PERCEPTIONS AND EXPERIENCES OF LIFE SCIENCES TEACHERS ON THE INTEGRATION OF A VIRTUAL LABORATORY FOR RURAL TEACHING

by

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DECLARATION

I, BRIAN SHAMBARE, student number: 2021728858, declare that the thesis, PERCEPTIONS AND EXPERIENCES OF LIFE SCIENCES TEACHERS ON THE INTEGRATION OF A VIRTUAL LABORATORY FOR RURAL TEACHING, submitted for the qualification Doctor of Philosophy (PhD) with specialisation in Subject Education in Science and Technology at the University of the Free State is my own independent work.

All the references that I have used have been indicated and acknowledged by means of in-text citations and in the list of references.

I further declare that this work has not previously been submitted by me at another university or faculty for the purpose of obtaining a qualification.

06 November 2023

SIGNED DATE

ABSTRACT

In line with South Africa's National Development Plan Agenda 2030, the current educational objective is to provide technology to schools. However, effective integration of these technologies in teaching hinges on teachers' acceptance to use them. Therefore, it is imperative to investigate issues of technology acceptance, particularly teachers' perceptions and experiences, before introducing such technologies. Neglecting this step risks the technology tools being underutilised or abandoned once deployed in schools, especially innovative ones like Virtual Lab. This study investigated Life Sciences teachers' perceptions and experiences regarding integrating Virtual Lab for rural teaching. The Technology Acceptance Model (TAM) (Davis, 1989) and the Technological Pedagogical Content Knowledge framework (TPACK) (Koehler & Mishra, 2006) guided this research. The study used a sequential explanatory mixed-methods approach with two phases: a quantitative survey involving 200 Life Science teachers in Eastern Cape province and qualitative interviews with four teachers from rural secondary schools in the Joe Gqabi District. Findings were analysed using descriptive and inferential statistics in Phase One and thematic analysis in Phase Two, and the integrated results matrix facilitated meta-inferences.

The study found that Life Sciences teachers perceive integrating Virtual Labs into teaching positively, primarily driven by its ease of use and usefulness. Notably, they emphasise the benefits over the ease of use, indicating a solid understanding of Virtual Lab's potential advantages. Furthermore, teachers with higher technological pedagogical content knowledge hold more positive perceptions of Virtual Lab. Interestingly, this study found that perceived usefulness and technological knowledge significantly influence teachers' intention to use Virtual Lab. This finding affirms that combining TAM and TPACK theories can offer a comprehensive framework for analysing teacher perceptions and acceptance of novel technologies in rural schools. However, challenges exist. Many teachers lack the knowledge to use Virtual Lab effectively. Limited electricity supply, insufficient school support, and a lack of professional development hinder Virtual Lab adoption. To overcome these, the study recommends tailored professional development and school support. Looking ahead, future research should shift its focus towards exploring learners' perceptions and experiences regarding the integration of Virtual Lab to gain a holistic understanding of its uptake in education.

KEYWORDS: laboratory experiments, perceptions, science education; Virtual Laboratory, technology-user-acceptance, TPACK, TAM

DEDICATION

From street kid to PhD graduate…
A journey wrought with suffering and fate,
Orphaned at three months, born into a chaos of anguish,
Where dreams wither, hopes drift away.

This thesis is dedicated to my brothers Royce Shambare & Rodwell Muzanenhamo,
who forsook the classroom's door and toiled on the farms,
Their dreams deferred,
So I could learn.

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LIST OF ACRONYMS AND ABBREVIATIONS

BI	BEHAVIOURAL INTENTION
CAPS	CURRICULUM AND ASSESSMENT POLICY STATEMENT
CK	CONTENT KNOWLEDGE
DBE	DEPARTMENT OF BASIC EDUCATION
ECDoE	EASTERN CAPE DEPARTMENT OF EDUCATION
LFSC	LIFE SCIENCES
PCK	PEDAGOGICAL CONTENT KNOWLEDGE
PEOU	PERCEIVED EASE OF USE
PK	PEDAGOGICAL KNOWLEDGE
PU	PERCEIVED USEFULNESS
SA	SOUTH AFRICA
SMT	SCHOOL MANAGEMENT TEAM
SPSS	STATISTICAL PACKAGE FOR SOCIAL SCIENCES PROGRAMME
TAM	TECHNOLOGY ACCEPTANCE MODEL
TCK	TECHNOLOGICAL CONTENT KNOWLEDGE
TPACK	TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE
TPK	TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE
UFS	UNIVERSITY OF THE FREE STATE
VL	VIRTUAL LABORATORY
VLE	VIRTUAL LEARNING ENVIRONMENTS
VR	VIRTUAL REALITY

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

Science is a discipline requiring experimental inquiry and evidence such that theories can be validated. Accordingly, effective teaching of scientific concepts has to rely more on learners' hands-on experiences involving experiments (Schauble, Glaser, Duschl, Schulze & John, 1995; Hodson, 2014; Hudson, Olin-Scheller & Stolare, 2023). Several scholars in science education confirm the effectiveness of science teaching when learners touch, measure, draw, record, and interpret data (Onwu & Stoffels, 2005; Mccrory, 2014; Olimjon o'g'li, Juraqulovna & Kamoliddinovna, 2022). Moreover, some science education practitioners argue that "hands-on experience is at the heart of science teaching and learning" (Contant, Tweed, Bass & Carin, 2018:2). Based on these tenets, South Africa (SA), like several other Global South nations, follows a Curriculum and Assessment Policy Statement (CAPS) that mandates teachers to assist learners in planning and carrying out investigations through hands-on work and experimentation in the study of science. However, while hands-on practical activities with actual laboratory instruments are preferred, most schools, particularly in rural communities, are poorly resourced regarding proper conventional science laboratory facilities. This could be one reason that contributes to mediocre science teaching (and learning) outcomes in most rural schools, as Stroupe (2015) and García-Carmona (2020) observe in their analysis of rural science teaching.

Considering this limitation of the absence of science laboratories, it is crucial to explore new alternative laboratory facilities such that science learners and teachers in rural areas can perform basic experiments to attain the curriculum's pedagogical goals. Recently, the emergence of technologies in education and the potential to enhance science teaching has been recognised by many scholars (Pedretti, Mayer-Smith & Woodrow, 1998; Hofstein & Lunetta, 2004; Budai & Kuczmann, 2018; Kabra, Ghosh & Joshi, 2023) who see technology as being a panacea to plug the gaps in the teaching of the sciences (especially in disadvantaged and rural settings). Hence, there is a growing call for teachers to leverage technology in their teaching, which should be mainly driven by technology's perceived usefulness, particularly in science

teaching. One of the novel technological developments in the science education landscape is the Virtual Laboratory (VL), which does not require traditional physical science facilities. Abou-Faour and Ayoubi (2017:55) define VL as "a simulated version of a conventional laboratory where learners are presented with virtual representations of actual laboratory instruments and objects used in traditional labs." As such, this study views VL as a tool that enables learners and teachers to conduct experiments where laboratory instruments, apparatus, chemicals, and equipment are provided on digital devices such as computers and smartphones. Therefore, with VL, the buildings and the physical laboratory instruments are converted into computer software applications. Presently, many VL programmes are free and do not require school internet infrastructure - something which schools can exploit.

My initial literature review highlighted several benefits of teaching science via VL. For example, a seminal literature review by Ali and Ullah (2020) examined 42 empirical studies of VL use across sixteen countries and found that they improved student learning outcomes. Specifically, Bogusevschi, Muntean and Muntean (2020) point out that performing hands-on practicals in conventional labs can be very expensive, considering the procurement and maintenance costs of state-of-the-art lab apparatus. However, with VL, experiments are performed in a virtual domain using simulated equipment that does not deteriorate and chemical reactants that do not diminish. Further, Kapilan et al. (2021) found that VLs help study three-dimensional (3D) objects by allowing learners to examine them from varying dimensions, including exploring the objects' interiors. This feature of VL is advantageous as it can enable learners to comprehend minute structures such as organelles and atoms. However, it is essential to note that VL, like any other educational technology tool, has its shortcomings. These include that in VL, learners do not develop the skills to manipulate the actual objects practically and physically, whereas, in real life, the learners are required to be competent in handling the actual objects. Also, VL has no lab supervisor, as the learners are expected to interact according to the computer's instructions - this may disadvantage learners who may not be technologically competent.

While numerous investigations have been carried out to assess the efficacy of VL for teaching purposes, there is limited knowledge about science teachers' perceptions and experiences of VL. Most available studies concerning VL focused on its impact

on learners' achievement in science (Tatli & Ayas, 2012; Ambusadi et al., 2015; Bogusevschi, Muntean & Muntean, 2020; Makarova et al., 2023.) and learners' attitudes towards VL in science learning (Herga, Grmek & Dinevski, 2014; Monita & Ikhsan, 2020; Engel et al., 2023). The present study argues against using learners as participants for studies on integrating VL for teaching; this is because the drivers for accepting an educational technology such as VL from the teachers' and learners' viewpoints might differ. Research shows that teachers' perceptions have a bearing on their acceptance (or rejection) of educational technologies, which may impact technology integration into their classrooms (Suparjan, 2021). Hence, this research was premised on the view that the effective integration of the VL into classrooms requires an incisive understanding of teachers' perceptions towards introducing technologies into teaching-learning situations, specifically in the field of science. This research is therefore crucial as it investigates the acceptance and adoption of a novel technology (VL) in a less explored rural context from the secondary school Life Sciences teachers' perspectives.

1.2 BACKGROUND

For a long time, teaching science has been widely perceived as a challenging and intricate endeavour (Herron, 1971; Atilla, 2012; Hudson et al., 2023). This perception flows from the notion that science is inherently an 'abstract' discipline, demanding learners to possess advanced cognitive abilities to establish logical connections between arguments and reconstruct meanings to comprehend the 'abstract' scientific principles. Furthermore, each of the three branches of science (biology, chemistry, and physics) and their respective sub-branches employ specialised scientific terminology, further contributing to the discipline's complexity. Notably, the lack of performing practical hands-on experiments, especially in rural schools, has made science teaching arduous for most Life Sciences teachers. However, with the rapid evolution in technological advancements, the emergence of VL in the science education space presents itself as a potential panacea. VL is seen as a platform encompassing a range of solutions to effectively tackle the myriad challenges that have long hindered the seamless delivery of science education. My literature review indicated a notable surge in the number of studies on VL. However, it is crucial to underscore that the predominant focus of most of these studies has revolved around evaluating the effects of the VL on learners' academic achievement. These include

Oloruntegbe and Alam's (2010) study in Malaysia; Herga, Grmek and Dinevski's (2014) research in Slovenia; Pellas' (2014) project in Italy; Davenport, Rafferty, Yaron's (2018) investigation in the USA; and Kapici, Akcay, Cakir's (2022) research in Turkey, and Alam and Mohanty's (2023) work in India. Similarly, in Africa, the few studies that I found on the use of VL include Bhukuvhani et al.'s (2010) research in Zimbabwe; George and Kolobe's (2014) investigation in Lesotho; studies in Nigeria by Gambari, Obielodan, and Kawu (2017), Aliyu and Talib (2019), and Falade, Olafare and Aladesusi (2020); and Banda and Nzabahimana's (2023) work in Malawi. While these previous studies have examined the influence of VL on students' academic achievements, none have explored science teachers' perceptions and experiences regarding VL's utilisation. Since researchers contend that teachers' perceptions are the predictors of their behaviour (Davis, 1989; Ertmer, 2005; Larijani & Abedi, 2021), any initiative to introduce novel technologies into teaching (e.g., VL) should first consider the teachers' perceptions concerning the utilisation of such technology tools in teaching-learning scenarios.

In SA, secondary school curriculum policies have been revised over the years, leading to the design of the present CAPS as the country's curriculum framework. The CAPS strongly advocates learner involvement in practical activities, especially in the sciences. In support of the CAPS, several researchers (Hattingh, Aldous & Rogan, 2007; Mtsi & Maphosa, 2016; Ramnarain & Hlatswayo, 2018; Olivier & Kruger, 2022) have praised the usefulness of the laboratory in practical activities that make science teaching effective. However, Tsakeni, Vandeyar, and Potgieter (2019) observe that in SA, science teaching has been adversely impacted due to the unavailability of the required science equipment in most rural schools. Several other researchers, such as Oguoma, Jita, and Jita (2019), Ramnarain (2020), Kibirige and Maponya (2021), and Nemadziva, Sexton, and Cole (2023) report similar findings, adding that if these challenges are not addressed timeously and effectively, then effective science teaching may be a dream deferred in these rural contexts. As illuminated in the literature, Life Sciences teachers in rural contexts can strategise to tackle the obstacles related to the unavailability of laboratory facilities by considering VL's advantages.

However, there is a dearth of information on VL in SA. My initial perusal of previous literature suggests that this study could be among the first attempts to explore Life Sciences teachers' perceptions and experiences, specifically concerning utilising the VL in under-resourced rural schools. Hence, this investigation sought to fill the research gap and bring to the fore new knowledge about Life Sciences teachers' perceptions and experiences regarding utilising VL in rural secondary school teaching.

1.3 PROBLEM STATEMENT

Recently, the utilisation of VL in science teaching has been a subject of interest for many science education researchers, with a number of academic articles appearing in the science education space. However, much of this research focuses mainly on establishing the enhancement of learners' learning outcomes with little or no research on the perceptions of rural science teachers towards these VLs, particularly in SA compared to the Global North (Du Plessis & Webb, 2012; Roth, Appel, Schwingel & Rumpler, 2019; Monita & Ikhsan, 2020). In SA, the VL concept is still in the early stages. Although its benefits are highlighted in the literature, VL is yet to get off the ground to become integrated into classroom practice in SA rural schools. For this to occur, Glasco (2020) suggests that one of the first steps would be to examine and understand teachers' perceptions of the VL. This is because teachers are critical components in teaching-learning scenarios; hence, their perceptions and experiences of utilising technology tools often determine whether and how educational technologies are integrated (or not) into their teaching.

Based on the above premise, the present study focused on understanding teachers' current perceptions and experiences of teaching with VL, which could possibly promote pedagogy that will transition towards the integration of VL into science teaching. Sadly, international scholars observe that research concerning technology in schools has so far provided limited insights into understanding science teachers' perceptions of VL (Oloruntegbe & Alam, 2010; Herga, Grmek & Dinevski, 2014; Jogezai, Baloch, Jaffar, Shah, Khilji & Bashir, 2021). Similar findings have been reported by scholars in Africa (Bhukuvhani et al., 2010; George & Kolobe, 2014; Aliyu & Talib, 2019). In SA, there are few studies that have been conducted on teachers' perceptions regarding virtual learning environments (Zhane'Solomon, 2018; Umesh & Penn, 2019; Jantjies & Matome, 2021; Ramnarain & Penn, 2021). Specifically,

Zhane'Solomon (2018) studied how lecturers perceive Virtual Realties (VR) for science teaching, while Ramnarain and Penn (2019) focused on university students' attitudes and perceptions of science learning on virtual platforms, whereas Jantjies and Matome (2021) honed in on student perceptions of VR in universities. All these research investigations were carried out in higher education contexts and focused on university students and lecturers' perceptions and attitudes toward VL, with almost none in secondary school contexts. This points to the paucity of research concerning science teachers' perceptions and experiences of VLs in rural secondary school contexts in SA. The present study sought to close this knowledge gap whilst also bringing new knowledge on science teaching in rural spaces to the fore.

1.4 SIGNIFICANCE OF THE STUDY

The present study probed Life Sciences teachers' perceptions and experiences of utilising VL in rural schools. This undertaking could extend the knowledge frontiers by contributing to the literature on the utilisation of VL from the perspectives of Life Sciences teachers within rural secondary school contexts, especially in African settings.

My professional experience as a District Education Official (ECDoE Subject Advisor - Life Sciences) who works with Life Sciences teachers in rural secondary schools that lack adequate science equipment and laboratories triggered the passion to conduct research related to the introduction of VL in under-resourced schools. Having taught Life Sciences in rural schools that did not have science labs, coupled with holding the position of Science Departmental Head in such schools, I gained first-hand experience with the challenges of teaching science where learners study science without engaging in practical activities. Therefore, this study that dissects teachers' perceptions and experiences of VL is a step towards integrating technology into science classrooms. This research initiative holds the promise of delivering crucial insights to Education Officials, including myself, regarding the experiences, support and resources essential for enabling Life Sciences teachers in rural schools to effectively incorporate VL into their teaching. Moreover, this study could benefit the teacher-participants as they will have the opportunity to reflect and change any negative perceptions of using the VL in their teaching.

Presently, little is known about how science teachers in rural schools perceive VL as a teaching tool. Thus, further studies are required in this direction. Should this study succeed in unpacking rural Life Sciences teachers' perceptions and experiences in using VL, that could contribute to improvements in policy and practice to the advantage of learners and learning. Moreover, it is essential to note that this research was conducted specifically in one Eastern Cape district, and thus, its generalisability might be limited due to its scope. However, it is anticipated that the findings of this research would establish a solid foundation that could potentially inform and set the stage for future researchers in similar educational settings, contributing to the broader field of science education, particularly in under-resourced areas.

To achieve its outcomes, the current study pursued the following research questions:

1.5 RESEARCH QUESTIONS

The main research question was:

- How do rural Life Sciences teachers perceive and experience the integration of the Virtual Lab for rural science teaching?

The sub-questions were:

- What are rural Life Sciences teachers' views and understanding of the integration of Virtual Lab in classroom practice?
- What are rural Life Sciences teachers' experiences concerning the integration of Virtual Lab into science teaching?
- How can rural Life Sciences teachers' perceptions and experiences of the integration of Virtual Lab be understood and explained?

