical skills to teach content (Shulman, 1986). The study found that the study participants utilise technology in their instruction, using tools to access information relevant to their subject matter, such as pictures, worksheets, and videos, to aid learners in comprehending science concepts. This aligns with Heitink et al.'s (2016) finding that most teachers' technology use in practice reflects aspects of the knowledge transfer teaching model.

Moreover, the study revealed that the study participants selected specific technologies based on learning objectives from the curriculum. This implies that teaching content influences their technology integration, prioritising technological content knowledge (TCK), pedagogical knowledge (PK), and specialised pedagogical knowledge (PCK) as they choose the most suitable technology for a given content to achieve learning objectives. Teachers' decision-making demonstrates that content, pedagogy, and technology should be considered in collaboration with the central intersection of TPACK (Mishra & Koehler, 2006).

The findings also suggest that the study participants effectively use technology in their instruction, as they deliberately and thoughtfully select technological tools that best fit the content being taught (Henriksen et al., 2019). Even though these teachers reported using technology in their instruction, their students' needs influenced their TCK, PK, and TPK. This study's findings are consistent with those of Santos and Castro (2021), who identified TCK and TPK as the most significant predictors of TPACK. While Santos and Castro (2021) also prioritised TCK and TPK. However, Santos and Castros' study did not consider teaching content and learners' needs as influencing factors.

The study participants frequently employ technology tools to illustrate science concepts, enabling learners to gain a deeper understanding. The data has never revealed evidence of these teachers using technology to allow learners to control their learning. The evidence seen in this study concurs with the finding from McKnight et al. (2016) study, which explored how educators use technology to improve student learning. They surveyed teachers' familiarity, use, and comfort with technology. Their study's findings revealed that allowing students' choice and control in their learning process had never been used by most of the participants. The result also aligns with Heitink et al.'s (2016) finding that most teachers' technology use in practice reflects aspects of the knowledge transfer teaching model.

5.3.3. Factors attributed to the rural Natural Science teachers' use of technology in teaching

The study's findings revealed the conditions that have the potential to influence technology integration, such as lack of technologies, learners' needs, inappropriate professional development, technological knowledge, time constraints, teachers' interest and attitudes, and access to hardware and Internet connectivity. These challenges to technology integration surfaced in a study by Ghavifekr et al. (2016), who analysed teachers' perceptions of the challenges faced in using ICT tools in classrooms. The study's findings revealed issues and challenges found to be significant in teachers' use of ICT tools, such as limited accessibility and network connection, limited technical support, lack of practical training, limited time, and lack of teachers' competency. However, their study did not investigate the potential influence of technology integration, as was also the case for this study.

The study underscores the influence of student learning needs on teachers' Technological Content Knowledge (TCK), Pedagogical Knowledge (PK), and Technological Pedagogical Content Knowledge (TPCK). This highlights the importance of considering individual learners' requirements and adapting teaching strategies and technology use. It emphasises the need for teachers to be flexible and responsive, tailoring their approach based on the diverse needs of their learners.

Furthermore, the results revealed ICT training and teachers' attitudes and interests as the potential factors influencing teachers to integrate technology. This suggests that the Ministry of Education should offer ICT development programs for teachers as it will ultimately encourage them to integrate technology.

5.4 Summary of the chapter

This study assessed primary school Natural Science teachers' technological pedagogical content knowledge (TPACK) in rural areas. It delved into how these teachers perceive their understanding of TPACK components, the sources they rely on for TPACK, and the experiences that influence their use of technology in teaching. The collected data highlighted increased comfort and confidence among rural science teachers when incorporating technology to enhance science education. The data highlighted that these science teachers understand all TPACK components, although they need to utilise them in their teaching practices. Interestingly, the study participants are seen to be more self-assured in their subject matter expertise and traditional teaching methods. At the same time, they express less confidence in their technological skills and how they relate to teaching. This raises questions and prompts further investigation into the existing gaps in this context.

The study participants place a high value on content knowledge, the learning needs of their students, and technological proficiency when integrating technology into their teaching. However, barriers such as a lack of access to technology tools, inadequate technology training, time constraints, ICT training gaps, teachers' interest and attitudes, insufficient hardware, and internet connectivity issues can potentially hinder the seamless integration of technology in their teaching practices. These influencing factors underscore the need for the Ministry of Education to provide adequate technological resources and facilities and to consider subject-specific technology training for all teachers.

The subsequent chapter will conclude this study, encompassing a summary of the findings, an exploration of the study's limitations, and recommendations based on the study's findings. These recommendations will outline the areas that warrant further research in the same field.

CHAPTER 6: CONCLUSION, LIMITATION AND RECOMMENDATION

6.1	• Introduction
6.2	• Overview of the study
6.3	• Conclusion of the study
6.4	• Recommentation for TPACK Practices
6.4	• Recommentation for Future Studies
6.6	• Limitations of the Study

Figure: 6.1 The structure of Chapter 6

6.1 Introduction

Chapter 5 provides an in-depth analysis of the study's findings, connecting them to the existing body of literature and the analytical and theoretical framework. The discussion of the findings not only underscores the importance of the study's results about what is already known about the research problem but also elucidates any novel discoveries or insights that have emerged from the data. This chapter offers a comprehensive overview of the study, encompassing a summary of the research, an exploration of its limitations, and a presentation of the recommendations derived from the study's findings. It also outlines potential areas for future research in the same field.