1.6 RESEARCH AIM AND OBJECTIVES

The research aim was:

- To uncover and understand rural Life Sciences teachers' perceptions and experiences on the integration of Virtual Lab for rural science teaching.

The specific objectives were:

- To investigate rural Life Sciences teachers' views and understanding of the integration of Virtual Lab into their classroom practice.
- To explore rural Life Sciences teachers' lived experiences concerning the integration of Virtual Lab into their teaching practice and

- To understand and explain rural Life Sciences teachers' perceptions and experiences of integration of Virtual Lab into practical teaching.

1.7 THEORETICAL FRAMEWORK OVERVIEW

Two theoretical frameworks underpinned this study: Davis's (1989) Technology Acceptance Model (TAM) and Koehler and Mishra's (2006) Technological Pedagogical Content Knowledge (TPACK).

Firstly, I employed TAM in this study for several compelling reasons. For instance, TAM proved to be well-suited for investigating teacher perceptions towards new technologies (VL) and exploring pertinent contextual factors such as skills, prior experience, technology availability, school technology policies, and support from the SMTs (Casey, Pennington & Mireles, 2021). Consequently, TAM's ability to offer a comprehensive framework for assessing teacher perceptions, emotions, and attitudes aligns perfectly with the present study's objective: to explore Life Sciences teachers' perceptions and experiences of VL. TAM's adaptability was another key factor in its selection. The model offers the flexibility to account for external variables, encompassing both barriers and enablers, such as social influence and the impact of facilitating conditions for successful VL adoption for rural science teaching.

Secondly, it is worth noting that many studies focusing on teacher perceptions frequently rely on technology acceptance models such as TAM. However, the models often fall short in delineating the specific professional knowledge teachers need to incorporate technology in their classrooms effectively. The essential facets of this professional knowledge are explicated in the TPACK framework. Consequently, I also adopted the TPACK framework for this research. The decision to incorporate TPACK into this study was driven by its alignment with the research objective, which primarily aimed to gain insights into how Life Sciences teachers perceive and experience the integration of VL in rural teaching settings.

The TPACK framework extends Shulman's (1986) earlier work, which explored the interplay between pedagogical and content knowledge (PCK). In essence, TPACK offers a conceptual model that delves into the intersection of three domains of teacher knowledge: content, pedagogy, and technology. These domains provided incisive

perspectives for understanding how teacher knowledge shapes their perceptions and experiences on the integration of VL in rural classroom contexts. Consequently, the TPACK framework was a fitting complement to TAM due to its ability to articulate the types of knowledge teachers require to leverage technology into teaching. Notably, given that teachers' perceptions and experiences with technology are intricately linked to their specific teaching contexts, TPACK was aptly suited for this study as it systematically analyses the impact of contextual factors on both technology acceptance and use. An in-depth presentation of the theoretical framework is given in chapter three of this study.

1.8 RESEARCH METHODOLOGY OVERVIEW

This research employed the mixed-methods approach rooted in the pragmatic paradigm by applying the sequential explanatory research design. The research design encompassed both qualitative and quantitative data collection and analysis. Since the research questions were neither exclusively quantitative nor qualitative, I employed the pragmatic paradigm because it advocates for adopting approaches best suited to address the research questions without contemplating whether they are solely qualitative or quantitative. Moreover, Alise and Teddlie (2010:18) suggest that the pragmatic paradigm "allows for a combination of methods that, when used together, could provide a better understanding of the actual behaviour of the participants and their contexts, and the perceptions behind those behaviours". Thus, the pragmatic paradigm was also best aligned with the chosen theoretical frameworks (TAM and TPACK), which recognise participants' contexts and perceptions as significant aspects of an inquiry.

In addition, I adopted the sequential explanatory design, which clearly distinguished this study's qualitative and quantitative phases. This particular design offered a notable benefit by initially acquiring quantitative results from a population during the initial phase, followed by a comprehensive exploration of these findings through in-depth qualitative research in the subsequent phase (Creswell, 2020). In the quantitative phase, I used a questionnaire to collect data relating to the teacher perceptions and experiences of VL. To enhance the alignment of my research instruments with the theoretical framework, the questionnaire consisted of questions based on TAM and TPACK principles. I administered the questionnaire to 200 Life Sciences teachers

drawn from across the Eastern Cape (SA). I considered this population somewhat representative of Life Sciences in other rural and poorly resourced schools across SA. The use of a questionnaire enabled me to collect original data from a population too extensive to observe directly (Babbie, 2010). The participant population (and sample) was confined to Life Sciences teachers only and did not include other subject teachers, such as in the Physical and Agricultural Sciences. This was because, presently, the VL platform was mediated to Life Sciences teachers only. Therefore, perceptions and experiences of other science subject teachers without exposure to VL were not explored.

In the qualitative phase, I adopted a case study method to facilitate a comprehensive and in-depth exploration of teachers' perceptions, views, understanding, and experiences concerning the integration of VL in rural school contexts. This approach aligns with the present study's theoretical frameworks, which emphasise understanding teachers' contexts to interpret their perceptions better. I selected four participants in this phase using convenience and purposeful sampling. For convenience sampling, I selected the participants using proximity and easy accessibility as criteria. For purposeful sampling, I selected the participants who possess characteristics and are information-rich to answer the research questions. The qualitative data were collected and recorded verbatim using semi-structured interviews with questions formulated based on the dimensions of TAM and TPACK principles. I expected that the interviews would foster incisive understanding and insight to corroborate the findings elicited from the survey.

The quantitative data were analysed using the SPSS programme version 29 to examine descriptive and inferential statistical trends, while qualitative data were thematically analysed using the NVivo software package to explain the statistical results. To ensure alignment with the theoretical frameworks, the analysis process was guided by TAM constructs, allowing for a comprehensive evaluation of teachers' perspectives on the VL as a teaching tool. At the same time, I drew on the TPACK framework as a lens to understand the teachers' self-reported TPACK levels to integrate VL into science classrooms. A detailed exposition of the study's methodology is provided in chapter four.

1.9 DELIMITATIONS

The study selected Life Sciences teachers in rural and resource-poor schools to understand their perceptions of teaching by using the VL in rural contexts. The study was confined to a quantitative-dominant mixed-method inquiry, an in-depth case study utilising semi-structured interviews. Although the present research was restricted to the Joe Gqabi District in the EC, the findings may cautiously be applied to other similar school contexts in SA and elsewhere; for example, Life Sciences teachers in poorly resourced township schools, and teachers in other science subjects such as Physical sciences, Agricultural sciences, and Technical sciences, either in rural or resource-poor schools.

1.10 LIMITATIONS

Although all methodological aspects of this investigation were strengthened to ensure the validity of its findings, the following limitations might affect the data validity. First, due to the self-administration of questionnaires by participants, there was a possibility that some questionnaires may be returned with incomplete sections. Moreover, the lack of clarity in answers and poor response rates may also negatively impact the validity of the findings. To mitigate these limitations, I piloted the survey questionnaires and addressed all the possible issues of clarity that may arise. Second, the study dealt with the perceptions and experiences of teachers who report to me as their supervisor. This might influence how they respond to the questions. To circumvent this, I positioned myself as a co-researcher, intending to learn from them. Lastly, since this research only applies to Life Sciences teachers' perceptions and experiences concerning teaching science lessons by utilising the VL, there remains a need to understand Life Sciences learners' perceptions and experiences of the VL to attain its successful integration into classroom teaching.

1.11 DEFINITION OF KEYWORDS

For this research, the following definitions are provided for the reader's benefit:

Perceptions: "The thoughts or mental images teachers possess about their professional activities and their learners, which are influenced by their background, knowledge and life experiences, and professional behaviour" (Burić & Moe, 2020:4).

Virtual Laboratory or Virtual Lab: “A genre of digital simulations intended to simulate hands-on laboratories where students can transform theoretical learning to practical learning through experimentation” (Tatli & Ayas, 2012:6).

Technology or Educational Technology: “Any sort of digital learning tool used to aid in the learning of educational content, including but not limited to computers, the Internet, mobile devices, interactive whiteboards, and other emerging technologies and devices, apps, web resources, internet access, technical support and other digital tools to deepen learning” (Mangal & Mangal, 2019:22).

1.12 LAYOUT OF THE CHAPTERS

Chapter One: Introduction and Background

This chapter presented the study’s background, including the problem statement, significance, critical questions, aim, and objectives. It also provided a concise overview of the theoretical frameworks, methodologies, study delimitations, limitations, and term definitions.

Chapter Two: Literature Review

This chapter synthesised the latest and pertinent literature pertaining to the subject, guided by the research questions. The literature was sourced from reputable academic journals, expert-authored books, and recent conference materials. Given the limited availability of literature on VL within the SA context, the review primarily focuses on the Global North context.

Chapter Three: Theoretical Framework

The theoretical frameworks foregrounding the study were explained in this chapter. The rationale for choosing these theories was justified, and their shortcomings were acknowledged.

Chapter Four: Research Methodology

Chapter 4 explored the methodology used in this research, focusing on the study population, sampling procedure, data collection instruments and procedures, and ethics requirements.

Chapter Five: Data Analysis and Interpretation

This chapter presented, analysed, and interpreted the data.

Chapter Six: Discussion, Recommendations, and Conclusions

This final chapter summarised the research and discussed the findings. The findings were compared to previous literature. The dissection of the findings provided recommendations as drawn from the results. This enabled drawing conclusions and suggesting solutions and strategies to overcome challenges in the Life sciences classrooms.

1.13 SUMMARY

The present chapter presented convincing arguments for the need to examine the perceptions and experiences of Life Sciences teachers regarding the integration of a VL in rural schools. This undertaking is crucial because the successful integration of innovative and novel technologies, such as the Virtual Lab, is dependent on teachers' willingness and skills to accept and utilise such technologies in the classroom. Thus, it is critical to thoroughly examine and understand technology-user-acceptance issues, including teachers' perceptions and experiences of technology before its introduction; without this investigation process, technologies become heavily underutilised or abandoned once supplied to schools. Additionally, this chapter discussed the context of the research, the problem statement, and the study's significance. Furthermore, the study's theoretical framework and methodological approach were also discussed. Lastly, this research's limitations, delimitations, and definitions of terms were outlined. The next chapter dissects the literature on science teachers' perceptions and experiences on the integration of VL into teaching.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The primary purpose of this research was to construct an understanding to explain Life Sciences teachers' perceptions and experiences of the integration of VL for rural teaching. To accomplish this objective, I posed three questions to execute the empirical aspect of this study (Section 1.5). The first question is: what are rural Life Sciences teachers' views and understanding of the integration of VL in classroom practice? Second, what are rural Life Sciences teachers' experiences on the integration of VL into science teaching? Third, how can rural Life Sciences teachers' perceptions and experiences of the integration of VL be understood and explained?

To ground the empirical work and set a reference point for analysing and interpreting the results (Xiao & Watson, 2019), I dissected the existing literature concerning each of the three research questions. This Chapter (2) reviewed the literature on science teachers' perceptions and experiences of teaching while using VL. The goal of this literature review, in the broader sense, was to give me, the researcher, the chance to relate the findings of my empirical research to other studies on the topic at hand (Hirose & Creswell, 2022). In particular, this literature review's objectives were:

- To present the essential knowledge related to the topic under study (Haddaway et al., 2015).
- To avoid duplicating previous research (Snyder, 2019).
- To acknowledge and give credit to other scholars who have contributed to the field (Xiao & Watson, 2019).
- To identify contradictions and gaps in existing research; and
- To provide a justification for why this study is crucial.

In alignment with the research questions and the study's objectives, this chapter drew from the most relevant literature gleaned from authoritative and authentic sources. Before reviewing the literature, I would like to outline the theoretical framework underpinning this research.

2.2 OVERVIEW OF THE THEORETICAL FRAMEWORK

Two theoretical frameworks underpinned this study: Davis' (1989) Technology Acceptance Model (TAM) and Koehler and Mishra's (2006) Technological Pedagogical Content Knowledge (TPACK).

First, I adopted TAM in this study because it was appropriate for examining user perceptions towards new technologies, in addition to identifying external factors related to technology acceptance (Casey, Pennington & Mireles, 2021). Further, TAM deals with teacher perceptions, feelings, and attitudes, which are appropriate to this study. Additionally, TAM is flexible as it considers external variables (barriers and enablers) while examining their influence on technology integration in classroom practice (Casey et al., 2021). Also, the TAM approach enabled me to consider, among others, variables such as skills, prior experience, availability of technologies, school technology policies, and SMTs' support.

Second, the adoption of TPACK in the present research was driven by the study's objective, which primarily sought to understand Life Sciences teachers' perceptions of VL. Research focusing on teacher perceptions is often underpinned by various technology acceptance models such as TAM; however, most fail to describe the kinds of professional knowledge teachers need to leverage technology into teaching effectively. These kinds of professional knowledge are articulated in the TPACK framework. The TPACK framework builds upon Shulman's (1986) prior research, which examined the relationship between pedagogy and content knowledge (PCK). In essence, TPACK proposes a conceptual model that explores the convergence of three spheres of teacher knowledge: content, pedagogy, and technology, which are useful lenses to understand how teachers comprehend technology integration into classroom settings. Hence, I decided that knowledge-related factors be considered in this study as they might also influence teacher perceptions of the VL. Therefore, TPACK principles were integrated with TAM principles. Moreover, the TPACK framework was appropriate for this inquiry due to its alignment with the research objective coupled with the possibility of generating data to address the research questions. Since teacher perceptions and experiences of technology are context-based, TPACK was aptly suited for this study because it analyses contextual factors.

2.3 LABORATORY EXPERIENCE IN SCIENCE EDUCATION

In science education, it is universally acknowledged that learning through laboratory hands-on experience using experiments is central to teaching and learning (Herron, 1971; Schauble et al., 1995; Olin-Scheller & Stolare, 2023). This is because laboratory experiments provide the means to strengthen, verify, and construct scientific knowledge. In support, Alam and Mohanty (2023:886) assert that "learners learn better when they measure, touch, feel, manipulate, draw, record and interpret data and make their conclusions." Accordingly, engaging learners in hands-on experiments provides them with what Kolb (1984:38) called 'science experiential learning,' which he views as "the process whereby knowledge is generated through the transformation of experiences." While experiential learning emphasises the process of teaching and learning rather than the outcomes, it is possible for both learners and teachers to attain enhanced learning outcomes by employing teaching methods that foster the acquisition of scientific knowledge through profound engagement with science. Thus, Kolb's (1984:21) science learning framework contends that "experiential learning is a comprehensive and integrated approach to learning that encompasses perception, experience, behaviour, and cognition." Thus, the experiential learning strategy operates by leveraging learners' understanding of the surrounding world, prioritising the teaching-learning process rather than the specific learning outcomes (see Figure 1).

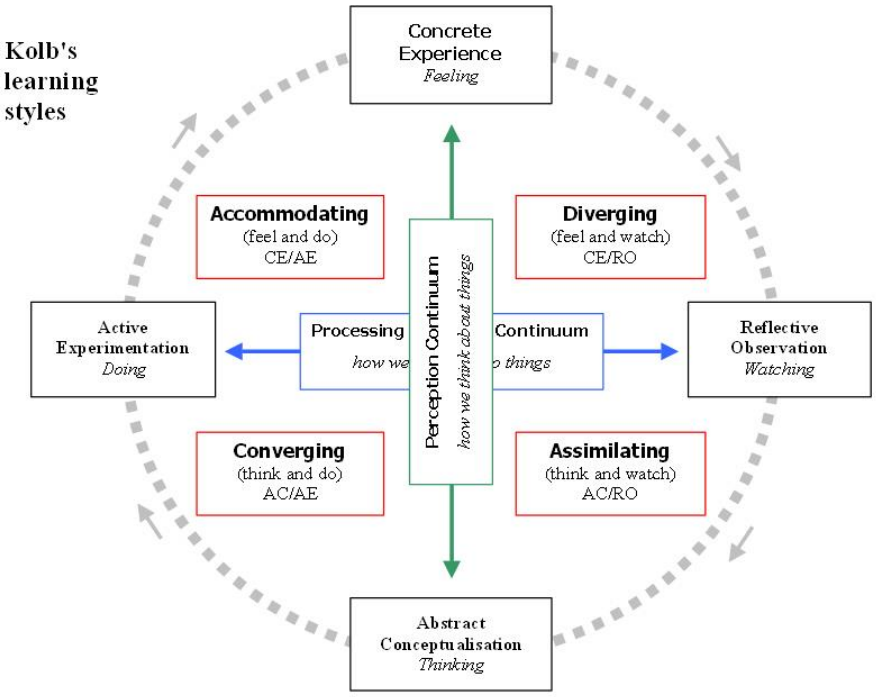

Figure 1: Kolb's experiential learning model (Kolb & Kolb, 2018:28)

Kolb and Kolb's (2018:28) model of experiential learning delineates the progression of science learning into four consecutive phases:

- A concrete experience.
- Reflective observation.
- Abstract conceptualisation, and
- Active experimentation.

First, the learning process in rural secondary schools begins by providing learners with concrete, hands-on experiences that serve as the foundation for their learning. Through these hands-on encounters, the learners engage directly with the subject concepts, igniting their curiosity and initiating the learning cycle. Second, following the hands-on experiences, learners engage in reflective observation, critically analysing what they have experienced and making connections. This process of thoughtful reflection deepens their understanding and allows them to uncover patterns and relationships. Third, building upon their reflections, learners then progress to abstract conceptualisation, connecting their observations to abstract science concepts. By conceptualising the phenomena that they have experienced, learners develop a broader understanding of the science and its underlying principles. Fourth, learners design and conduct experiments to test their observations and findings, engaging in scientific inquiry and practical application. This experimentation not only validates their understanding but also stimulates new experiences that continue the learning cycle.

When applying Kolb and Kolb's (2018) four-step process to rural secondary classroom pedagogy, it becomes essential for science teachers to incorporate reflection as a vital component of experiential teaching. In this process, the science teacher's role shifts from a mere information and knowledge provider to that of a learning facilitator. Silberman (2007:15) also highlights the significance of experiential learning, describing it as "experiential learning involves engaging learners in tangible activities that allow them to directly 'experience' the subject matter they are learning, coupled with opportunities for reflection on those activities." While engaging learners in hands-on laboratory experiments is essential, Silberman (2007) stresses the need for reflection to ensure that learners derive meaningful learning from these experiences. The reflection process is crucial in facilitating the assimilation of newly acquired

knowledge with learners' existing knowledge. It allows learners to make connections, identify patterns, and gain deeper insights into the subject content.

By integrating reflection into the experiential learning process, Life Sciences teachers in rural schools can create an environment where learners actively construct their knowledge. The teachers guide learners in reflecting on their experiences, helping them draw conclusions, and encouraging them to apply their learnings to real-world contexts. This reflective approach promotes critical thinking, metacognition, and the development of higher-order cognitive skills. Ultimately, by embracing experiential teaching methods and incorporating reflection, science teachers empower learners to take ownership of their learning. Therefore, learners not only engage in hands-on activities but also actively process and integrate their experiences, fostering an incise appreciation of the subject content and enhancing their overall learning outcomes.

Notably, by interrogating the laboratory experiences in science teaching-learning, several scholars observe the impact of laboratory experiments in science classrooms. For example, Lee and Sulaiman (2018) explored the efficacy of hands-on practicals on students' science learning in Malaysia. In the study, the experimental class received teaching through hands-on activities, whereas the control class was exposed to unconventional teaching approaches. The data were gathered through questionnaires and interviews, respectively. The findings revealed a significant difference in students' comprehension of Physics. Hence, the researchers recommended that laboratory work (experiential) should be part of teaching Physics. In another study, Musharrat (2020) investigated science teacher perceptions regarding laboratory activities in two schools in Bangladesh. He found that most science teachers agree that laboratory activities are integral in science teaching. However, they could not expose learners to the lab practicals due to the lack of laboratory infrastructure.

Furthermore, through a quasi-experimental study in the United Arab Emirates, Shana and Abulibdeh (2020) examined the influence of hands-on laboratory activities on Grade 10 science learners' academic achievement. The Grade 10 science learners were divided into two classes. The traditional method was utilised to teach the control class, while the same topic was presented to the experimental group using the hands-

on method. The mean score comparison of pre-post tests showed significant differences between the control and experimental class performance. Hence, the researchers recommended that students be exposed to practical science activities. Also, Kehinde et al. (2021) investigated the impact of laboratory activities on pupils' learning outcomes in Nigeria. The study's results revealed a substantial distinction between hands-on activities and conventional teaching methods, with hands-on activities proving more effective and advantageous. Based on their findings, the researchers recommended that teachers be encouraged to incorporate hands-on activities into their lessons.

Considering the above studies, overwhelming evidence in the literature supports hands-on laboratory practicals' importance and effectiveness. However, while the actual practical laboratory work with real lab equipment and chemicals is much preferred, most rural secondary schools, such as those in this study, do not have basic science laboratory facilities. In such cases, some contemporary science and technology scholars suggest that educational technologies may offer opportunities to support learner engagement in experiential learning (Afgan, 2015; Nelson, 2019; Putri et al., 2022). Through educational technology integration, science teachers in rural secondary schools could become more effective facilitators during laboratory experiments such that learners are guided to the acquisition of scientific knowledge. In the section that follows, I now examine scholarship on integrating educational technologies into science education.

2.4 EDUCATIONAL TECHNOLOGIES IN SCIENCE EDUCATION

While educational technologies have found their way into various teaching-learning domains, they are particularly prominent in science education. McCrory (2014:243), in her exploration of technology integration in science classrooms using the TPACK framework, contends that science classrooms are inherently conducive to technology adoption, given the widespread influence of technology in modern scientific practices. As a result, several scholars specialising in science education advocate for the seamless integration of educational technologies within science classrooms (Afgan, 2015; Nelson, 2019; Kulaksız & Karaca, 2023). The integration of technologies into science education is intended to furnish learners with authentic and engaging experiences that align with present-day issues, real-world contexts, and questions.

This pedagogical approach fosters profound, deep, purposeful, and participatory learning, empowering learners to attain proficiency in fundamental scientific skills and principles. Consequently, it is imperative to regard science education technologies as supplementary teaching tools that augment the teaching-learning process. This necessitates a shift in focus towards experiential learning opportunities facilitated by technology.

In recent times, science teachers have had a noteworthy inclination to embrace technology integration in teaching environments. This shift is evident in research done by Vermette and Hzechter (2014:37) with 433 science teachers from Manitoba, Canada, wherein they examined the adoption of technology integration practices through the lens of the TPACK framework. The research revealed several prevalent motivations driving the integration of educational technology, which I outline below:

- advancing learner engagement (56%),
- promoting 21st-century skills for future success (36%),
- technology use as best practice (33%),
- to remain relevant and current (26%),
- to ensure hands-on, collaborative learning (20%),
- for diversification of teaching strategies (19%), and
- to conduct lab demonstrations and experiments (17%).

While science teachers make use of various educational technologies, there is a discernible preference for certain technologies over others. Notably, PowerPoints have emerged as the most employed technology among science teachers, primarily owing to their visual appeal, ability to captivate learners, time efficiency, and ease of both preparation and implementation (Kriek & Stols, 2010; Vermette & Hechter, 2014; Mwapwele et al., 2019). However, recent research suggests a shift in the utilisation patterns towards SMART Boards and interactive whiteboards (Vermette & Hechter, 2014; Van Dijk & Van Deursen, 2020; Ong & Annamalai, 2023). These technologies have gained prominence due to their interactive features and the enhanced learning experiences they offer. In other studies, there was moderate use of videos (Kriek & Stols, 2010; Samancıoğlu et al., 2015; Gürfidan &Koç, 2016) and the occasional use of animations (Olympiou & Zacharia, 2014; Olivier & Kruger, 2022).

Additionally, other scholars report that science teachers seldom use simulations (Jang, 2010; Vermette & Hechter, 2014; Chernikova et al., 2020). Furthermore, Khashan's (2019) study uncovered that microscopes, mobile phones, iPods, and probe ware were the least utilised technologies within science classrooms. Notably, an initial literature review indicated a lack of attention towards modern technologies in articles addressing science and technology integration. However, subsequent academic reviews expanded their scope to incorporate journal articles explicitly focusing on educational technologies. Present-day advancements in the integration of educational technologies in science education encompass the incorporation of augmented reality (AR) (Jaradat, 2020; Ramnarain & Penn, 2021; López-Belmonte et al., 2023), virtual reality (VR) (Oser & Fraser, 2015; Ramnarain & Penn, 2021; Rojas-Sánchez, Palos-Sánchez & Folgado-Fernández, 2023), robotics (Brady, 1984; Ashok et al., 2022; Darmawansah et al., 2023), coding (Greenberg et al., 2012; Armoni et al., 2016; Jiang et al., 2023), game-based science teaching (Squire, 2003; Hall et al., 2022; Djelil & Sanchez, 2023), and artificial intelligence (AI) (Winston, 1992; Vrontis et al., 2022; Holmes, Bialik & Fadel, 2023). Amongst these technology tools, AI, VR, and AR are considered cutting-edge models and prototypes for developing simulation-based learning experiences. The subsequent section of this discussion will delve into the specific applications of VL in science education.

2.5 VIRTUAL LABORATORIES IN SCIENCE EDUCATION

My perusal of the existing literature on this subject demonstrates that the term 'Virtual Laboratory' (VL) is generally loosely used. VL is generally used to refer to web platforms or software that offer an immersive and rich learning platform employing interactive applications, visualisations, and graphics from networked content for purposes of conducting science experiments. In fact, the concept of VL involves three different types whose boundaries are also blurred (Ma & Nickerson, 2006; Herga & Dinevski, 2012; Kapilan et al., 2021):

- Simulations available online contain several aspects of laboratory experiments that are chiefly used for visualisations. These are called 'CyberLabs' or classical simulations.

- Real experiments managed through a network whose output and settings are presented via the Internet. Such labs are called Remote Laboratories.
- Simulations that undertake to imitate real laboratory experiments as closely as possible through teachers' and learners' engagement in 'hands-on' experiences. These are called VLs, which is this study's focus.

It must be noted that discussions about CyberLabs and Remote Labs are beyond the scope of this review. This study reviewed VLs (simulations that closely imitate actual laboratory experiences). To begin defining VL, I acknowledged that a widely accepted definition is yet to emerge. For example, Murphy (2016:17) defines VL as:

> [A] website or software designed for interactive learning through the simulation of actual phenomena. It enables students to investigate a subject by comparing and contrasting various scenarios, pause and resume applications for note-taking and reflection, and gain practical, experiential knowledge over the internet.

On the other hand, Pellas (2014:43) views VL as "A virtual laboratory facility accessible through the internet, allowing users to conduct experiments and simulations in a digital environment." According to Oloruntegbe and Alam (2010:24), VL is "An experiment configured within a remote laboratory accessible to users via the internet from any location and at any time, or the implementation of the laboratory using software simulation." Further, Tatli and Ayas (2012:14) define VL as "a simulated laboratory environment, often a software program, that enables users to conduct experiments." This study adopted Tatli and Ayas' (2012) definition of VL. To fully grasp the rationale for this study's exploration of Life Sciences teachers' perceptions and experiences of VL for rural teaching, one must first comprehend the evolution of VL. I, therefore, proceed to present the history of VL and how they support science teaching-learning in the subsequent sub-sections.

2.5.1 History of Virtual Laboratories

The evolution of VLs dates to the 1970s when higher learning institutions and educational companies developed this technology through software or websites.

Presently, VLs are used mainly in the developed world at various levels of schooling, from primary to tertiary, and for job training in aviation (O'Neil et al., 2000), medicine (Afgan et al., 2015), and the military (Chen, 2022), among others. While the notion of VLs dates back five decades, the emergence of VLs associated with the Life Sciences field is more relevant to the current study. The Genetics Construction Kit (GCK) was one of the first such projects in the 1980s, and it simulates fruit-fly variations and demonstrates conventional Mendelian genetics. Likewise, the VirtualCATTLAB (http://www.emescience.com/sci-genetics-catlab), which simulates the inheritance of genetic characteristics in cats, the VirtualFlyLab (http://www.biologylab.awlonline.com/fruitfly), for fruit-flies, and the VirtualBiologica (http://www.biologica.concord.org/peaplants) in pea plants emerged in the late 1980s and became extensively utilised in science teaching-learning. Later, the Virtual Bio Experiments (ViBE) (http://www.ece.rutgers.edu/marsic/SE/projects/ViBE/bio) emerged in 2002 to enable learners to explore science phenomena and improve their lab aptitudes. Then, all these VL programmes led to the development of the Virtual Genetics Lab (http://vgl.umb.edu/) in 2007, which was used to carry out genetic crosses to predict several hypothetical insects' characteristics. Presently, there is a plethora of VLs that have been developed in the last decade. For example, the Labster (https://www.labster.com/), founded by two PhD students in 2013, is currently being used by several international universities such as Harvard, the University of Hong Kong, California State University, the University of New England, and many others. Another example of a VL is the PraxiLab (http://www.praxilabs.com/), developed in 2016 in Egypt and is currently utilised in several science disciplines in secondary schools and universities worldwide. In addition, starting as recently as September 2022, the Florida International University began to use VirtualPXN Lab (https://pnxlabs.com/) for Science, Technology, Engineering, and Mathematics education.

The development of these types of innovative VLs continues to increase such that VL developers have particularly sought to improve some essential features of VLs. These features include presentation, engagement, and immersion (Herga et al., 2012; Kapilan et al., 2021). Regarding presentation, VLs employ various interactive multimedia forms such as sound, texts, hypertext, images, videos, animations, and graphics. The VL platform, accessed on internet sites, allows learners to engage with

graphical components representing experimental apparatus (Faour & Ayoubi, 2017; Nylen, 2023). The laboratory experiments are done online using the internet. In VLs, the experiments are done using computers, and in recent times, even on mobile cell phones. In VLs, graphical models depicting the real experiment are used to visualise the virtual experiments. The experimental process and the results are observable through animation (Lestari & Supahar, 2020). The learners can simulate their classroom environment on computers using Virtual Reality Systems (VRSs), which provide the required VL instruments (Faour & Ayoubi, 2017). Regarding engagement and immersion, this is concerned with the VLs' levels of replication of reality. A VL's ability to replicate real experiments has an impact on the immersion level or "sense of presence" and feeling of "being there" for learners using the VL (Herga et al., 2012; Kapilan et al., 2021). Accordingly, VLs that cultivate a feeling of "being there together" with other learners may lead not only to high engagement with the VL instruments but also engagement or collaboration with other users.

2.5.2 How do Virtual Labs help learners learn?

Several scholars have suggested that if VLs are to support teaching and learning effectively, learners must be involved in authentic learning experiences (Oloruntegbe et al., 2010; Pellas, 2014; Arista & Kuswanto, 2018; Engel et al., 2023). This is because authentic learning experiences allow learners to construct meaningful connections with their prior experiences from which new knowledge can be developed. The authenticity of the VL learning experience depends on the degree to which the interactions in the VL environment promote learners' engagement in cognitive aspects like those precipitated by interacting with the real laboratory environment (Kapilan et al., 2021). Authentic learning environments do not always have to be established in accordance with activities like those in conventional laboratories; they can also be established in a VL, provided the cognitive processes that learners self-activate allow for significant links to real-life experiences (Faour & Ayoubi, 2017). Therefore, VLs can be effective if they offer learners learning experiences and challenges similar to those that experts in the field face.

A VL's authenticity depends on the simulation fidelity degree (Goel et al., 2022). Fidelity is "the extent to which the model on which the simulation is based is a faithful representation of the actual phenomenon it represents." (Goel et al., 2022:32).

Significantly, the activities conducted in the VL should have the capability to transmit skills and knowledge gained in the VLs practice to align with the actual laboratory practical skills (Roth et al., 2019). Gaining skills to work with actual equipment depends on the VL supplying correct feedback via the fidelity function (Nylen, 2023). Accordingly, VL feedback should give prompts comparable to those experienced in real circumstances. Inaccurate VL feedback could result in negative skills transmission, resulting in more damage than good in the quest for skills development (Roth et al., 2019). Therefore, skills development and transfer largely depend on the teaching-learning environment. The VL teaching-learning environment has to ensure adequate situational features to afford learners an imaginary leap to real-life situations involving minimum cognitive energy. As a result, as VL evolves and their use becomes widespread, it is critical to probe the elements that may advance (or hold back) their incorporation into science education. For the present research, it was crucial to explore the teacher acceptability of VLs. The next section offers the benefits of VL for science teaching.

2.6 BENEFITS OF VIRTUAL LABORATORIES IN SCIENCE EDUCATION

This section aims to explore the various benefits associated with the integration of VL in science teaching. Due to the increasing availability of new educational technologies, technological innovations in science teaching have become crucial. Science education researchers and teachers recognise that VL can encourage better conceptualisation of concepts and strengthen a constructivist approach by enabling students to be more immersed in their studies (Herron, 1971; Schauble et al., 1995; Vaez & Potvin, 2021). Moreover, real laboratories encounter various logistical problems related to high maintenance costs, low learner-lab ratio, and ethical and safety issues when working with biological specimens and poisonous chemicals. In contrast, with the VL, matters related to safety, limitations, geographical location, time, and high costs are non-existent.

2.6.1 Learner-centredness

Users of VLs assert that their experiential nature makes them effective in learner-centred teaching-learning environments (Roth et al., 2019). In learner-centred teaching approaches, learners perform most learning tasks by constructing their knowledge. Such learners who learn by executing tasks are thought to develop a

broader and more profound comprehension of concepts and phenomena instead of just shallow memorisation of procedures, rules, or facts (Kapici et al., 2022).

Several studies in science teaching reveal that permitting learners to 'fool around' in their surroundings involving VL enhanced their theoretical understanding of science concepts (Alam & Mohanty, 2023). For example, in quantitative comparative studies, learners who conducted experiments in VLs had a tendency to experiment with various dimensions of the experimental items, and this ultimately improved learners' performance in written theory assessments (Hatting., 2007; Herga., 2014; Jogezai., 2021). This underscores that learner engagement is crucial for learner-centred teaching. Some scholars have suggested that learners involved in a VL appeared to be more 'immersed' or engaged in their tasks as compared to when in real labs (Davenport et al., 2018; Alam & Mohanty, 2023). Thus, VLs encourage learner-centred teaching by enabling learners' active interaction with the virtual experiment. Hence, the frequent use of VL would ultimately lead to learners mastering how it works. However, some concerns have been raised that learners often get occupied with figuring out how to operate the system instead of exploring the subject concepts.