6.2 Overview of the study

Chapter 1 outlined the primary purpose of this study, which was to assess rural senior primary Natural Science teachers' technological pedagogical and content knowledge (TPACK) in the Endola education circuit. Two objectives were identified to support the significant purpose. The first objective was to assess the rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs, whereas the second objective was to determine sources of TPACK the rural senior primary natural science teachers draw on and experiences shaping technology use in their teaching. To achieve these objectives, two main research questions were considered: 1. What are rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs? 2. What sources of TPACK do rural senior primary natural science teachers draw on and experiences shaping technology use in their teaching?

Chapter 2 introduced the conceptual framework of the study. Existing and relevant literature on the integration of technology in education was reviewed. The literature about the adoption of technology in education, the use of ICT in teaching and learning, technological pedagogical content knowledge, TPACK use in integrating into science teaching, and assessment of TPACK was reviewed. Critiques of the exisisting literature were presented. The chapter ended with a discussion of the TPACK framework.

Chapter 3 discussed the research design and methodology used in the study. The study used the research onion metaphor to guide the research choices and design. The study adopted an interpretive philosophy using a mixed research approach. A case study design was utilised with a multi-method qualitative approach and four data-gathering techniques: semi-structured questionnaire, semi-structured interview, focus group, and observation. Purposive sampling was employed to select participants. Thematic analysis through colour coding was used to deduce themes. The trustworthiness of the research methods and designs was ensured, and the researcher's positionality and ethical considerations are all discussed in this chapter.

Chapter 4 presented the empirical findings of the study. Twenty-three participants from senior primary schools in a selected circuit participated in the study. Data collected from the participants was analysed through the lens of the TPACK framework, and empirical findings were established, whereas conclusions were also drawn. The results are presented according to the research questions, and direct quotes were used to increase the findings' validity and show the findings' original meaning.

Chapter 5 presents the discussion, which gives a critical interpretation of the findings, literature alignment with the finding analysis, and the explanation of the significance of the results. The discussion of findings is done based on the research questions. After that, Chapter six discusses the study's conclusions, recommendations to the Ministry of Education and professional development programs, and limitations. The conclusions of the study are presented below

6.3 Conclusion of the study

This research aimed to assess the rural senior primary natural science teachers' TPACK. The study used a mixed methods approach (Creswell, 2008) whereby one part of the questionnaire generated the quantitative data to ascertain the rural senior primary science teachers' understanding of TPACK constructs while the other part, together with the semi-structured interviews, observations, and focus group generated the in-depth qualitative data, to ascertain the sources of TPACK the science teachers draw on and experiences shaping technology use in teaching. The TPACK framework provided lenses to get the teachers' Technological and pedagogical Content Knowledge indicators in the data. The qualitative and quantitative data were analysed thematically and triangulated to help comprehensively analyse the topic under discussion (Cohen et al., 2011). The data findings are presented and discussed.

Research question 1: What are rural senior primary natural science teachers' perceptions of their understanding of TPACK constructs?

In accordance with the research question, the findings suggest a lack of adequate technological facilities and resources within Namibian schools. The tools accessible to teachers in these schools include laptops, computers, and internet connectivity. Educators use laptops, computers, smartphones, and the internet to craft learning materials and download videos, effectively enhancing the science learning experience The rural science teachers possess Technological Pedagogical Content Knowledge (TPACK). They possess high Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) than their Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Technological Pedagogical Content Knowledge (TPCK). Despite indicating their ability to use technology for enhancing science teaching, rural science teachers regard their Technological Knowledge (TK) as lower than all other TPACK constructs. The availability of technological tools and their active utilisation underscores the potential for integrating technology into the teaching practices of science educators in rural areas. This conclusion was reached by gathering primary data sources and subsequently analysing them using both qualitative and quantitative methods.

The study's findings suggest that the teachers' understanding of TPACK constructs is essential for the successful integration of technology into teaching practices. The TPACK framework provides a useful guide for teachers to integrate technology effectively into their teaching practices. The study's findings also suggest that professional development programs should be provided to rural senior primary natural science teachers to enhance their understanding of TPACK constructs and improve their teaching practices.

The study's findings not only shed light on the current state of TPACK perceptions among rural senior primary natural science teachers but also provided valuable implications for educational practice and policy. By understanding the teachers' perceptions of TPACK constructs, educational stakeholders can develop targeted interventions and support mechanisms to enhance the integration of technology in teaching and learning in rural primary schools.

Furthermore, the study's focus on rural schools in Namibia fills a significant gap in the existing literature, as no prior research had specifically explored the science teachers' TPACK in this context. Therefore, the findings of this study contribute to a more comprehensive understanding of the challenges and opportunities related to technology integration in rural educational settings.