2.6.2 Scaffolding and Progressive Difficulty

Most VL exponents believe that one of the pedagogical advantages of VLs from a constructivist learning perspective is allowing learning to occur at an appropriate difficulty level (Vaez & Potvin, 2021; Repetto, Bruschi & Talarico, 2023). Effective learning is often believed to progress from novice to expert, and at any stage, the teaching should be customised to levels that enable learners' understanding of concepts (Palincsar, 1998; Pande & Bharathi, 2020). This is crucial in a subject such as science that presents a high level of abstraction. Also, VLs can offer learners simplified and basic forms of reality, which allows them to cognitively contextualise phenomena or concepts that are unfamiliar to them (Faour & Ayoubi, 2017; Chang et al., 2023). This aligns with the Zone of Proximal Development [ZPD] (Vygotsky, 1972), which describes circumstances where a learner can potentially understand a concept but needs external support or mediation (Vygotsky, 1972). A VL suitably customised to the rural secondary school learners' level enables them to observe phenomena as they unfold and thus enhances learners' comprehension of the concepts. This can be accomplished by reducing VL complexity, allowing learners to receive timeous, ideal,

contextualised, and relevant feedback. In this approach, VL is set at a simplified prototype where the experiments are intended to cultivate learners' comprehension of the fundamental concepts. However, some critics have cautioned that simplifying experiments in VL could lead learners to interpret reality inaccurately (O'Neil, 2000; Hattingh et al., 2007; Hodson, 2014).

2.6.3 Practice

One of the expectations in skills development is the progression from less skilled to more proficiently skilled. This can be accomplished through intentional and regular practice in diverse circumstances (Tobin, 1986). In this regard, VL allows learners unlimited opportunities to practise and repetitively explore the same knowledge domain. This ultimately enhances the learners' development of a higher-level mental outlook on the domain (Hattingh et al., 2007; Kapici et al., 2022).

Moreover, since VLs focus on authentic science learning experiences, learners can review their initial predictions for experiments through instant feedback and formulate more accurate mental representations of phenomena. Further, virtual simulations can offer learners the opportunity to practise and conceptually prepare for complicated hands-on experiments (Goel et al., 2022). In addition, since virtual experiments can be repeated in and off school, this can help prepare learners before commencing real experiments since it permits them to repeat experiments after conducting them.

2.6.4 Learning from Failure

In any skills training programme, novice learners will likely make errors in performing their tasks. Therefore, training should offer learners opportunities to fail, but they must learn from their mistakes (Tobin, 1986; Silberman, 2007; Hodson, 2014). As such, VLs have been commended for allowing learners to make errors in a fail-safe environment (Vaez. & Potvin, 2021). In conventional hands-on laboratories, it is challenging to incorporate learning by failure in training due to many reasons. First, failure is not permissible in settings where failure can be dangerous to equipment and humans (Roth et al., 2019). Sometimes, learners can be hesitant to experiment with failure as they may be intimidated by the cost of failure. Second, in many laboratory experiments, learners do not have the opportunity to repeat specific experiments (Arista & Kuswanto, 2018). In addition, accessing the actual laboratory can depend on

specific time allocation and place. Contrastingly, VLs allow learners to fail without fear of failure. Therefore, learners have unlimited opportunities to correct themselves until they master what they need to learn.

2.6.5 Access to internal state variables

In science education, achieving more effective learning becomes feasible when learners can observe the internal processes of systems (Herron, 1971). The emergence of VL provides the opportunity to measure internal processes or aspects that are not easily measurable in real-life experiments. For instance, gauging the core temperature of an object's interior may be impossible in reality, but VL makes it possible. By enabling learners to visualise and manipulate internal operations, VL becomes a powerful tool that facilitates a more profound comprehension of processes (Herga, 2012). In addition, other advantages of VL include the flexibility it offers in controlling experiments. For example, learners can stop, pause, or rewind the experiment at any stage or time, allowing them to focus on specific aspects of the process. Furthermore, VL can present simplified beginner experiments, preventing overwhelming novice learners with excessive details. On the contrary, it also offers more complex versions that encourage learners to develop a more intricate understanding of the processes.

2.6.6 Differentiated Learning Approach

Although some VLs are intended to include learner collaboration, others are designed to train learners to grasp specific concepts and skills during experiments (Monita & Ikhsan, 2020). The types of VLs designed to allow learner collaboration have a high-level ability to imitate real scientific experiences of not only investigations but also the building of communities of practice where learners work together, for example, Chat rooms (Davenport et al., 2018). Further, VLs that focus on the individual learner are also of benefit as they allow introverted learners to express themselves more freely, thus limiting the pressure exerted by fellow learners, thereby providing a secure and conducive platform for them to be more comfortable making and learning from their mistakes (Afgan, 2015).

2.6.7 Safe platform for conducting experiments.

Concerning safety, VL can offer platforms where simulations of catastrophes that include consequences of natural disasters or pandemics are observable safely. In addition, VLs provide a safe platform for physically disabled learners to conduct experiments in secure environments that avoid complex safety-hazard laboratory instruments (Chen, 2022). Furthermore, VLs based on animations and visualisations have been touted as crucial to learners' cognitive comprehension of complex concepts, specifically those involving acute mathematical aptitudes and continued logic that sometimes overburden learners' cognition and jeopardise their capabilities to grasp concepts (Kapilan, 2021). Although several studies reviewed in the preceding sections on VLs mainly emphasise the benefits, research concerning the integration of VLs in science teaching is inconclusive. Given the benefits of VL above, I am also cognisant of some of its drawbacks. Therefore, in the following section, I outline some arguments against VL to critique the technology objectively.

2.7 ARGUMENTS CRITICAL OF VIRTUAL LABS

In contrast to the benefits above, it is essential to address the limitations and shortcomings associated with the use of VL in science teaching.

2.7.1 Lack of physical manipulation of equipment

The critics of VL have highlighted various limitations and issues associated with this technology. These limitations are mostly tied around the lack of physical manipulation of equipment. Firstly, scholars such as Polat and Ekren (2023) have questioned the efficacy of VLs regarding the extent to which they can replicate the realism and authenticity of real laboratories. More specifically, Ali and Ullah (2020) expressed concerns about VLs as substitutes for hands-on experiences in physical laboratories on the basis that even the level of realism and practicality offered by different VLs, when compared amongst themselves, vary. Some scholars have insisted that substituting the actual laboratory with VLs would inherently create a problem regarding the absence of functional and physical fidelity (Budai & Kuczmann, 2018; Engel et al., 2023). For example, the physical observation of actual processes entails measuring real variables such as pressure, mass, temperature, humidity, etc. Measuring these may often lead to systematic and random errors. Therefore, when learners constantly interact with real laboratory systems and equipment, they ultimately develop an innate

awareness of these errors, thus making suitable cognitive adjustments. Related to this, Papadimitropoulos, Dalacosta and Pavlatou (2021) argue that learners can physically interact with specimens, equipment, and chemicals in a real laboratory. They can feel the texture, weight, and temperature, adding to the learning experience. In VLs, although there may be simulations of these interactions, the absence of physical touch can hinder the development of fine motor skills and the intuitive understanding that comes from handling real-world materials.

Furthermore, Vergara et al. (2022) contend that actual laboratories engage multiple senses, including sight, touch, smell, and sometimes taste, depending on the experiment. These sensory inputs can enhance memory retention and overall understanding. On the contrary, VLs mainly rely on visual and auditory senses, potentially limiting the depth of learning that occurs. Moreover, in a real laboratory, learners might encounter a broader range of equipment, some of which may be outdated, such as those in the present study's rural contexts, or require maintenance (Serrano-Perez, 2023). By navigating such limitations, learners can develop adaptability and resourcefulness. In addition, delays in real life and the processes of considering the alternative steps in cases of experimental design failures all form part of learning. VLs, on the other hand, often offer pristine and up-to-date virtual equipment, which does not expose learners to these real-world challenges.

Furthermore, other scholars maintain that learners practising in VLs do not grapple with the risks, interferences, and noises associated with measuring real parameters (Bogusevschi et al., 2020). Thus, these learners may wrongly create unrealistic models or schema of processes and thus react inaccurately to the real processes and systems. Consequently, learners may eventually develop a sense of fictitious reality that may lead to safety risks when they must handle real-life equipment. This observation aligns with Stroupe (2015) and Hernández-de-Menéndez et al. (2019) that while VLs are designed to provide a risk-free learning environment, this safety net may lead to complacency and a lack of awareness about potential hazards. In contrast, real laboratories instil a sense of responsibility and caution in learners, as they would be dealing with genuine hazards and safety protocols.

Additionally, the critics of VL argue that “hands-on” is an experience about “interaction, interpretation and revelation, more than it is about equipment use” (Pyatt & Sims, 2012:133). This implies that exploring concepts through manipulating experimental variables is much more valuable to learners than simply handling real lab instruments. Moreover, other researchers have demonstrated that after conducting a few experiments in VLs, learners were observed to accurately guess experimental outcomes as they become more predictable (Squire, 2003; Pyatt & Sims, 2012; García-Carmona, 2020). Learners then acquire superficial reactions that can be insufficient when unusual circumstances arise. In actual processes, however, different results are often produced on various occasions of conducting the experiments despite using the same reactants. For this reason, learners practising with real processes will have exposure to diverse circumstances that may not necessarily be simulated in VLs. Moreover, Diwakar et al. (2023) highlight a limitation of VL related to its inability to foster learners’ emotional connection with the experimental work. The scholars posit that performing experiments in real laboratories can evoke emotions such as excitement, wonder, or even frustration when things go wrong. These emotional experiences are said to be an essential part of the learning process. However, VLs might struggle to evoke the same emotional responses and thus may not fully engage learners on an emotional level.

In addition, Oser and Fraser (2015) argue that the perceived authority of technology in VL can compromise the authenticity of the inquiry process. Learners may rely heavily on the technology itself, potentially overlooking the critical thinking and decision-making skills that are typically developed through direct engagement with physical materials in traditional laboratory settings. Moreover, robust technology tools such as VLs can favour learners who already possess prior technological knowledge compared to learners whose technology background is not as strong. In sum, real laboratory supporters focus on the experiences in which learners make and learn from their mistakes (Tobin, 1986; Pyatt & Sims, 2012), while VLs campaigners emphasise the benefit of increased conceptual understanding (Pellas, 2014; Arista & Kuswanto, 2018).

2.7.2 Lack of Context

One more disadvantage of VLs is associated with the lack of context in which virtual experiments are conducted (Oser & Fraser, 2015). Contrary to the VLs, in real laboratories, experiments are conducted in environments with various interacting elements that cannot be replicated in VLs. For example, the influences of diverse apparatus and social interactions are absent in the VLs. Nonetheless, when taken together (benefits and limitations of VL), the present study argues that VL benefits far outweigh its limitations. The present study's argument that VL provides significant benefits is well-founded and holds merit. This is because while VL may have limitations compared to real laboratories, they offer unique advantages that can be transformative in in offering opportunities for better science learning experiences in rural and under-resourced schools that lack physical laboratories, such as those in the present study. Given the negatives of VL discussed above, I now proceed to discuss the factors that shape science teachers' integration of VL in the following section.

2.8 FACTORS INFLUENCING SCIENCE TEACHERS' USE OF VIRTUAL LABS

This section explores the factors influencing science teachers' use of VL. The section further examines prior research on teachers' integration of VL. Though the advantages of VLs in science learning are widespread, the following factors may result in either the integration or the insignificance of VLs.

2.8.1 Self-efficacy

Research shows that science teachers' technology self-efficacy can hugely impact their perceptions of teaching with educational technologies (Falade et al., 2020; Polat & Ekren, 2023). Teachers with high self-efficacy characteristically use a broader range of technologies, while those with minimal self-efficacy are usually more reluctant to use technologies and, thus, less likely to integrate technologies in their science classroom (Davis, 1989; Ertmer, 2005). Moreover, technology self-efficacy is influenced by the level of technology ownership (Du Plessis & Webb, 2012). Science teachers who invest more money and time in technology tools tend to have higher technology self-efficacy (Burić & Moe, 2020; Stumbrienė, Jevsikova & Kontvainė, 2023). Regarding the school context, Du Plessis and Webb (2012) indicate that teacher technology self-efficacy differs depending on whether the school context is

rural or urban, with rural teachers showing higher technology self-efficacy. This indicates that context may be a factor in teachers' technology self-efficacy.

2.8.2 Science teachers' perceptions

Although various factors influence technology integration in science teaching, several scholars contend that teachers' perceptions hold particular importance in shaping their decision-making process (Kriek & Stols, 2010; Carver, 2016; Zeichner, 2021). For example, in Ertmer's (2005) study, the teachers reported that their internal barriers, mostly perceptions, significantly influenced their technology integration. In addition, other studies report that compared to other teachers, science teachers mostly regard educational technologies as necessary and demonstrate more positive perceptions toward technology integration in teaching (Carver, 2016; Larijani & Abedi, 2021). Specifically, Larijani and Abedi's (2021) investigation of Tehran teachers' perceptions of technology adoption in teaching demonstrated that positive teacher perceptions have resulted in successful technology integration even in situations where technology access is limited. This finding is consistent with Davis (1989), Ertmer (2005), and Kabra, Ghosh, and Joshi (2023), who point out that teachers' perceptions are the most significant predictors of their behaviour. More specifically, Nelson et al. (2019) assert that teachers' positive perceptions are essential for meaningful technology integration. Likewise, Davis (1989:23) observed that "the success or failure of any technology depends on user acceptance." Zeichner (2021) supports the notion that teachers possessing the requisite capabilities to adopt and use technology in teaching but do not believe in its effectiveness will likely not incorporate technology into their educational practice. Thus, Davis (1989) and Romiszowski (2004) emphasise the importance of considering teachers' perceptions of technology before looking at actual technology use. In the present study, it was essential to understand science teachers' perceptions of teaching with the VL as a tool before looking at, for example, the VL's effectiveness in learner achievements.

As I perused the literature on this subject, it became evident that the number of studies investigating VL is on the increase. However, most of these studies have used learners as participants to assess the effectiveness of VL on learners' performance. For example, Davenport et al. (2018) investigated VL effects on chemistry learning using 1300 secondary school learners and found that learners using VL showed improved

performance from pre- to post-tests. Similarly, Jaradat (2020) used students as participants to investigate the impact of VL on Jordanian learners' attainment in physics. The research employed a quantitative approach using a questionnaire comprising 25 Likert-type scale statements. The study's results indicated that VL improved learners' achievement in physics. In addition, Kapici's (2022) factorial quasi-experimental design examined the impact on intermediate school learners' (n = 116) theoretical understanding and inquiry skills achievement of exposing learners to traditional and VLs on the topic of electricity. The findings revealed that VL and a traditional lab are similarly efficient for improving students' science understanding.

More recently, guided by the TAM-3, Yazici and Nakıboğlu's (2023) qualitative case study in Turkey examined 26 chemistry teachers' perceptions and factors affecting their VL use. The study revealed only four teachers having incorporated various VL functions into their teaching, suggesting low usage patterns. While the chemistry teachers demonstrated positive perceptions towards using VL in chemistry lessons, certain factors hindered their practical implementation. Among the challenges reported by the chemistry teachers were technical difficulties, including limited technology skills and knowledge, internet connectivity issues, lack of suitable VL applications, and challenges stemming from learner engagement. Also, the study identified the key factors that encouraged some teachers to integrate VL into their teaching. These factors included recognising VL's contribution to chemistry education, ensuring safety in their usage, and saving time in the teaching process.

It is noteworthy to mention that Yazici and Nakıboğlu's (2023) recently published research shares many similarities with the current study, as both explored science teachers' perceptions of VL and investigated the factors influencing their adoption of this new technology. However, what sets the present study apart from Yazici and Nakıboğlu's (2023) work is its focus on rural and under-resourced schools in a Global South country (SA), while the latter was conducted in Turkey within a Global North context. Additionally, the current study employed a mixed-method approach to conduct a more complete and in-depth examination of the topic under inquiry, in contrast to the previous qualitative study. Furthermore, the current research utilised two frameworks (TAM and TPACK) to obtain an incise understanding of the topic by dissecting it from

different viewpoints, whereas the other study relied solely on a singular framework (TAM-3).

More so, in SA, the available research on virtual teaching-learning platforms are those done by Zhane'Solomon et al. (2018), Umesh and Penn (2019), Jantjies and Matome (2021), and Ramnarain and Penn (2021). However, Zhane'Solomon's (2018) study focused on the perceptions of university lecturers towards VR for science teaching. Ten lecturers who were purposively sampled revealed that although VR is regarded as valuable and easy to use, the current adoption of VR for teaching and learning is hampered by challenges associated with the lack of infrastructure, finance, and required VR skills.

In contrast, Penn and Ramnarain's (2019) mixed-method research examined the impact of virtual chemistry simulations on university students' attitudes towards chemistry. The qualitative results showed that students experienced independence and fun while interacting with the virtual environment. They also perceived that the virtual environment enhanced their conceptual understanding of chemistry concepts. However, the students recognised that simulations could not substitute the practicality and legitimacy of the practical work in actual laboratories. The researchers claimed their results were essential for science teaching in schools lacking proper science facilities.

Furthermore, like Penn and Ramnarain's (2019) research, Matome and Jantjies (2021) carried out a mixed-method study that explored the perceptions of university students regarding Virtual Reality (VR) at a university in SA. The researchers aimed to answer how VR can improve learning in universities, and the findings show that VR can support teaching and learning at SA universities. The study recommended considering various resource access constraints when presenting such technologies, specifically in poorly resourced communities. From the above, it must be noted that most research was done in a university context compared to secondary school contexts. Therefore, the existing body of research concerning science teachers' perceptions and experiences of incorporating VL as a teaching-learning instrument remains limited. Thus, the current study stands as an innovative and pioneering endeavour to bridge this knowledge gap and shed light on this less-explored territory. By delving into the

perceptions and experiences of science teachers in utilising VL, this research promises to offer groundbreaking insights and aspires to make a significant contribution that expands the range of teaching methods available to science teachers in rural schools.

2.8.3 Professional Teacher Development

A prominent challenge hindering technology adoption in teaching has long been acknowledged as inadequate knowledge and understanding of effectively teaching using technology (Koehler & Mishra, 2005; Koh & Chai, 2011; Mishra, 2019). Despite this challenge, science teachers increasingly recognise educational technology's benefits in science teaching and learning environments. Consequently, teachers desire to enhance their skills and knowledge in integrating technology into their classrooms. Many teachers express the need for further training and professional development opportunities focused on technology integration in teaching (Niess, 2011; Putri et al., 2022). This, therefore, reveals a need for superior technology professional development.

However, it is essential to note that when provided, professional technology development does not translate into improved technology integration, including simulations (Cox & Graham, 2009; Carver, 2016; Ong & Annamalai, 2023). Currently, several studies have shown that most science teachers are underprepared to meaningfully teach with VLs, which can be a significant barrier to integrating VLs (Vermette & Hechter, 2014; Ali & Ullah, 2020; Kulaksız & Karaca, 2023). To address this barrier, professional development programmes must consider teacher intentions and perceptions of VLs because they are crucial to effective technology integration (Monita & Ikhsan, 2020). Through professional development, teachers should be encouraged to perceive that teaching science using VLs is better than what they previously did. It is crucial to emphasise that professional teacher development programmes should not solely focus on the technical aspects of operating VL or various software and hardware components. Instead, these programmes should encompass technology integration into pedagogy (Budai & Kuczmann, 2018). This is because knowing how to use technology is distinct from understanding how to teach with its aid effectively. Therefore, teachers need to acquire the pedagogical knowledge and skills necessary to design meaningful learning experiences, align technology use

with instructional goals, and facilitate learner engagement and learning through the integration of VL in science education in rural secondary schools.

2.8.4 Availability of functioning technology

Effective integration of VL into science teaching requires the availability of functional VL technology. According to reports, significant technological barriers to effective integration include inadequate technology and internet infrastructure, as well as a lack of technical support (Squire, 2003; Mthembu, 2014; Davenport, 2018). Nelson et al. (2019) recommend that technology infrastructure should include the following guidelines:

- Ensuring that teachers and learners have adequate and reliable internet in and out of the schools.
- Ensuring teachers and learners possess functional internet devices to facilitate communication, collaboration, research, and multimedia content creation.
- Promoting the development and utilisation of openly licensed VLs to increase the VLs and
- Developing sustainable strategies for VL infrastructure maintenance issues such as upgrades, updates, and device refresh plans.

From the above guidelines, Pyatt and Sims (2012) and Falade (2020) point out that successful VL integration in science teaching hugely depends on functional VL technology availability. While this may be so, scholars such as Oser and Fraser (2015) and Baydere (2021) caution that the availability of VL technology alone may not necessarily lead to its successful integration in science classrooms if technological assistance is absent.

2.8.5 Time

Another challenge teachers experience when integrating technology is the lack of time (Jadhav & Takale, 2020; Hall, 2022). Researchers such as Oser and Fraser (2015) indicate that science teachers who devote more time to teaching-learning and attempt to use VL are likelier to teach better with it. The present study argues that VLs can address teachers' time constraints in integrating technology into teaching, as previous

studies have shown (Ertmer, 2005; Pyatt & Sims, 2012; Burić & Moe, 2020). VLs offer opportunities for teachers to facilitate lab experiments for learners without the need for extensive planning and oversight. More so, VLs not only alleviate time constraints for teachers but also have the potential to significantly save class time, as evidenced by research (Pyatt & Sims, 2012; Engel et al., 2023). By utilising VLs for lab experiments, teachers can efficiently conduct practical experiments without spending time on tedious tasks such as setting and calibrating equipment, collecting data, recording, and cleaning up after conducting experiments. This newfound time can be redirected towards planning other class activities, such as discussions, interactive exercises, and other associated cognitive endeavours (Jaradat, 2020). Moreover, the flexibility offered by VLs empowers teachers to tailor their class time according to their learners' specific requirements and progress. Teachers can adapt the pace and complexity of experiments based on the learners' understanding, which is challenging to achieve in traditional lab settings with time constraints. This personalised approach enables teachers to nurture a more engaging and enriching learning environment that caters to their learners' diverse needs and interests.

2.8.6 Cost and materials

Research indicates that VLs are a cost-effective alternative to actual laboratories for experiential learning (Tatli & Ayas, 2012; George & Kolobe, 2014). Unlike real labs, which can be financially burdensome, especially for rural and poorly resourced schools, VL overcomes the challenge of costs associated with the real lab (Tatli & Ayas, 2012; Alam & Mohanty, 2023). A notable advantage of VL is enabling learners to participate in virtual experiments, even in schools lacking functional lab materials or equipment. This advantage ensures that learners can still have practical science experiences without being hindered by resource limitations.

When examining the overall impact of VL in science education, the present study's literature review demonstrates that VL benefits far surpass any drawbacks. Their cost-effectiveness, accessibility, and practicality make VLs valuable for enhancing students' scientific understanding and fostering their curiosity through engaging hands-on virtual experiences. Below, I present an overview of studies on VL in science education.

2.9 SUMMARY OF RESEARCH ON VL IN SCIENCE EDUCATION

This section presents a synopsis involving 26 empirical studies from 17 countries on VL integration in science classrooms during the past two decades. This review is confined to VLs that:

- Are studied in educational contexts (i.e., for enhancing science education) and not for improving a product's design from a technological perspective.
- Aim to replicate real lab experiments using inquiry skills and
- Result in positive learning outcomes.

Table 1. Summary of research on VLs in education (2001 – 2023)

Scholar & Year	Aim	Sample	Country	Findings
Romli et al. (2001)	To study how the VL affects chemistry students' comprehension of chemistry concepts.	170 college students	Malaysia	VL offers very effective learning environments that promote constructivist and student-centred learning and allow for science learning at reduced costs.
Trindadah et al. (2002)	To determine VL efficacy to teach water phases.	70 university students	Portugal	VL enhanced students' spatial skills and conceptual understanding of the phases of water.
Mercer-Chalmer (2004)	To examine the VL effects on chemistry students' lab practice.	80 university chemistry students	United Kingdom	VL enabled students to conduct their experiments whenever and wherever they pleased, with less attention paid to the lab's tools.
Ergül et al. (2006)	To investigate VL impacts on teaching "gas diffusion and Graham diffusion law."	138 university students	Turkey	VL can supplement or replace the real lab.
Limniou et al. (2007)	To investigate VL effects on pupils' academic performance.	88 university students from the chemistry department	United Kingdom	VL increased students' achievement: they felt more relaxed, got less exhausted and understood the lessons easier.
Dobrzański & Honysz, (2009)	To examine VL impacts on high school pupils' learning outcomes.	464 secondary school students	United States of America	The students who used VL performed better in assessments.
Tüysüz (2010)	To evaluate the effectiveness of VL on students' attitudes and success.	341 high school students	Turkey	VL positively impacts students' attitudes, success, and motivation. VL can be a viable alternative to the real lab.
Bhukuvhani et al. (2010)	To explore student teachers' VL integration.	16 student teachers	Zimbabwe	While student teachers acknowledged VL benefits, they did not integrate them into their classroom practice.
Tatli & Ayas (2012)	To determine the suitability of virtual and	90 9th-grade students	Turkey	Students felt safe when conducting the experiments.

	real laboratory work on constructivist learning.			They could find a link between their daily lives and the experiments and explore tiny objects such as atomic structures.
Herga et al. (2014)	To investigate the importance of the VL as a visualisation tool in chemistry.	109 7th-grade pupils	Turkey	Regarding knowledge acquisition, using VL was more effective than classes that did not use VL.
George & Kolobe (2014)	To determine chemistry teachers' and students' views of teaching via VL.	166 university students	Lesotho	The majority of students (96%) generally accepted the VL. Only 4% stated that VL could never replace real labs.
Falode & Onasanya, (2015)	To investigate VL efficacy in teaching physics concepts	22 physics teachers and 60 physics students	Nigeria	VL was effective in physics teaching and learning.
Aşıksoy & Islek (2017)	To determine the effect of VL experiences on attitudes towards physics labs.	42 university students	Turkey	VL experiences improved students' attitudes towards physics labs.
Faour & Ayoubi (2018)	To examine VL effects on Grade 10 pupils' attitudes and performance on electric circuits.	50 10th-grade students	Lebanon	VL improved the comprehension of the direct current electric circuit.
Arista & Kuswanto (2018)	To determine the impact of VL on the comprehension of rotational dynamics.	40 high school students	Indonesia	VL can be used both in and out of school and is a good learning platform.
Zhane'Solomon, et al. (2018)	To examine lecturers' perceptions of VR	10 university lecturers	South Africa	Although VR is regarded as useful and simple to use, the adoption of VR into teaching is constrained by the unavailability of necessary infrastructure, funding, and skills.
Aliyu & Talib (2019)	To determine Virtual Reality Technology (VRT) impact on chemistry learning.	60 pre-service chemistry teachers	Nigeria	VRT benefits included immersability, visualisability, and interactivity.
Umesh & Penn (2019)	To investigate the effect of the virtual learning environment (VLE) on physics learning	68 pre-service teachers	South Africa	VLEs improved mean achievement test scores in physics.
Lestari & Supahar (2020)	To investigate student views of VL.	67 7th-grade students	Indonesia	94.3% of students needed VL to support practical science experiments.
Jantjies & Matome (2021)	To explore university student perceptions of virtual reality (VR) applications.	90 university students	South Africa	VR supports teaching and learning in South African universities.
Ramnarain & Penn (2021)	To explore pre-service physical science teachers' instructional scaffolding within simulations.	50 pre-service physical science teachers	South Africa	Simulations enabled guided inquiry and increased students' interest in science.
Asare (2022)	To investigate VL effects on student teachers'	100 student teachers	Ghana	VL improved student teachers' practical skills and students'

	achievement in Integrated Science			performance in Integrated Science.
Safarati & Lubis, (2022)	To evaluate the effect of VL on physics students' comprehension of principles and critical-thinking skills.	40 university students	Indonesia	VL improved students' critical-thinking skills and conceptual understanding.
Atmojo (2022)	To investigate the effects of VL on student teachers' scientific character	80 pre-service teachers	Indonesia	Students assisted by VL showed improved performance compared to those exposed to regular online science lessons.
Banda & Nzabahima (2023)	To investigate the effects of PhET simulation-based teaching-learning on secondary students' academic achievement and motivation in the study of oscillations.	280 secondary school students	Malawi	PhET simulation-based learning enhances students' motivation and academic achievement levels by offering visualizations and instructional tools that facilitate a clear understanding of content knowledge.
Yazici & Nakıboğlu (2023)	To examine teachers' perceptions and factors affecting the adoption of VL for Chemistry teaching	26 Chemistry teachers	Turkey	Teachers demonstrated positive perceptions of VL but are affected by a lack of knowledge and skills in technology.

Table 1. above indicates that most studies revealed that the VL improves learners' academic achievement. While several studies have been conducted on the VL, this review indicates gaps in the literature concerning VL integration in science teaching and learning.

First, it is worth noting that most studies concerning VL in science education have been conducted in the Global North, with limited representation from the Global South, including SA. Consequently, the literature on VL in science education is predominantly influenced by perspectives derived from Global North contexts. However, Mishra (2019) asserts that the effectiveness of teachers' technology integration relies very much on their context and their perceptions of the technologies. Teachers' contexts include various issues, from a teacher's mindfulness of existing technologies to knowing how his/her institution operates and how power dynamics and school politics can influence their teaching with technology (Mishra, 2019). In addition, context would include teachers' knowledge of the school, circuit, cluster, or provincial policies that guide technology integration in teaching. Since different regions have unique contexts, including varying infrastructure, resources, cultural norms, and educational systems, these factors can highly influence the success or failure of technology, such as VL

integration. Subsequently, the findings and recommendations on VL integration from the Global North may not directly apply to the Global South contexts. It is crucial to consider these regional differences when implementing and assessing the impact of educational technologies like VLs to ensure their relevance and effectiveness in diverse educational settings. Therefore, a greater emphasis on research in the Global South is needed to bridge the existing knowledge gap and promote more equitable access to quality education and technology-driven learning experiences worldwide.

Second, the majority of research on VL was done in a university context (Romli et al., 2001; Bhukuvhani et al., 2010; Safarati & Lubis, 2022), and very few on secondary schools in rural schools. This implies that VL integration in secondary schools, particularly in rural schools, has not received much academic interest over the years; hence, much could be unearthed in this direction.

Third, most available studies concerning VL focused on its impact on learners' achievement in science (Limniou et al., 2007; George & Kolobe, 2014; Banda & Nzabahima 2023) and learners' attitudes towards the Virtual Lab in science learning (Tatli & Ayas, 2012; Herga, Grmek & Dinevski, 2014; Lestari & Supahar, 2020; Banda & Nzabahima 2023). In this study, I opposed using learners as participants for studies on integrating VL for teaching because the drivers for accepting an educational technology such as the VL from the teachers' and learners' viewpoints might differ. Research shows that teachers' perceptions have a bearing on their acceptance (or rejection) of educational technologies, which may affect technology integration in their teaching (Suparjan, 2021; Yazici & Nakıboğlu, 2023).

Fourth, those studies that focused on teachers' VL integration in science education have mainly resolved around pre-service science teachers compared to in-service teachers (Ergül & Binici, 2006; Aşıksoy & Islek, 2017; Ramnarain & Penn, 2021). Specifically, there is limited information regarding the perspectives and encounters of in-service science teachers concerning their use of Virtual Learning (VL) in the teaching process. Hence, this research aimed to contribute valuable insights to the existing knowledge on incorporating VL in science education, focusing on the Life Sciences teachers' perceptions and experiences in rural schools. I now close the chapter in the subsequent section.

2.10 SUMMARY

Guided by the research aim, research questions, and objectives, this literature review began with a summary of the problem statement. Next, the literature on science laboratories and educational technologies in science education was explored. This was followed by a review of studies on VL in science education. Results of the various studies on VL were discussed, but their focus was queried. The lack of focus on teacher perceptions and experiences of VL was noted and thus served as justification for the current study. The next chapter presents the study's theoretical framework.

CHAPTER THREE

THEORETICAL FRAMEWORK

3.1 INTRODUCTION

The preceding chapter (2) provided relevant literature on integrating VLs into science education and presented the theoretical frameworks (TPACK and TAM) to underpin this research. Furthermore, Chapter 2 uncovered some past research gaps, indicating why this research is crucial. The present chapter discusses the theoretical framework that forms the backbone of this research. The chapter also explains the rationale for selecting the specific theoretical frameworks while acknowledging their limitations. It is crucial to underscore that the primary object of a theoretical framework is to provide a solid grounding for research, guiding the formulation of questions, study design, and the research methodology (Ravitch et al., 2016). Furthermore, Varpio et al. (2020a) posit that a theoretical framework facilitates meaningful discussions among researchers and contextualises micro-level studies within a broader perspective.

Drawing upon Osanloo and Grant's (2016) perspectives, it becomes evident that researchers can draw upon one or more suitable theoretical frameworks that align with their study. This strategic selection of multiple theoretical frameworks empowers researchers to construct a robust foundation for their investigations and potentially gain multi-dimensional insights into the phenomena under scrutiny. Similarly, Koehler and Mishra (2006) argue that no single framework can fully address all the complexities and variations within a domain as intricate as technology integration in teaching. This perspective underscores the invaluable richness that can be gleaned from embracing multiple theoretical frameworks in the pursuit of knowledge.

Moreover, when it comes to employing multiple theories in research, James (1890), in his seminal work in psychology and philosophy, employs a compelling metaphor involving fishing nets. He argues that just as casting more nets increases the chances of a more abundant catch, similarly, employing multiple theories enhances the ability to grasp the intricacies of reality. He eloquently states: "Theories are nets cast to catch what we call reality. We must cast many nets, and pull them in many different ways, for each reveals something" (James, 1890:8). In the same spirit, Bagozzi (2007:244)

teases that it is “unreasonable to expect that one simple model could explain decisions, behaviours, and experiences across a wide range of technologies, adoption situations, and differences in decision making.” Consistent with these theorists, I drew on two theories: TPACK (Koehler & Mishra, 2006) and TAM (Davis, 1989). I now discuss each of the frameworks below.

3.2 THE TECHNOLOGY ACCEPTANCE MODEL (TAM)

When integrating a novel technology tool (in this case, VL) into the teaching-learning spaces, several factors influencing its acceptance inevitably arise. These factors may include resistance to its use and user perceptions and attitudes. According to Carver (2016), 60% to 70% of all technology-related initiatives collapse, not because of technical challenges but because of the absence of technology acceptance. Likewise, Davis (1989) points out that issues of technology acceptance, such as perceptions, are influential in whether new technologies succeed or fail. Davis (1989) and Carver (2016), therefore, underscore the importance of looking at matters of user technology acceptance before considering actual technology use. Over the years, many technology acceptance models have been developed. These comprise Ajzen’s (1985) Theory of Planned Behaviour, Taylor and Todd’s (1995) Decomposed Theory of Planned Behaviour, Rogers’ (1995) Theory of Diffusion of Innovations, and Fishbein and Ajzen’s (1975) Theory of Reasoned Action. Out of all these frameworks, the TAM (Davis, 1989) has emerged as one of the most dominant models, which deals with perceptions that determine technology integration.