Research question two: What sources of TPACK do rural senior primary natural science teachers draw on and experiences shaping technology use in their teaching?

Analysing data from questionnaires, semi-structured interviews, focus group discussions, and observations has yielded noteworthy insights in addressing the research question. The findings highlight that rural science teachers prioritise Content Knowledge (CK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Pedagogical Content Knowledge (PCK), influenced by curriculum content, learners' needs, and technology affordance. The teachers, mindful of their specific context, integrate technology into their teaching practices by selecting tools aligned with their pedagogical goals.

One significant revelation is the paramount influence of curriculum Content Knowledge (CK) on teachers' technology choices. This underscores the importance of aligning technology integration with the science curriculum's specific content and learning objectives. It reflects a conscious effort by teachers to enhance subject-specific content delivery, thereby enriching the overall learning experiences for students—a principle congruent with the TPACK framework, emphasising the interplay between content knowledge and technological knowledge.

The study further indicates that teachers' consideration of learners' needs significantly informs their decisions regarding technology integration. This exemplifies a learner-centered approach, emphasising the necessity of tailoring technological tools to cater to diverse learning needs.

Acknowledging learners' needs demonstrates a pedagogical sensitivity aligning with effective TPACK integration.

Moreover, the research highlights the impact of teachers' knowledge and understanding of how specific technologies enhance science learning on their choices regarding technology integration. This underscores the importance of Technological Pedagogical Knowledge (TPK) in guiding decisions about technology use in teaching. It emphasises the need for teachers to possess a profound understanding of integrating technology effectively to support and enhance the pedagogical aspects of science education—a core tenet of the TPACK framework.

Additionally, the study identifies various influencing factors affecting technology integration in teaching and learning processes. These factors encompass a lack of professional development, teachers' attitudes, insufficient hardware, and internet connectivity issues. Recognising these challenges emphasises the need for targeted interventions and support mechanisms. It underscores the importance of providing teachers with adequate technological resources, facilities, and subject-specific technology training to facilitate seamless TPACK integration in rural educational settings.

6.4 Recommendations for TPACK Practices

The findings of this research work have revealed some evidence of technological knowledge as the basic knowledge required for technology integration in teaching and TPACK development. This section suggests the key recommendations for Namibian schools and other developing countries. The following are the proposed recommendations for TPACK practices.

Given that the study identified a perceived lack of in-depth technological knowledge among rural science teachers, there is a pressing need for targeted professional development in this area. Training programs should focus on providing teachers with practical skills to utilise different technologies and address common technical issues. It was observed that despite their low perception of their technological skills, rural science teachers could incorporate technology into their teaching with assistance from colleagues. Schools should, therefore, encourage a culture of collaboration and shared learning among teachers.

Teachers need training programs tailored to their specific subjects, considering their pedagogical content knowledge is rated high. This could include exploring how different technologies can enhance teaching and learning within specific subject domains. One of the barriers to technology integration highlighted was a lack of access to adequate hardware and internet connectivity. There should be investment in ICT infrastructure to ensure that teachers can reliably access and use technology in their teaching.

While it was noted that rural science teachers integrate technology into their teaching, they have yet to use it in learner-centered approaches. There is a need for training and support to develop teaching strategies that put the learner at the center of the learning process, using technology to facilitate this. The teachers cited time constraints as barriers to effectively integrating technology into teaching. Schools must explore ways to redesign their schedules and teachers' responsibilities to allow for more time to plan for and implement technology-rich lessons.

Teachers should not necessarily have to be technology experts to incorporate it into their teaching. Creating an environment where teachers can collaborate and seek support from colleagues with technological knowledge can provide an effective integration of technology into their teaching practices. Ensuring rural schools are adequately equipped with basic technology and stable connectivity is vital. This will give teachers the foundation for integrating technology into their teaching practices.

Teacher training programs need to include units about the TPACK framework. This can help prospective teachers build a solid understanding of integrating technology, pedagogy, and content knowledge effectively from the beginning of their careers. Teachers' understanding and application of TPACK constructs should be regularly assessed. This can provide insights into areas that might need further development or support.

6.5 New Knowledge Contribution

The study has uncovered valuable new perspectives on the integration of technology in teaching methodologies. By thoroughly exploring the experiences and viewpoints of participating teachers, this study has made significant contributions to the existing knowledge base. It has deepened our comprehension of the challenges Natural Science educators face in rural senior primary schools when incorporating technology into their teaching approaches. Examining the participants' experiences in utilising technology has emphasised the impact of technological proficiency, learners' needs, availability of technology resources, interests and attitudes, and ICT training. Through a detailed analysis, the study has illuminated the intricate interplay of these elements within the Technological Pedagogical Content Knowledge (TPACK) framework, shaping the effective use of technology in senior primary-level Natural Science education.