In psychology research, Davis developed the TAM in 1989 from the TRA (Ajzen & Fishbein, 1975). According to Davis (1989:23), “TAM deals with feelings, attitudes, perceptions, beliefs, and behaviours related to technology acceptance.” At the same time, Kriek and Stols (2010:13) claim that “TAM currently enjoys the status of being the prime tool for examining user acceptance of new technologies.” Siegel et al. (2017:15) observe that “TAM is grounded on the principle that when users are introduced to new technology, various factors play a role in determining their choices regarding whether, how, and when they will use it.” Further, according to TAM, an individual’s intent to integrate technologies depends on his/her perceptions of the technologies. The TAM claims that perceptions, that is, “Perceived Ease of Use (PEOU) and Perceived Usefulness (PU), are the two essential determinants of user

acceptance of technology" (Davis, 1989:123). The PEOU refers to "the extent to which an individual believes that using a specific technology would be effortless or require minimal effort" (Davis 1989:231). The PU refers to "the degree to which a person believes that using a particular technology will improve his or her work performance" (Davis, 1989:230). Thus, TAM theorises that PEOU influences PU; that is, if Life Sciences teachers in rural secondary schools find an educational technology (VL) "easy to use," they are likely to perceive it as being "useful." The TAM presents the contributing inter-relationships of these two elementary constructs (PU and PEOU) together with three other constructs: "attitude toward using (ATT)," "behavioural intention to use (BI)," and "actual use (AU)." Therefore, Life Sciences teachers' positive attitudes and perceptions of VL could result in an intention to utilise the technologies (Figure 2).

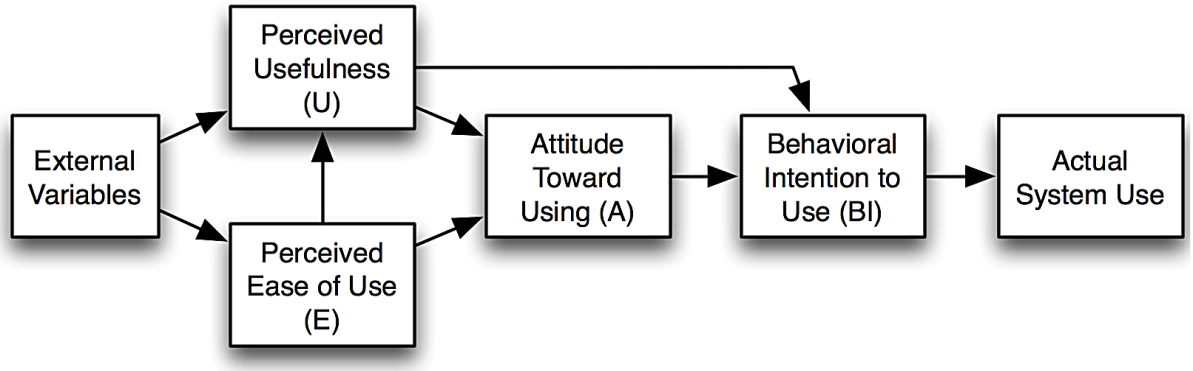

Figure 2: TAM (Davies et al., 1989:23)

3.2.1 Justification for the Adoption of TAM

I adopted TAM in this research based on the following considerations: TAM is dominant and robust for examining user perceptions towards new technologies (Siegel et al., 2017), and TAM identifies external factors related to technology acceptance (Casey et al., 2021). Firstly, because the TAM deals with teacher perceptions, feelings, and attitudes, I deemed it appropriate as this study deals with Life Sciences teachers' perceptions of adopting VL in teaching. Secondly, the TAM allows for the flexibility to consider external variables (barriers and enablers) and examines the influence on technology integration (Casey et al., 2021). Davis (1989) explains that external variables in the TAM framework can include institutional policies, school management teams' (SMTs') support, infrastructure, and technology access, adding that internal

factors encompass skills, abilities, perceptions, and attitudes. Meanwhile, the present study's objective was to gain insights into teacher perceptions and experiences of teaching by using the VL. Thus, I expected that TAM would enable me to consider all the variables, such as skills, prior experience, and factors, such as availability of technology infrastructure and school technology policies. In adopting TAM, I was also aware that TAM was "modified to TAM-2 and TAM-3 to account for other factors such as social and cognitive aspects of user acceptance" (Bagozi, 2007:187-188). However, I adopted the original TAM to foreground this study. This was because this study focused on the two perceptions (PEOU and PU) that the TAM adequately provides for.

3.2.2 Limitations of TAM

Bagozi (2007:244) recognises TAM as a valuable model that describes user perceptions of technology. Nonetheless, he finds it "unreasonable to expect that one simple model could explain decisions and behaviours across a wide range of technologies, adoption situations and differences in decision-making" (Bagozi, 2007:244). He adds that TAM "can sometimes lead researchers to overlook its apparent simplicity, as it may not encompass all crucial decision-making factors, and researchers may inadvertently disregard its inherent limitations." (Bagozi, 2007:244). This, in part, is because TAM is silent about what transpires in the classroom when technology is utilised and why it occurs. The TAM critics observe that empirical studies using TAM reveal that the findings are inconsistent or unclear (Casey et al., 2021). Similarly, Teo and Zhou (2017:45) also observed that "significant factors such as teacher knowledge of technology are not included in TAM." Since this study also aimed to examine teacher knowledge of technology to leverage VL, I adopted the TPACK framework, which articulates the teacher knowledge and contextual factors to complement the TAM. Below, I provide a comprehensive discourse regarding the TPACK framework.

3.3 TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) FRAMEWORK

The TPACK model, which Koehler and Mishra introduced in 2006, serves as a comprehensive framework for defining teachers' essential knowledge to integrate technology into their teaching proficiently. TPACK draws upon the seminal work of

Shulman (1986), who initially proposed the notion of a point of convergence between pedagogical knowledge and content knowledge (PCK). By exploring the convergence of three distinct domains of teacher knowledge - pedagogy, content, and technology - the TPACK model offers a valuable lens to comprehend the intricate dynamics of technology integration in teaching. Scholars, notably Mishra (2019) and Leahy and Mishra (2023), emphasise the significance of the TPACK framework in shedding light on how the incorporation of technology influences the complex interplay between content expertise, pedagogical strategies, and the effective utilisation of technological tools in the classroom. In this regard, Mishra (2019:13) contends that TPACK directs attention towards that:

> New technological resources reshape pedagogical knowledge, content knowledge, and pedagogical content knowledge. Furthermore, effective teaching with technology is context-dependent, and it necessitates a profound understanding of how technology interacts with pedagogy and content.

From this understanding, Koehler and Mishra (2006) characterise TPACK as the intricate relationships and interconnectedness of the three fundamental components of teacher knowledge: content knowledge (what to teach), pedagogical knowledge (how to teach), and technological knowledge (how to incorporate technology into teaching). Accordingly, Koehler and Mishra (2005:87) point out that:

> Good teaching is not simply adding technology to the existing teaching and content domain. Instead, the introduction of technology causes the representation of new concepts. It requires developing a sensitivity to the dynamic, transactional relationship between all three components suggested by the TP[A]CK framework.

Moreover, Mishra et al. (2022:2198) add that the TPACK framework (see Figure 3) “involves asking how technology can enhance and broaden effective teaching and learning within a particular discipline. This process also entails adapting to the changes in content and pedagogy that technology inherently introduces.”

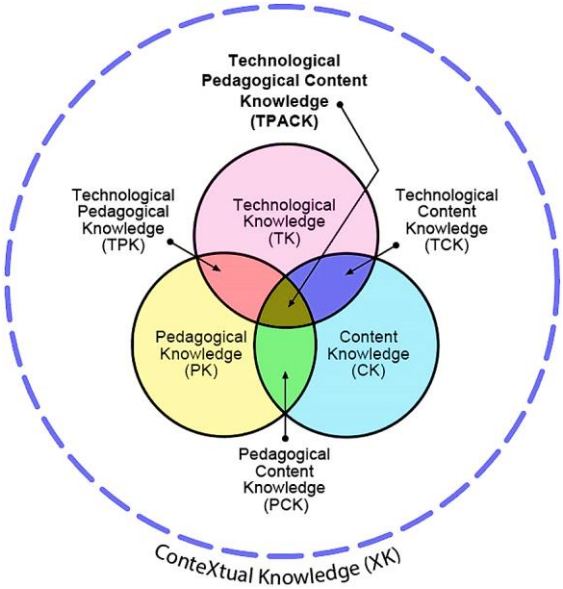

Figure 3: Updated TPACK diagram (Mishra, 2019:2)

The resulting TPACK knowledge constructs are shown in Table 2 below.

Table 2. The eight TPACK framework constructs (Mishra, 2019:9)

The Construct	Abbreviation	Definition
Contextual Knowledge	XK	Knowledge of the context
Content Knowledge	CK	Knowledge of subject content
Technological Knowledge	TK	Knowledge of numerous technologies
Pedagogical Knowledge	PK	Knowledge of teaching approaches
Technological Content Knowledge	TCK	Knowledge of teaching content using technology
Technological Pedagogical Knowledge	TPK	Knowledge of integrating technology to carry out various teaching strategies
Pedagogical Content Knowledge	PCK	Knowledge of teaching approaches for varying kinds of content
Technological Pedagogical Content Knowledge	TPACK	Knowledge of technology application in implementing teaching approaches in different subject content

The TPACK framework illustrates the intricacies and interconnected nature of the three essential knowledge domains: technology, pedagogy, and content (Koehler &

Mishra, 2005). This model emphasises that effective teaching with technology requires a deep understanding of how these domains interact and influence one another. Therefore, TPACK emphasises that the effective integration of technology into teaching necessitates a balanced and synergistic combination of its knowledge components. In the paragraphs that follow, I discuss the TPACK knowledge domains.

3.3.1 Contextual Knowledge (XK)

The XK is the teacher's knowledge of the context. Mishra (2019), one of the proponents of TPACK, recently revised TPACK by adding another knowledge domain (Contextual Knowledge – XK) to the seven traditionally known domains (TK, CK, PK, TCK, TPK, PCK & TPACK). Contextual XK includes all factors, from teachers' mindfulness of existing technology tools to knowing how their institution operates and how power dynamics and school politics can influence their teaching with technology (Mishra, 2019; Warr & Mishra, 2023). In addition, XK would include knowing the school, circuit, cluster, or provincial policies that guide technology integration in teaching. For this research, XK pertains to an understanding of the rural setting. Specifically, secondary schools in rural areas are typically situated far from urban centres and tend to have limited development. As a result, these schools face more formidable and distinct challenges than their counterparts in more affluent urban communities. These challenges encompass a dearth of essential infrastructures, such as classrooms, libraries, and science laboratories, along with inadequate service delivery that hampers effective science teaching and learning in rural secondary classrooms.

Another aspect included in XK is the awareness among science teachers that the rural secondary schooling context is influenced by unique factors, such as a significant outflow of young people to urban areas, leaving mainly elderly populations behind (Muktiar & Sharma, 2019). This situation further exacerbates high levels of adult illiteracy in rural areas, leading to reduced parental involvement in their children's schooling (Bouchard & Wike, 2022). Hlalele and Mosia (2020) underscore that many teachers in rural secondary schools encounter challenges related to limited parental involvement and collaboration. Additionally, most teachers in rural secondary schools contend with many single-parent households, where the household head typically possesses a limited educational background (Assey & Babyegeya, 2022). The

cumulative effect of these challenges is a complex and impoverished rural secondary teaching context, such as the one in the present research, which adversely impacts science teaching quality in these areas. Hence, the recent addition of XK on the TPACK diagram (Figure 3) shows that the effectiveness of Life Sciences teachers' technology integration in rural secondary schools relies very much on their knowledge of the context (XK) within which they teach.

3.3.2 Content Knowledge (CK)

CK is the knowledge of the subject content (Koehler & Mishra, 2009:63), which comprises theories, facts, ideas, concepts, and the structure of a subject field, including knowledge of proofs, evidence, and recognised methods of such knowledge development. Different subject fields are different in their knowledge or content types. For instance, the type of science content differs from the arts content. In addition, content in many fields is also different depending on the grades. While CK in secondary school science may include knowledge of evidence-based inquiry and scientific concepts, primary school art may incorporate knowledge of well-known paintings and art principles. In this regard, Koehler and Mishra (2006:64) explain that:

> CK is essential for teachers, and they must possess a solid foundation of subject-matter knowledge to prevent students from receiving inaccurate information and forming misconceptions about the subject matter.

Shulman (1986) agrees that teachers, including Life Sciences teachers in rural secondary schools, should possess authentic (and extensive) CK. This would enable the teachers to present Life Sciences concepts in more accessible ways, including why it is essential to know them and how they connect to other content areas.

3.3.3 Pedagogical Knowledge (PK)

PK is the teacher's sound knowledge of appropriate teaching approaches (Koehler & Mishra, 2008). This knowledge incorporates knowing general educational aims, standards, lesson planning, assessment, and class management. In addition, it also incorporates an understanding of different learning styles and theories (Koehler & Mishra, 2009; Koh & Chai, 2011). Thus, Life Sciences teachers require pedagogical

knowledge to comprehend how to effectively utilise their skills and knowledge for classroom delivery to make Life Sciences content easily understandable to learners.

3.3.4 Technological Knowledge (TK)

The nature of TK is not easily defined because of the rapidly changing nature of technologies. As technologies constantly change, new ones emerge. Thus, various TK definitions have emerged in the existing literature concerning the type of technologies involved in teaching science (Niess & Gillow-Wiles, 2017). For example, Koehler and Mishra (2006:1027) view TK as "knowledge about standard technologies such as books, chalk- and blackboard, and more advanced technologies such as the internet and digital video. This knowledge involves skills [that are] required to operate particular technologies" (Koehler & Mishra, 2006:1027). In this definition, TK entails knowing various kinds of technology tools. This understanding has been accepted by numerous researchers (Cox & Graham, 2009; Koh & Chai, 2011; Hamam & Hysaj, 2021). Warr and Mishra (2023) highlight that the nature of TK is temporal and should be viewed as an evolving knowledge type because technology is constantly evolving.

Consequently, Koehler and Mishra (2009:64) revised their TK definition as a "developed technology literacy where an individual can broadly apply technology productively to his or her everyday life and recognise where technology can assist or impede achieving of a goal." Some scholars identified TK as knowing how to use digital technologies only (Li, 2007; Choi & Paik, 2021). Some researchers view TK as knowledge of all digital technologies (Niess, 2011), and some see it as knowledge of specific technologies (Chai et al., 2010; Violanti, 2023). Nonetheless, despite the technology types, Koehler and Mishra (2006) maintain that teachers must be able to learn and acclimatise to novel technologies. Therefore, the choice of technologies and when to use them during teaching must be made by each Life Sciences teacher in rural secondary schools. If the Life Sciences teachers use technology, there is a chance for comprehensive TK. For instance, a resourceful secondary school Life Sciences teacher in a rural area with access to new technologies such as VL would be capable of learning the necessary skills to use the new technology independently. Therefore, TK gives Life Sciences teachers in rural secondary schools a chance to leverage VL in teaching, enhance their TK, and transition to competent and self-sufficient teachers.

3.3.5 Pedagogical Content Knowledge (PCK)

PCK is formed when CK and PK intersect to enable teachers to teach a particular subject effectively. PCK, thus, becomes the knowledge of how to represent the subject content (Koehler & Mishra, 2009). This idea of PCK is related to Shulman's (1987) theory of knowing how to blend content and pedagogy. According to Jang and Tsai (2013:13), "PCK is knowledge about what teaching approaches fit the content and how elements of the content can be arranged for better teaching." PCK entails understanding learners' existing knowledge and epistemology and how the content resonates with learners' knowledge and experiences. In addition, Koehler and Mishra (2005) point out that PCK incorporates predicting what challenges and questions teachers are likely to face and knowing what causes specific subject content to be interpreted as easy to grasp or challenging.

Moreover, teachers possessing PCK are conscious of generic misconceptions, including how to tackle some contradictions (Koehler & Mishra, 2009; Baturay, Gökçearslan & Sahin, 2017; Njiku, 2022). From this viewpoint, Koehler and Mishra (2007:1027) explain that:

> PCK includes understanding teaching approaches that integrate suitable conceptual representations to address learner misconceptions and difficulties effectively, ultimately promoting meaningful and effective comprehension.

Also, PCK enables Life Sciences teachers in rural secondary schools to recognise that different subject concepts require different teaching strategies. For example, allowing learners to watch a VL simulation repeatedly at their own pace and schedule can effectively reinforce previously taught material. This approach takes advantage of the benefits of repetition, which is a critical factor in the learning process.

3.3.6 Technological Content Knowledge (TCK)

The TCK refers to the knowledge domain formed when TK and CK intersect. Thus, TCK is the knowledge of technology tools used to research, create, and represent subject content. Hence, TCK focuses more on learning than teaching; that is, the knowledge of technologies is utilised to learn and address the particular subject

content. For instance, TCK can be the knowledge of using VL technologies to experience phenomena at places that are impossible or too dangerous to physically observe, for example, the deep sea or volcanic processes of complex real-world problems (Budai & Kuczmann, 2018). According to Koehler and Mishra (2007:87), TCK is knowing "the manner in which technology and content influence and constrain one another." Thus, Life Sciences teachers in rural secondary schools must recognise the "manner in which the application of technology can change the subject matter" (Koehler & Mishra, 2006:65) and how technology can be used in CK sense-making. Additionally, rural Life Sciences teachers need expertise in their subject and practical experience with diverse VL applications to effectively impart that knowledge to their learners.