Furthermore, the empirical findings, scrutinised through the TPACK framework, have unveiled specific insights into the origins of TPACK that teachers leverage, along with their perceptions of TPACK constructs. This has deepened our understanding of how rural senior primary Natural Science teachers conceptualise and apply TPACK in their teaching methods, thus enhancing the current knowledge regarding TPACK utilisation in science education

6.6 Recommendation for Future Studies

Several suggestions for upcoming research initiatives emerge from the findings of this study: Firstly, considering the focus on assessing TPACK among rural senior primary natural science teachers, it could be beneficial to expand the study to incorporate other subjects and various educational levels. This would contribute to a comprehensive understanding of TPACK constructs and their applicability across the curriculum. Secondly, this study highlights several barriers teachers encountered when integrating technology into their teaching, such as lack of technologies, internet connectivity issues, and time constraints. Future work could focus on exploring these barriers more extensively and devising targeted strategies to address them. Thirdly, the study showed that teachers perceived their Technological Knowledge as lower than other TPACK constructs. Future studies may try to uncover the root causes of this perception, possibly leading to more action-oriented solutions. Finally, the study occurred in a specific geographical context - rural primary schools. Comparative research between rural and urban settings or with different cultural backgrounds could illuminate how context and culture influence teachers' TPACK. This can guide customised training and professional development programs. In conclusion, the study offers valuable insights and opens numerous prospective research paths that could significantly enrich the literature in this field.

6.7 Limitations of the study

Research studies are typically prone to shortcomings, which could result from the unavailability of resources or sampling size. Graedel and Reck (2016) point out that no study is flawless and inclusive of all possible aspects. Therefore, this study presents several limitations that may have influenced the outcome and interpretations of the findings. One significant limitation is the geographic restriction, as the study only involved a case of rural senior primary schools in the Endola education circuit, potentially limiting the generalizability of the findings. The results might have been more if a broader range of rural schools in varied geographic settings were included. Future research could consider expanding the geographic scope to encompass a more diverse range of rural settings, allowing for a more comprehensive understanding of the challenges and opportunities in rural education.

Moreover, the study is confined to natural science teachers, thereby limiting the applicability of the results to other subjects. Including teachers from various disciplines might have yielded a more nuanced understanding of teachers' technological pedagogical content knowledge. The small sample size constitutes another limitation of the study. For instance, only 23 teachers participated in the questionnaire phase, and only seven in the interviews and focus group discussion. While a small sample size can allow for depth in qualitative research, it limits the generalisation of results. Future research endeavors could consider increasing the sample size to enhance the study's external validity and statistical power. Future researchers may also explore diverse sampling strategies to ensure a more comprehensive representation of the target population, improving the generalizability of the study's findings to a wider context.

Additionally, the data analysis methods primarily relied on teachers' self-reported assessments of their Pedagogical Technological Content Knowledge, potentially subject to bias. Direct observation or other assessment forms might provide more objective measures of teachers' competencies. Future research could consider combining self-reported data with more objective measures can strengthen the study's methodological approach and contribute to a more comprehensive understanding of teachers' Pedagogical Technological Content Knowledge.

Regarding the research design, the study employed an interpretive paradigm, which might have resulted in findings particular to the participants' unique experiences rather than universally applicable. Future researchers might consider complementing interpretive research with other paradigms to provide a more comprehensive understanding. Triangulating findings with quantitative data could help balance the richness of interpretive insights with the generalizability and replicability associated with other research paradigms.

Lastly, since the researcher belongs to the same profession and locality as the participants, personal biases could have influenced the research findings, presenting another limitation. To address these implications, researchers in similar situations could consider involving external collaborators or experts who are not closely tied to the profession or locality could provide a fresh perspective and enhance the study's objectivity.

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APPENDICES

APPENDIX A: RHODES CLEARANCE CERTIFICATE

RHODES UNIVERSITY
Where leaders learn

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 8028
email: e.rosenberg@ru.ac.za

https://www.ru.ac.za/researchgateway/ethics/

24 January 2023

Dr Clement Simuja

Education Department

C.Simuja@ru.ac.za

Dear Dr Clement Simuja

Your application Assessing rural senior primary Natural science teachers' technological pedagogical content knowledge. A case study., 2023-5959-7372 has been reviewed by the Education Faculty Research Ethics Committee (EF-REC)

Ethics approval has been granted pending the required Permission Letters being obtained from the organisation(s) listed in your application.

Regional Director of Education

Educational Circuit Inspector of Education

School principal/s

Your application can be downloaded as a PDF version and forwarded with your permission letter request. Please refer to the Applicant User Guide for how to do so.

Please forward the required permission letter/s, once received, to the EF-REC Chair (E.Rosenberg@ru.ac.za) and to the Education Research Ethics Coordinator (ethics-committee@ru.ac.za) in order for your approval to be finalised.

Sincerely

ERosenberg

Professor Eureta Rosenberg

Chair: Education Faculty Research Ethics Committee

APPENDIX B: APPROVAL LETTER FROM OHANGWENA DIRECTORATE OF EDUCATION

REPUBLIC OF NAMIBIA
OHANGWENA REGIONAL COUNCIL
DIRECTORATE OF EDUCATION, ARTS AND CULTURE

Office of the Director
Tel: (+264) 65 290200
Fax: (+264) 65 290224
Enquiries: Mirjam N N Nambahu
Email: [illegible]
Our Ref: 13/2/9/1

Hamutumbangela Street, Greenwell Complex Building
Private Bag 88005
EENHANA

27 January 2023

Ms Secilia T Silvanus
Email: mrsmulek@gmail.com
Cell: 0812964404
Endola

SUBJECT: REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN ENDOLA CIRCUIT, OHANGWENA REGION

1. Receipt of your letter dated 26 January 2023 is hereby acknowledged.
2. Be informed that permission to collect data for research from selected schools in Ohangwena region has been granted under the following conditions and request:
   - The data to be collected should only be used for the completion of your studies.
   - You have to liaise with the concerned Principals to make prior arrangements before the date of the research.
   - No other data should be collected other than the data stated in the request.
   - You may share the final report of your study with the directorate.
3. It is trusted that you will find this arrangement in order while wishing you all the best with your studies.

Yours Sincerely,

30/01/2023
ISAK HAMATWI
DIRECTOR

APPENDIX C: PERMISSION LETTER FROM ENDOLA EDUCATION CIRCUIT

REPUBLIC OF NAMIBIA

OHANGWENA REGIONAL COUNCIL

DIRECTORATE OF EDUCATION, ARTS AND CULTURE

ENDOLA CIRCUIT

[illegible]
Tel: [illegible]

P O Box 3658
Ongwediva
31st, January, 2023

Enquiries: Mr. Simon Vaeta
E-mail Address: [illegible]@gmail.com
Our Ref: [illegible]

To: Ms. Secilia T Silvanus
Email: [illegible]@gmail.com
0812964404

Dear Ms. Secilia T Silvanus,

SUBJECT: APPROVAL GRANTED TO CARRY OUT A RESEARCH STUDY AT SCHOOLS IN ENDOLA CIRCUIT, OHANGWENA REGION

1. Receipt of your letter on the above matter is hereby acknowledge.
2. The Endola Circuit Office of Education indeed supports and herewith grants approval to you to carry out the envisaged research on "Assessing rural senior primary natural science teachers' technological pedagogical content knowledge".
3. Your case study is most welcomed as it will be done with a specific focus on the Senior Primary Science Teachers integrating ICT in teaching.

Additionally, this permission is given on condition that:

4. Schools activities are not disrupted during your research
5. The data collected should only be used for research purposes and for the completion of it.
6. You are kindly advised to make pre-arrangements with the school management before you embark on your research.
7. Sharing your study findings with the circuit office will be highly welcomed.
8. It is our firm believe that all ethical requirements will indeed be upheld and hope that you will find this arrangement in order and very fruitful.

Yours Sincerely,

31.01.2023

Mr Simon Vaeta
Inspector of Education
Endola Circuit

OFFICE OF THE INSPECTOR
ENDOLA CIRCUIT
31-01-2[illegible]

APPENDIX D: PERMISSION LETTER FROM THE SCHOOL PRINCIPALS

REPUBLIC OF NAMIBIA

MINISTRY OF EDUCATION: OHANGWENA REGION

ENDOLA COMBINED SCHOOL, SHITUWA CLUSTER, ENDOLA CIRCUIT

Tel: 065-268827, P. O. Box 2544, Oshakati

25 February 2023

Re: Permission to carry an educational research study.

Permission is hereby granted by Endola Combined School Management for Secilia, Tulikefo Silvanus who is a part-time student at Rhodes University, South Africa, doing Masters of education in ICT in education, student number 13S7075 to carry on educational research study at this school.

Terms and conditions as give by the Inspector of Education, Endola Circuit and also from the Education director of Ohangwena Region must apply.

Trusting you will enjoy working with our colleagues.

Yours Faithfully

Gerhard Iipumbu

Principal Endola C.S

...ISTRY OF EDUCATION
OFFICE OF THE PRINCIPAL
ENDOLA COMBINED SCHOOL
ENDOLA CIRCUIT
OHANGWENA REGION
2023 -02- 2 5
PO BOX 2544, OSHAKATI
TEL: 065 - 268827

OHANGWENA REGIONAL COUNCIL

DIRECTORATE OF EDUCATION
ENDOLA CIRCUIT
SHITUWA CLUSTER
EVATELO COMBINED SCHOOL

TEL/FAX: 065 – 268895, BOX 1320, OSHAKATI

Enq: Mrs. M. David
Cell: 0813577396

08 March 2023

Mrs Secilia T Silvanus
Email: mrsmulek@gmail.com
Cell: 0812964404
Endola

SUBJECT: REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT EVATELO COMBINED SCHOOL IN ENDOLA CIRCUIT, OHANGWENA REGION.

1. Receipt of your letter dated 01 February 2023 is hereby acknowledged.
2. Evatelo Combined School Management indeed supports and herewith grants approval to you to carry out the envisaged research on "Assessing Rural Senior Primary Natural Science Teachers' Technological Pedagogical Content Knowledge".
3. Your case study is most welcomed as it will be done with a specific focus on the Senior Primary Science Teachers integrating ICT in teaching.