3.3.7 Technological Pedagogical Knowledge (TPK)

When TK and PK intersect, TPK is formed to represent "an understanding of how teaching and learning can change when particular technologies are used in particular ways" (Koehler & Mishra, 2006:74). Similarly, Cox (2008:76) views TPK as:

> [A]n understanding of the affordances and constraints of various technologies for teaching and learning, as well as how these technologies can be used to support teacher pedagogical strategies and student learning outcomes.

Therefore, TPK involves understanding how specific technologies support general teaching approaches without focusing on specific content. Therefore, Life Sciences teachers in rural secondary schools need to be open-minded, creative, and flexible in searching for types of technology to enhance learners' understanding of the content. Accordingly, TPK is particularly crucial as many new technology tools are not designed for teaching and learning (Squire, 2003; Du Plessis & Webb, 2012; Zeichner, 2021). Thus, Life Sciences teachers in rural secondary schools must "look beyond the immediate technology and 'reconfigure' it for their pedagogical purposes" (Koehler & Mishra, 2006:17). In such cases, TPK would allow teachers to re-purpose technologies for teaching-learning purposes. This understanding suggests that competent Life Sciences teachers in rural schools should be able to assess and determine the advantages of incorporating VL into their teaching methods. They should be capable

of making informed decisions about when and how to use VL experiments to teach specific areas of Life Sciences, as well as selecting the most appropriate VL experiments that align with their lesson objectives and the needs of their learners.

3.3.8 Technological Pedagogical Content Knowledge (TPACK)

All the elements of knowledge come together here (as explained above). When teachers use appropriate pedagogical strategies and educational technologies, a comprehension of content representation emerges. Koehler and Mishra (2005, 2009) emphasise that the TPACK domain differs from all the other three domains (CK, PK, and TK). As a result, TPACK is described as:

> [U]nderstanding technological concepts is necessary when using technologies, which is the foundation of effective technology-based teaching. This encompasses pedagogical techniques that employ technology constructively to convey content, understanding what factors make certain concepts challenging or accessible for learning, recognizing how technology can mitigate some of the challenges students encounter, awareness of students' prior knowledge and epistemological theories, and understanding how technology can be leveraged to build upon existing knowledge and cultivate new epistemological perspectives or reinforce existing ones (Koehler & Mishra, 2006:66).

Furthermore, existing literature posits that TPACK is a dynamic and evolving form of knowledge subject to contextual influences and individual variations among teachers (Koehler & Mishra, 2007; Gentles & Haynes-Brown, 2021). Similarly, Cox and Graham (2009:47) emphasise that:

> [T]he effect of different contexts is that the nature of technological pedagogical and content knowledge is situated, unique, idiosyncratic, adaptive, temporary, and specific and distinct for each teacher within each specific situation.

As a result, possessing a well-developed TPACK would be crucial for Life Sciences teachers in rural schools to effectively appropriate VL resources for pedagogical

purposes in any given scenario. In the subsequent section, I elaborate on why I adopted the TPACK framework in the current study.

3.4 JUSTIFICATION FOR THE ADOPTION OF TPACK IN THIS RESEARCH

In this section, I present a justification for adopting the TPACK framework in the current study. This study's objectives align with the rationale for adopting TPACK in this research because it primarily sought to gain insights into the science teachers' perceptions of the VL. Various technology acceptance models have often framed such research by focusing on teacher perceptions. However, as Teo and Zhou (2017) note, most technology acceptance models have not adequately articulated the forms of professional knowledge Life Sciences teachers require to meaningfully appropriate technology into their lessons. These kinds of professional knowledge are articulated in the TPACK framework. Hence, I considered that teacher-knowledge-related factors be examined in the present study as they might also influence teacher perceptions of VL. Accordingly, TPACK principles were incorporated with the TAM principles as teacher knowledge components.

Moreover, I adopted the TPACK framework because it aligned with the present study's objectives, including its potential to offer lenses required to address the research objectives. According to Picciano (2017), teacher perceptions of educational technologies are not context-neutral. Since the TPACK framework was designed to consider all the contextual factors, I adopted it in this investigation. Although the TPACK framework is broadly perceived as a leading framework for technology research in teaching, some shortcomings of the framework have been reported that might compromise this study. For example, Koehler and Mishra (2009:24) concede that the "TPACK framework is too neutral on the broad teaching objectives, does not specify what needs to be covered and how it should be taught." In this regard, I acknowledged that, as Koehler and Mishra (2006) note, there is no prescribed technology integration method into the classroom and that the process of integrating technology in teaching is complicated. Thus, Life Sciences teachers must understand this complexity in their quest for effective VL integration into science teaching in rural schools. The next section justifies why I combined TAM and TPACK principles in this study.

3.5 COMBINING TAM AND TPACK PRINCIPLES

Researchers have recently reported that combining TAM and TPACK principles can provide a more holistic understanding of teachers' integration of technologies in their practice. This combined approach is perceived as helpful in unpacking the various factors influencing technology integration and the interplay between teachers' technology acceptance and their expertise to leverage technologies in teaching. For example, Scherer et al. (2019), in their meta-analysis of 115 empirical investigations on technology integration encompassing over 34000 teachers, found that TAM was the most dominant theoretical framework in all 115 studies. The meta-analysis shows that teacher perceptions were the key determinants for teachers' technology integration. However, the meta-analysis also highlights significant limitations in existing research that solely rely on the TAM framework. While TAM has been valuable in understanding technology acceptance, it may not fully capture the complexities and nuances of teachers' integration of technologies in educational settings. The exclusive use of TAM may overlook crucial factors related to pedagogy, content knowledge, and the contextual intricacies that influence successful technology integration in teaching (Scherer et al., 2019). Consequently, Scherer et al. (2019) argue that the TAM framework provides an incomplete and limited perspective on understanding how teachers effectively integrate technology into the classrooms. Hence, I assert that combining TPACK and TAM could yield more comprehensive insights into Life Sciences teachers' perceptions of the VL. I now summarise this chapter (3) below.

3.6 SUMMARY

Chapter three presented the theoretical frameworks underpinning this study. These involved TPACK (Koehler & Mishra, 2006) and TAM (Davis, 1989). After that, a justification for adopting each theoretical framework and how the two frameworks complement each other in the present research was explained. The next chapter (4) presents the present study's methodology, including the design, population, sampling methods, data collection, and data analysis.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 INTRODUCTION

The forgoing chapter (3) presented the theoretical frameworks (TPACK and TAM) that underpin the present research. The present chapter discusses the methodology applied in this study. Hirose and Creswell (2022:53) explain methodology as “a broad term that refers to the research methods, designs, approaches, and procedures employed in an investigation that is well-planned to address a research problem.” Specifically, the present chapter elucidates the research paradigm, approach, design, population and sampling techniques, tools, data collection and analysis procedures. Further, applicable principles such as research validity and reliability and the related aspects of triangulation and pilot studies are covered. An account of how I addressed ethical considerations folds the chapter. Below, I discuss the paradigmatic disposition within which I located this research.

4.2 RESEARCH PARADIGM

According to Ryan (2018), a paradigm is a set of shared beliefs, values, and assumptions about the nature of reality and the methods for studying it. In the social sciences, different paradigms lead to different ways of understanding and explaining social phenomena. The essential components of a paradigm are ontology, epistemology, methodology, and axiology, which communicate its fundamental assumptions, norms, and values (Kivunja & Kuyini, 2017). Cast in the research context, a paradigm represents the researcher’s shared system of beliefs, standpoints, or a cognitive framework that shapes the understanding and interpretation of research data (Pandey & Pandey, 2021). Consequently, a paradigm guides individuals to pose specific questions and employ suitable methodologies for systematic investigations. Four paradigms are evident in existent literature: interpretivist, critical, positivist (Ryan,2018), and pragmatic (Teddlie and Tashakkori, 2011).

This research was underpinned by the pragmatic paradigm whose roots are traceable to James’ (1907) and Dewey’s (1917, 1923) work, which subsequent writers such as Rescher (2017) and Kivunja & Kuyini (2017) extended upon. Kivunja and Kuyini

(2017), for example, advocate for “a worldview that offers research methods considered most suitable for investigating the particular phenomenon under consideration.” (2017:35). As such, the pragmatic paradigm is grounded in constructivist knowledge, intervention, and action (Goldkuhl, 2012). In advancing the pragmatic paradigm, research approaches are made pluralistic and practical, permitting a blend of procedures that, when employed together, would afford an understanding of participants’ behaviour, the thinking underlying such actions, and the possible consequences (Alise & Teddlie, 2010; Kivunja & Kuyini, 2017). In sum, Teddlie and Tashakkori (2012:187) articulate as follows:

> The pragmatic paradigm promotes a relational epistemology, where research relationships are determined by what the researcher finds suitable for the specific study. The pragmatic paradigm acknowledges a non-singular reality ontology, recognising that there is no single objective reality and that reality is constructed by individuals and groups through their interactions. It employs a mixed methods methodology, combining quantitative and qualitative research methods for a holistic understanding of the research problem. Additionally, it emphasises a value-laden axiology committed to conducting research that benefits people.

Since the kind of questions that I asked in this research are neither exclusively qualitative nor quantitative, I chose the pragmatic paradigm. This paradigm capitalises on research approaches and designs best suited to answer my research questions without contemplating whether the questions are solely qualitative or quantitative. In addition, “the pragmatic paradigm emphasises the workability of research; that is, the adoption of what works to allow the researcher to address the questions being investigated” (Kivunja & Kuyini, 2017:37). Moreover, as Alise and Teddlie (2010:18) suggest, the pragmatic paradigm “allows for a combination of methods that can provide a better understanding of the actual behaviour of the participants in their contexts.” This aligns the pragmatic paradigm to the theoretical frameworks that I chose, TAM and TPACK, which all recognise the participants’ perceptions, experiences, and the rural school contexts as connected aspects of the inquiry. In the subsequent section, I outline the key characteristics and principles of the research approach and demonstrate how it aligns with the research objectives and the kinds of

data to be collected. Additionally, I discuss the advantages of using this particular research approach and how it contributes to the overall study's validity and reliability.

4.3 RESEARCH APPROACH

I drew on the mixed-methods approach, which "employs both quantitative and qualitative methods to gather, analyse, and integrate both quantitative and qualitative data into a study to address the research questions" (Harrison, Reilly & Creswell, 2020:457). Mohajan (2020) points out that quantitative research investigates variances between quantifiable measurements. In contrast, qualitative research explores participants' experiences or behaviours. Combining quantitative and qualitative research approaches is not unusual; it is becoming a trend in humanities research (Patton, 2005; Mayoh & Onwuegbuzie, 2015; Silverman, 2020). In choosing the mixed methods approach, I adhered to Hirose and Creswell's (2022) guidance by considering the research aim, objectives, research questions, theoretical lens, kinds of data to collect, and the timing (sequential or parallel). In this study, I used what Hitchcock and Onwuegbuzie (2020:74) call "quantitative dominant mixed methods, which involves including qualitative data and approaches into otherwise quantitative research." This research adopts a qualitative case study approach, chosen for its ability to offer a thorough grasp of the study's rural schooling context (Hirose & Creswell, 2022), which would allow "for collecting different but complementary data to answer research questions on the same topic" (Flick, 2018:122).

Roni et al. (2020:229) define quantitative research as "explaining phenomena by collecting numerical data that are analysed using mathematically based methods, particularly statistics." Likewise, Bloomfield and Fisher (2019) highlight that quantitative research concentrates on analysing and generalising arithmetic data to a larger sample or explaining a specific phenomenon. These two definitions emphasise numerical data as being the focus of quantitative research. In this research study, I collected quantitative data on science teachers' perceptions and experiences of VL using a closed-ended Likert scale-type questionnaire to garner and analyse responses that would help answer the main research question. Pandey and Pandey (2021) suggest that quantitative research is most useful in working with data that cannot ordinarily be measurable (e.g., perceptions). This can be achieved by designing an instrument, such as the Likert scale, that converts specific data into an arithmetical

format which can be statistically analysed. To achieve this, I used objective quantitative instruments (Likert scales) to maintain a non-biased stance in the research and promote the results' trustworthiness (Sürücü & Maslakci, 2020). In addition, the quantitative method also afforded me breadth in terms of working with many (n = 186) participants from a vast province such as the EC, in addition to applying "prescribed procedures to ensure replicability, reliability, and validity" (Flick, 2018:32).

While quantitative research permitted me expansiveness in research, it is "shallow when one wants to examine a problem in-depth" (Dawadi et al., 2021:33). Moreover, when determining the meanings and explanations of perceptions and experiences of VL in rural schools, it becomes challenging to use quantitative research; hence, Aspers and Corte (2019) suggest that qualitative techniques are more useful in such cases. Accordingly, I opted to mix quantitative and qualitative methods to produce research characterised by the breadth and depth of rural Life Sciences teachers' perceptions and experiences of VL.

Furthermore, as noted by Rose and Johnson (2020:27), by integrating quantitative and qualitative approaches, I aspired to "combine the strengths of the quantitative data (e.g., reaching a large sample size) with those of qualitative data (e.g., incisive analysis)." This approach allowed me to examine the research questions in context by drawing from various research instruments, that is, data triangulation. In addition, my choice of using mixed methods was informed by my consideration of the main objective of this research, which was examining teachers' perceptions and experiences. In addition to the primary research question, my secondary questions were, in words similar to those used by Hamilton and Finley (2020:324), albeit in another context, "best answered by qualitative methods." The qualitative method permits a researcher to "discover the meanings that participants attach to their behaviour, how they interpret situations, and their perceptions and experiences on particular issues" (Rose & Johnson, 2020:44). Therefore, by also adopting the qualitative approach, I focused on "making thick in-depth descriptions, and understanding perceptions and experiences in terms of the rural secondary teaching context, rather than an attempt at generalisation to some theoretical population" (Carminati, 2018:2099). This aligns with this study's theoretical frameworks (TAM & TPACK) while emphasising the significance of context in research on educational

technology. While the mixed-method approach seemed advantageous for conducting this study, I was also aware of its disadvantages. For instance, it can “produce large volumes of data to be analysed, which can overwhelm the researcher if not managed well” (Cohen et al., 2017:347). Moreover, the collected data may be subjective and vulnerable to researcher and participant bias. Despite this criticism, I considered that the benefits of incorporating qualitative research into this study far outweighed its shortcomings.

When considering the three major qualitative research methods - life histories, ethnography, and case study - the case study approach was most appropriate for the present research in contrast to the other major qualitative research approaches. I adopted the case study method to engage in an incisive examination of the context regarding rural and under-resourced schools targeted by this study. In other words, the case study method enabled “focus on a specific context or individuals, primarily gathering data through qualitative methods, where researchers aim to comprehend and interpret case studies by providing a comprehensive description of the context.” (Hamilton & Finley, 2020:116). This approach aligns with the study’s theoretical frameworks, which emphasise the understanding of the teachers’ contexts in terms of their perceptions and experiences regarding *the integration of a VL for rural teaching*. Accordingly, there was a need for “examining events, actions, and norms from the viewpoints of the individuals under investigation” (Khatri, 2020:1439). However, in selecting the case study approach, I was aware of its shortcomings, one of which was that their “findings cannot be generalised to other contexts” (Englander, 2019:45). The current study was conducted in one rural district in a province in SA. However, this study did not seek to generalise its findings but to offer results that could be valuable to future researchers and readers in similar contexts.

4.4 RESEARCH DESIGN

Informed by existent literature, research design refers to “a set of advance decisions that make up the master plan specifying the procedures for collecting and analysing the needed information” (Headley and Clark (2020:157). Matović and Ovesni (2023) suggest that a suitable research design is vital to ascertain the data kinds, data gathering methods, and sampling techniques. There are diverse kinds of mixed-methods designs documented in the literature. Teddlie and Tashakkori (2012) indicate

nearly 40 distinct kinds of mixed-method designs. However, Creswell et al. (2011) identify the following main types: embedded, sequential exploratory, sequential explanatory, and triangulation design. I chose the sequential explanatory mixed-methods approach, also referred to as “the two-phase model” (Clark, 2019:134), out of some 40 possible mixed-methods designs. By utilising the quantitative data gathered from the survey in Phase 1, I formulated insightful probing questions during the interviews conducted in Phase 2. These questions were tailored to unpack the specific perceptions and experiences of VLs among Life Sciences teachers based on the responses obtained in the initial survey. The reasoning behind adopting this approach lies in the fact that quantitative data and findings offer a broad overview of the research issue. Further analysis, particularly through qualitative data collection, becomes necessary to fine-tune, expand upon, or elucidate the broader perspective (Creswell, 2014). Hence, the sequential explanatory design allows an in-depth investigation of the explored topic (Ponce & Pagan-Maldonado, 2014).

Thus, I conducted this research sequentially in two phases (Creswell, 2014; Harrison, Reilly & Creswell, 2020). Phase 1 focused on quantitative data gathering and analysis. I collected the data using the questionnaire to solicit responses to address the key research question on the Life Sciences teachers’ perceptions and experiences on integrating VL for rural teaching. Phase 2 focused on qualitative data gathering and analysis, which I did after finalising Phase 1. In Phase 2, I utilised semi-structured interviews to support or verify data collected from Phase 1. Thereafter, the sub-questions were answered by combining quantitative and qualitative data. The findings were then combined to analyse the Life Sciences teachers’ perceptions and experiences of utilising VL in the classroom. The rationale for choosing the sequential explanatory mixed methods design was that it clearly distinguished this study’s qualitative and quantitative phases. This benefited me as the researcher, as I avoided the arduous integration of two different data types. According to Harrison, Reilly and Creswell (2020:43):

> This design offers the significant advantage of harnessing the strengths of both quantitative and qualitative data. It involves obtaining quantitative results from a population during the initial phase and subsequently providing

a deeper understanding and illustration of these findings through an in-depth qualitative investigation in the second phase.