Additionally, this permission is given on condition that:

4. Schools activities are not disrupted during your research.
5. The data collected should only be used for research purposes and for the completion of it.
6. You are kindly advised to make pre-arrangements with the Natural Science and Healthy Education teachers before your embark on your research.
7. Sharing your study findings with the school will be highly welcomed.
8. It is trusted that you will find this arrangement in order while wishing you all the best with your studies.

Yours Sincerely,

....

MARIA DAVID
PRINCIPAL

MINISTRY OF EDUCATION
The Principal
Evatelo Combined School

2023 -03- 08

Ministry of education, Arts and Culture

Peumba combined school

P O Box 11441, Tel 065 228871

10 February 2023

Inq: Heita Johannes K.
0812 713 849

To Secilia T. Silvanus
Rhodes University student

Re: request for permission to contact the educational research

Dear Secilia

This letter serves to inform you that you, your request to contact the educational research has been approved on condition that, it will not disturb teaching and learning in any way.

We thank you for choosing Peumba combined school as part of your study while hoping that the findings will be shared with us to see how best we can use them to improve the use of ICT in our teaching.

Yours faithfully

JOHANNES K. HEITA
SCHOOL PRINCIPAL

OHANGWENA REGION DIRECTORATE
PEUMBA COM...
2023 -02-
P.O Box 11441
Tel 065 268 871
REPUBLIC OF NAMIBIA

APPENDIX E: THE SAMPLE OF A CONSENT FORM FOR TEACHERS

Declaration

I Saltiel Hangula Hashipala (full name and surname of participant) hereby confirm that I understand the contents of this letter and the nature of the research project. I consent to participate in the research project.

Signature of participant .... Date 27/02/2023

Thank you in advance for accepting to be the participant in this research study

Yours Sincerely

Secilia T. Silvanus

Thank you for your participation.
Please give your consent for semi- structured interview by ticking in the box below and provided your conduct number.

- **I am giving my consent for the semi-structured interview**
- **My conduct number is:** 0814878971

0812186775

8

APPENDIX F: THE SAMPLE OF A CONSENT FORM FROM PARENTS

Owamanguluka yoo okupula ouyelele kongodi yange 0812964404, mrsmulck@gmail.com ile komuhongi wange Dr Clement Simuja c.simuja@ru.ac.za

Woye ....

Secilia Tulikefo Silvanus

Ulika epitikilo lokaana koye kakufe ombinga moshinyangadalwa eshi pakuyadifa okafooloma takashikula

EPITIKILO LOMUDALI/OMUTEKULI WOMULONGWA

Ame (ame)... MARTHA MALAPI ....onga omudali/omutekuli wa ..PETRUS FILLEMON ohandi yandje epitikilo opo okaana kange kakufe ombinga moshinyangadalwasha osho tashi ningwa ku Secilia Tulikefo Silavnus, omulihongi koshiputudilosha Rhodes university. Ondi uditeko osho okaana kange kateelelwa okuninga no ndi na oufemba woku ningulula etokolo lange.

M.Malapi 27. 03. 2023

Eshaino lomudali/omutekuli Omukalelipo Efiku

Owamanguluka yoo okupula ouyelele kongodi yange 0812964404, mrsmulck@gmail.com ile komuhongi wange Dr Clement Simuja c.simuja@ru.ac.za

Woye ....

Secilia Tulikefo Silvanus

Ulika epitikilo lokaana koye kakufe ombinga moshinyangadalwa eshi pakuyadifa okafooloma takashikula

EPITIKILO LOMUDALI/OMUTEKULI WOMULONGWA

Ame (ame)......Julia Hamukwaya ....onga omudali/omutekuli wa ..SHINGULU VELONIKA ohandi yandje epitikilo opo okaana kange kakufe ombinga moshinyangadalwasha osho tashi ningwa ku Secilia Tulikefo Silavnus, omulihongi koshiputudilosha Rhodes university. Ondi uditeko osho okaana kange kateelelwa okuninga no ndi na oufemba woku ningulula etokolo lange.

Julia Hamukwaya .... 23 March 2023

Eshaino lomudali/omutekuli Omukalelipo Efiku

APPENDIX G: THE SAMPLE OF A CONSENT FORM FOR LEARNERS

Give your consent by completing the following section

CONSENT: I AM AWARE THAT

- I will be a respondent for the above-mentioned topic.
- I am free to withdraw at any time I may wish without negative or undesirable consequences.
- The information provided will be used only in the research project.
- I am also aware that the information provided by me will be strictly confidential and the findings will be reviewed in the research thesis.
- My identity in this study will be protected with the code of ethics stipulated by Rhodes University.
- Having taken note of the above information, I freely volunteer to participate in the research process and acknowledge that I have not been forced to do so.

DECLARATION

I Saima Hamukosho (full name and surname of the participant) hereby confirm that I understand the contents of this letter and the nature of the research project. I consent to participate in the research project.

Participant's Signature: [signature] Date: 30 March 2023

APPENDIX H: QUESTIONNAIRE FORM SAMPLE

Semi-structured questionnaire Sample

Introduction

This is a Masters in Education research questionnaire designed explore rural senior primary Natural Science teachers' Technological Pedagogical Content Knowledge (TPACK).Kindly be open and free as possible. Be assured that absolute confidentiality will be adhered to and no circumstances will your details be revealed to a third party. Please answer all the questions to the best of your knowledge. Your responses will be kept completely confidential. Thank you for your participation.

SECTION A: BIOGRAPHICAL AND BACKGROUND INFORMATION
(Please check √ only one option for each statement in this section)

1. How do you currently describe your gender identity?

Female	
Male	
Other	
Prefer not to answer	

2. What is your age?

21 and below		41-50	
22-30		51-60	
31-40		61 and over	

3. What grade(s) do you teach? Please select all that apply.

4	
5	
6	
7	

4. What is your current teaching experience?

0-4		15-19	
5-9		20-24	
10-14		25 or more years	

5. What is the highest level of qualification you have completed?

____

6. Are the following facilities available at the school you are teaching? (please tick √)

Available teaching and learning technology devices	Yes	No
Computer, Laboratory		
Computer/ Laptop for teachers' use		
White board		
Smart board Tablets' for teachers' use Tables for learners' use *i*Pad for teachers *i*Pad for learners		

7. Which of the above listed technological tools do you use in your teaching and how often?
……
8. Please give a brief description of how you use technology in your teaching and communication with your learners?
………………………………………………………………………………………………………

SECTION B: SENIOR PRIMARY NATURAL SCIENCE TEACHERS' UNDERSTANDING OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLDEGE

Technology is a broad concept that can mean a lot of different things. For the purpose of this semi-structured questionnaire, technology refers to all digital technology/technologies, that is, the digital devices and tools we use such a: computers, laptops, handhelds (tablets / cell-phones), data-projectors, interactive whiteboards, document viewers /document cameras, software programs, Apps, simulations, Internet services, etc.

Please read each item carefully and **SELECT** the response that best fits your understanding. If you are uncertain of, or neutral about your response, you may select "Neither Agree or Disagree". Mark only one column per row.

In this section, you will be asked to report on your understanding of **CONTENT KNOWLEDGE**. Please read each item carefully and **SELECT** the response that best fits your understanding.

Technological Knowledge (TK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I know how to solve my own technical problems					
I keep up with important new technologies					
I know about a lot of different technologies					
I have the technical skills I need to use technologies					
I have had sufficient opportunities to work with a range of technologies					
I am able to learn how to use new software easily on my own					
I am able to install a new technologiesthat I would like to use					

Comment on any of the above responses:

____

____

In this section, you will be asked to report on your understanding of **CONTENT KNOWLEDGE**. Please read each item carefully and **SELECT** the response that best fits your understanding.

Content Knowledge (CK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I have sufficient knowledge about the subject I teach					
I have various ways and strategies of developing my understanding of the subject I teach					
I have a deep and wide understanding of the subject that I teach					
I am able to comfortably plan the scope and sequence of concepts that need to be taught within my class					
I know about various examples of how my subject matter applies in the real world					
I am able to use a scientific way of thinking					
I have good understanding of the Nature of Science					
I am able follow up-to-date resources and developments in my subject					

Comment on any of the above responses:

____

____

In this section, you will be asked to report on your understanding of **PEDAGOGICAL KNOWLEDGE.** Please read each item carefully and **SELECT** the response that best fits your understanding.

Pedagogical Knowledge (PK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am able to assess student performance in a classroom					
I am able to adapt my teaching based upon what students currently understand or do not understand					
I am able to adapt my teaching style to cater for diverse learners.					
I am able to use a wide range of teaching approaches in a classroom setting					
I am able to use different assessment tools and techniques					
I am able to know how to organize and maintain classroom management					
I am able to determine the strategy best suited for the lessons I teach					
I am able to prepare lesson plans for the various topics I teach					

Comment on any of the above responses:

____

____

In this section, you will be asked to report on your understanding of **PEDAGOGICAL CONTENT KNOWLEDGE**. Please read each item carefully and **SELECT** the response that best fits your understanding.

Pedagogical content Knowledge (PCK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am able to select effective teaching approaches to guide student thinking and learning in my subject matter					
I understanding of the topics in my subject matter					
Ability to produce lesson plans with a good					
I am able to anticipate likely student misconceptions within a particular topic					
I am able to distinguish between correct and incorrect problem solving attempts by students within my class					
I am able to familiarise with common student understandings and misconceptions in my subject matter					
I am able to meet the objectives described in my lesson plans					
I am able to explicitly target aspects of the Nature of Science when teaching					
I am able to assist students in identifying connections between various concepts in my subject matter					

Comment on any of the above responses:

____

____

In this section, you will be asked to report on your understanding of **TECHNOLOGICAL CONTENT KNOWLEDGE**. Please read each item carefully and SELECT the response that best fits your understanding.

Technological Content Knowledge	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am able to know about technologies that I can use for teaching specific concepts in my subject matter					
I am able to know how my subject matter can be represented by the application of technology					
I am able to know about technologies that I can use to enhance the understanding of specific concepts in my subject matter					
I am able to use technological representations (i.e. multimedia, visual demonstrations, etc.) to demonstrate specific concepts in my subject matter					
I am able to use various types of technologies to deliver the content of my subject matter					
I am able to use technology to make students observe phenomenon that would otherwise be difficult to observe in my subject matter					
I am able to use technology to create and manipulate models of scientific phenomenon (e.g. animations, modelling, etc)					

Comment on any of the above responses:

____

____

In this section, you will be asked to report on your understanding of **TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE.** Please read each item carefully and SELECT the response that best fits your understanding.

Technological Pedagogical Knowledge (TPK)	**Strongly disagree**	**Disagree**	**Neither agree nor disagree**	**Agree**	**Strongly agree**
I am able to choose technologies that enhance the teaching approaches for a lesson					
I am able to choose technologies that enhance learners' learning concepts					
I am able to choose technologies that are appropriate for my teaching					
Ability to apply technologies to different teaching activities					
I am able to effectively manage a technology-rich classroom					
I am able to use technology to help assess student learning					
I am able to think critically about how to use technology in my class					
I am able to choose technologies that enhance the content for a lesson					

Comment on any of the above responses:

____

____

In this section, you will be asked to report on your understanding of **TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE**. Please read each item carefully and SELECT the response that best fits your understanding.

Technological Pedagogical and Content Knowledge (TPACK)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am able to teach lessons that appropriately combine my subject matter, technologies, and teaching approaches					
I am able to select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn					
I am able to use strategies that combine content, technologies, and teaching approaches in my classroom					
I am able to provide leadership in helping others to coordinate the use of the content, technologies, and teaching approaches at my school					
I am able to choose technologies that enhance the understanding of the content for a lesson					
I am able to find and use online materials that effectively demonstrate a specific scientific principle					
I am able to use technology to facilitate scientific inquiry in the classroom					
I am able to use technology to create effective representations of content that departs from textbook approaches					

Comment on any of the above responses:

____

Thank you for your participation
Please give your consent for semi- structured interview by ticking in the box below and provided your conduct number.

- **I am giving my consent for the semi-structured interview**
- **My conduct number is: ………………………………**

APPENDIX I: SEMI-STRUCTURED INTERVIEW GUIDE SAMPLE

Semi-Structured Guiding Interview Questions

1. What technological tools, devices, facilities and services are available at your school?
2. Which one are you able to use in your Natural Science teaching and where do you get support?
3. What informs your selection of a particular ICT tool to use in a lesson?
4. Describe the process you go through to select a particular ICT tool to teach a lesson.
5. Have you had to modify your teaching to accommodate the use of ICT? If so how?
6. How do ICT tools change your teaching in general?
7. Do you start with technology, pedagogy, content or some combination when building a lesson? In what order do you consider these components in your planning?
8. What do you find challenging in your use of technology in Natural science teaching?
9. Based on your experience of using technology to teach Natural science, how do you know that certain technologies are best suited for addressing certain topics?
10. From your experience of teaching using technology, what factors do you think:
    a. Can you encourage teachers to use technology in their teaching?
    b. Inhibit teachers from using technology in their teaching?
11. Are the trainings on use of ICT in teaching adequate for you to teach using technology? Explain.
12. Which technological tools, applications, or platforms were you trained on?

Is there any information that you would like to share with me related to this interview that I have not captured in my questions?

APPENDIX J: FOCUS GROUP INTERVIEW GUIDE SAMPLE

Focus group guiding interview questions

1. Are the following facilities available at your school?Computer laboratory; Computers/laptops for teachers' use; Internet connectivity; Tablets.

2. How do you select technologies to use in your classroom that enhance what you teach, how you teach and what learners learn?

3. How do you select and make use of those technologies to teach Natural science?

4. What do you find challenging in your use of technology in Natural science teaching?

5. Based on your experience of using technology to teach Natural science, how do you know that certain technologies are best suited for addressing certain topics?

6. From your experience of teaching using technology, what factors do you think:

    a. Can you encourage teachers to use technology in their teaching?

    b. Inhibit teachers from using technology in their teaching?

7. Are the trainings on use of ICT in teaching adequate for you to teach using technology? Explain.

8. Which technological tools, applications, or platforms were you trained on?

APPENDIX K: OBSERVATION GUIDE SAMPLE

Observation tool

Teachers' Technological Knowledge	
Observe	**Notes**
What technological tool is used by the teacher to teach	
Teacher demonstrates confidence in using technology to teach.	
Teachers have knowledge of how to install some software programs	
Teachers' Technological Content Knowledge	
Teacherunderstands which specific technologies are best suited for addressing certain topics.	
Teacher uses technology with little or no problems.	
Teacher'sconfidence in using different technologies for teaching.	
Teachers' Technological Pedagogical Knowledge	
Teacher has/does not have sufficient skills of integrating technology in teaching.	
Teacher is aware/ not aware of affordances and constraints of certain technologies.	
Teacher is able/not able to creatively use the available technology tools in a pedagogical context.	
Teachers' Technological Pedagogical Content Knowledge	
Teacher selects and makes use of appropriate technologies that are suitable for the content	