Therefore, the sequential explanatory design blended with the mixed-method objectives to exploit the robustness of both the quantitative and qualitative research. However, when choosing the sequential explanatory design, I was aware of its shortcomings; for example, in the first phase, I had to figure out which parts of the quantitative phase to pursue further, in addition to determining the quality of participants to engage in line with the question types to be asked. This was tedious and exhaustive. Nevertheless, the strengths of the sequential explanatory design outweighed its weaknesses; hence, its adoption in the present study. In the forthcoming section, I delve into an in-depth account of the research population and the various sites included in this investigation.

4.5 RESEARCH POPULATION AND SITES

It is essential that I describe the research population and the sites to facilitate an understanding of the context and breadth of the present research endeavours. Pandey and Pandey (2021:16) identify a research population "as any group of individuals who share at least one or more common traits that may be of interest to the researcher." Similarly, Aspers and Corte (2019:149) delineate a target population as "a category of people with some common defining features that the researcher can identify and study." These two definitions highlight that the target population is the sum of entities or individuals from which data can be drawn. Therefore, the units or persons that comprise a population must meet specific inclusion requirements or characteristics in the research. For this study, the inclusion criteria were restricted to a research population who had to be qualified Life Sciences teachers teaching in rural and under-resourced schools in the Eastern Cape province (Joe Gqabi District) and had to have access to technology tools such as computers at their workplaces. The participants for phases 1 and 2 were drawn from the same population.

The qualitative case study sites included four schools in the Eastern Cape (EC) Province of SA. Aspers and Corte (2021:17) suggest that:

> [A] case study should set boundaries: define specific aspects related to your research questions that can be examined within your time and resource constraints. These aspects should include concrete examples of what you aim to study.

I selected schools (research sites) due to their relevance regarding the study's objectives based on the following criteria: location in a rural area, schools that offered Life Sciences subject, lacked science laboratories, and teachers who had access to technology devices. Although many schools in the district met the criteria for selection, I used convenience sampling (Etikan et al., 2016) based on easy access and proximity to where I work. All four schools are situated in Mount Fletcher (renamed Tlokoeng in March 2022), a rural area in the Joe Gqabi District (Elundini Local Municipality). The school community is predominantly rural, and the people survive on Government social grants and subsistence farming. Because of its rural and traditional nature, chiefs and village headmen govern the region, and many schools are named after these leaders.

Consistent with the village's rurality and under-resourced state, all four schools are classified under quintile one ranking. A quintile one ranking in SA signifies a school that serves children from the bottom 20% of the country's poorest households (DBE, 2013). This ranking is determined by assessing the households' income or expenditure. These households are typically situated in rural and remote areas and face a higher risk of poverty. Consequently, the schools assigned to quintile one are entitled to free or subsidised educational services. Nedungadi et al. (2018) observe that education quality tends to decrease with an increase in rurality and remoteness. In Mount Fletcher, only 16.4% of the population as of 2022 passed matric, and 4.9% had higher education, based on the recent census of 2022 (Statistics South Africa, 2023). Like all schools in the EC Province, the schools in Mount Fletcher have also been provided with educational technologies to enhance the teaching-learning experiences. The provision of these technologies to rural schools reflected the Government's broader efforts to modernise rural education and provide learners and teachers with access to innovative tools and resources. The next section explains the sampling techniques I employed.

4.6 SAMPLING TECHNIQUES

A sample is a subset of events, items, or individuals that mirrors the attributes of the broader group or population from which the sample has been selected (Vasileiou et al., 2018). Blaikie (2018:643) mentions that "a sample can be seen as a limited subset from which the researcher gathers observations and subsequently extrapolates the results to the broader population." Therefore, for a sample to be deemed effective, it must accurately represent the entire group. In this research, the participants were drawn from the pool of Life Sciences teachers within the Joe Gqabi District of Education. I chose the research participants through what Taherdoost (2016:1342) calls "multi-stage purposeful random sampling." This involved choosing the participants in more than one phase, as outlined below.

4.6.1 Participants and the Sampling Procedure: Phase 1

To recruit participants for Phase 1 of this research, I sent an e-mail to all the Life Sciences teachers asking them to respond to the questionnaire. To boost the response rate, I sent an email to remind the participants about the due date before closing the questionnaire "open period." The sample of participants from Phase 1 included all the Life Sciences teachers in the Joe Gqabi District. In phase 1, I used random sampling because after sending the e-mail to recruit teacher participants, I was not involved in selecting who would respond to the call for participation. Participating in the study's Phase 1 depended on who would have chosen to complete the questionnaire in response to the invitation.

4.6.2 Participants and Sampling Procedure: Phase 2

Participants in Phase 2 included four Life Sciences teachers from four different schools. I gave participants a link to indicate whether they would participate in Phase 2 interviews after the Phase 1 survey was finished. In Phase 2, I used convenience and purposive sampling to choose four participants who indicated their willingness to participate. For convenience sampling, "participants who meet specific criteria [such as] geographical proximity, availability, desire to participate, or easy accessibility, are chosen from the target population" (Cohen et al., 2017:354). It was convenient for me to focus on Life Sciences teachers in the Joe Gqabi District as it is an area where I work, and the teacher-participants are acquainted with each other. Moreover, I used purposive sampling, which is "a deliberate choice of a participant due to the qualities

the participant possesses" (Aspers & Corte, 2019:153). I chose purposive because it is "effective in scenarios where the researcher must rapidly access a specific sample within constraints, with less emphasis on proportional representation" (Silverman, 2020:49). Moreover, guided by my research questions and a clear understanding of the areas to explore, I opted for purposive sampling to focus on specific individuals who possess characteristics most likely to offer the best answers to the research questions (Patton, 2002). Accordingly, Sharma (2017) labels purposive sampling as being very selective and judgemental in nature. Typically, the sample selected via purposive sampling should be small (4 to 35), as Pandey and Pandey (2021) recommend. However, Aspers and Corte (2019:154) state:

> Qualitative inquiry does not adhere to specific sample size rules. Instead, the sample size is contingent upon research objectives, the inquiry's purpose, its significance, the credibility of the findings, and what can be realistically accomplished within the available time and resources.

Therefore, I chose a manageable sample size of four (4) participants to facilitate an in-depth dissection of the topic under examination.

Although I adopted convenience and purposive sampling in Phase 2 of this study, this technique is not without flaws. Often, it is prone to the researcher's bias and subjectivity. Generally, the view that a purposive sample originates from the researcher's judgement is seen as defeating the purpose of alleviating possible researcher bias and subjectivities. In addition, due to the non-probability and possible subjectivity manner of selecting units in convenience and purposive sampling, it is impossible to draw a representative sample (Corte, 2019). Nevertheless, despite these shortcomings, I considered the convenience and purposive sampling best suited for this study's Phase 2. Specifically, the sampling procedure for this study relied on the accessibility of both participants and research sites. This study's Phase 2 aimed to gather data to understand various teachers' perceptions and experiences pertinent to the inquiry. The research instruments used in the study are extensively covered in the section that follows.

4.7 RESEARCH INSTRUMENTS

The principal objective of this investigation is to understand and explain "what teachers know, believe and think" (Borg, 2003:74) regarding VL for rural science teaching and investigate their perceptions and experiences of this technology as a pedagogical tool. To achieve its objective, the current study employed a blend of quantitative and qualitative data collection instruments. Harrison et al. (2020:485) point out that "methods can be mixed to enable researchers to leverage the strengths of both approaches (quantitative and qualitative) to enhance transferability and generalisability." Considering this, I chose a questionnaire and an interview protocol to gather quantitative and qualitative data, respectively.

4.7.1 The Questionnaire

Mohajan (2020:68) views a questionnaire as "a series of written questions provided to a chosen group of participants to collect their responses." Patten (2016:228) agrees that a questionnaire is "a set of written questions intended to be answered by various respondents." Questionnaires are primarily distributed to respondents by hand or email and typically consist of structured or unstructured questions. Krosnick (2018:453) explains that "unstructured [questions] prompt respondents to provide responses in their own words, while structured questions require respondents to choose an answer from a predefined set of options." The questionnaire used in the current study comprised two sections with structured questions. The first section focused on collecting respondents' demographic information, such as gender, age, educational background, and teaching experience. The second part utilised the Likert scale and presented questions based on TAM and TPACK principles (as discussed in Chapter 3).

Regarding the Likert scale-type questions, it is commonly assumed that the theoretical intervals between responses for the major Likert scale categories (ranging from "strongly agree" to "strongly disagree") are equal. In this regard, respondents are allowed to express their preferences on a five-point Likert scale, spanning from level 5 (strongly agree) to level 1 (strongly disagree). The decision to use a five-point Likert scale for this research is maintained by Joshi et al. (2015), who emphasise that Likert scales typically adhere to the standard practice of having an odd number of response points on the scale. I also chose the five-point Likert scale as "research affirms that

the accuracy of data derived from Likert items noticeably diminishes when the number of scale points falls below five or exceeds seven" (Josh, 2015:387). Furthermore, Joshi (2015) also supports using the Likert scales as they assist in bringing together the possibility of obtaining flexible and authentic responses driven by the propensity to uncover frequencies, correlations, and other statistical evaluation forms.

Moreover, I included a neutral mid-point for the respondents to be able to indicate their neutrality to a particular statement. The neutral mid-point in a Likert scale represents a state of neither agreement nor disagreement, signifying that respondents are neutral or uncertain about the presented question or statement. Supporting the notion, Krosnick (2018) cautions against using a methodology that forces respondents into a binary choice of agreeing or disagreeing with Likert-scale statements while omitting a neutral option. Essentially, by excluding a neutral option, respondents might feel pressured to choose a side even if they genuinely lack a strong opinion on the matter, potentially leading to biased or inaccurate data. Armstrong (1987:360) agrees that:

> The inclusion of a neutral mid-point option serves the clear purpose of preventing respondents from feeling compelled to express agreement or disagreement when they may not hold a definitive opinion. This not only avoids potential respondent frustration but also safeguards data quality.

Accordingly, using the mid-point becomes pivotal in averting what might be just a random selection of either disagreement or agreement. The present study's questionnaire contained questions that elicited teachers' perceptions and experiences on the topic under examination. This questionnaire is based on the TAM and TPACK questionnaires (adapted from Davis (1989) and Schmidt et al. (2009a)), respectively. To ensure internal coherence and alignment between the theoretical framework and research instruments, the questionnaire comprised questions related to TAM and TPACK. By including these elements in the questionnaire, I sought to establish a consistent and interconnected methodology for gathering relevant data for analysis. In addition, the question items emanated from the primary and secondary research questions. Moreover, to strengthen the study's coherence, the formulation of the survey questions was guided by the research questions (see Section 1.5). This approach ensured that the questionnaire instrument aligned closely with the specific

objectives of the research, contributing to a more cohesive and focused investigation. The questionnaire comprised 77 items (see Appendix C) organised into six sections. Section A provided demographic data where the respondents selected options that described their personal information or contexts, such as age, gender, and teaching experience. Then, section B focussed on the Life Sciences teachers' perceptions (PU, PEOU, and BI) of VL for rural teaching. Sections C and D sought to establish the teachers' experiences of teaching with VL by examining the enabling and constraining factors (FC, SI, and AU) in their use of the technology.

Furthermore, section E focussed on the teacher's knowledge of teaching with VL. These questions were based on six TPACK constructs: TK, PK, CK, PCK, TPK and TPACK. Specifically, the Life Sciences teachers had to respond to questions on PU = 4 items (8-11), PEOU = 4 items (12-15), SI = 5 items (16-20), FC = 4 items (21-24), BI = 4 items (25-28), AU =5 items (29-33), TK= 6 items (34-39), PK= 8 items (46-53), PCK = 5 items (54-58), CK = 6 items (40-45), TPK = 3 items (59-61), and TPACK = 3 items (62-64). Lastly, section F sought to establish the factors influencing teachers' use of VL for rural science teaching = 10 items (65-74). All the questions employed a five-point Likert scale, with the following response assignments:

- 1 - Strongly Disagree
- 2 - Disagree
- 3 - Neutral
- 4 - Agree
- 5 - Strongly Agree

4.7.1.1 Reliability and Validity of the questionnaire instrument

The validation of research measures is fundamental to guaranteeing the goodness of data, i.e., its reliability and validity. Tashakkori and Teddlie (2021) propose that reliability refers to the extent to which research results would remain consistent if the study were replicated using different subjects or conducted at different time points. The reliability of a measure signifies its ability to yield consistent results, free from errors, across various instrument items and time frames (Taherdoost, 2022). This reliability aspect is crucial in assessing the stability and consistency of research outcomes, ensuring the validity and robustness of the study's findings. In the present

study, two questionnaire instruments were amalgamated into one instrument, customised from Schmidt et al.'s (2009) TPACK and Davis's (1989) survey. The TAM and TPACK questionnaires were combined by adapting the items to address Life Sciences teachers' perceptions and experiences of VL for rural teaching. Prior to this study, several researchers had already evaluated the reliability of these instruments using the widely accepted Cronbach's coefficient alpha test of inter-item consistency reliability (Cronbach, 1951; Cliff, 1984; Hajjar, 2018). This test assesses the extent of consistency in participants' responses to all items within a specific measure, providing a measure of its overall reliability.

As discussed earlier, the questionnaire that I used was previously tested for reliability by several researchers. Paulsen and BrckaLorenz (2017:53) assert that "using existing, previously tested measures indicates that the data are reliable and can help increase the likelihood that new data are reliable." I have reviewed numerous studies that validated the TAM-TPACK questionnaire as a recognized, reliable, and valid instrument. Therefore, I considered the questionnaire that I used reliable and valid. The Cronbach's alpha coefficients obtained from the collected data demonstrate high reliability, with values falling within the range of 0.75 to 0.94. This reliability test indicates that the measurement scales I utilised in the present study exhibit robust internal consistency. As a result, the data can be considered trustworthy, and the research findings can be deemed reliable, enhancing the study's overall validity. This is in line with Cohen, Manion and Morrison (2017:638-641), who state as follows:

> Cronbach's alpha is a metric used to assess internal consistency, yielding a reliability coefficient ranging from 0 to 1. The interpretation typically considers scores above 0.90 as very highly reliable, 0.80 - 0.90 as highly reliable, 0.70 - 0.79 as reliable, 0.60 - 0.69 as minimally reliable, and scores below 0.60 as unacceptable.

Thus, with a median alpha of α=0.82, the twelve domain scores' reliability measures demonstrate that the questionnaire is highly reliable, as shown in Table 3 below.

Table 3: Questionnaire reliability statistics

Constructs	No. of variables	Cronbach alpha coefficient	Result
PU	4	0.94	Very highly reliable
PEOU	4	0.90	Very highly reliable
SI	5	0.92	Very highly reliable
FC	4	0.75	Highly reliable
BI	4	0.86	Very highly reliable
AU	5	0.76	Highly reliable
TK	6	0.78	Highly reliable
CK	6	0.82	Very highly reliable
PK	8	0.82	Very highly reliable
PCK	5	0.81	Very highly reliable
TPK	3	0.83	Very highly reliable
TPACK	3	0.75	Highly reliable
Total scale scores	57	0.82	Highly reliable

Table 3 displays that all Cronbach's alpha scales demonstrated high reliability, with values exceeding 0.70, indicating a robust level of consistency. Nonetheless, it is noteworthy that the TCK did not form a distinct domain, consistent with prior research showing that teachers may have difficulty conceptualising TCK as a discrete knowledge domain (see Section 2). Moreover, the reviewed literature suggested that more literature is available on teachers' TPK than on their TCK. Furthermore, the literature indicated that TCK could be conceptualised better when merged into TPACK, hence the decision to exclude TCK as a distinct domain.

Notably, as Aspers and Corte (2019) highlight, no data collection instrument, including questionnaires, is flawless. In adopting a questionnaire, I was aware of its limitations. First, with a questionnaire, it is most probable that respondents may misunderstand or misinterpret some of the questions. I was alive in the present study to the fact that some questions in the questionnaire might be unclear, leading some respondents to provide inappropriate answers, while others might opt not to respond to certain

questions. However, since all the respondents in this study were teachers who can be considered educated and knowledgeable, I deemed the questionnaires appropriate for use despite potential ambiguities. However, the questionnaire was pilot-tested to ensure that the questions' opacity was reduced to the absolute minimum (see section 4.12 on pilot studies).

4.7.2 The Semi-Structured Interview

Hockey and Forsey (2020) state, "We interview to find out what we do not and cannot know otherwise." Denzin and Lincoln (2011:255) add that the goal of interviewing "is to uncover existing knowledge in a manner that allows it to be articulated in the form of answers, making it accessible for interpretation." Interviews are data-collection instruments that dissect matters that are impossible to see or hear, for example, the interviewees' motives and the reasons underlying certain feelings, behaviours, and perceptions. Further, an interview is an "active engagement involving two or more individuals, resulting in negotiated outcomes shaped by the context." (Flick, 2018:119). There are three ways of conducting interviews. First, the focus group interview entails a small grouping of interviewees where the interviewer guides a particular discussion on a specific topic. There is anticipation that the group dynamics may result in robust interaction and engagement that produces rich and diverse insights into the topic under investigation. Second, interviews may be conducted online or via the telephone, limiting human interaction and body language interpretation. I did not utilise online or telephone interviews since I was studying the perceptions and experiences of people who required me to be able to read and understand clues from their body language. Also, using platforms such as Google Meetings, Microsoft Teams, and others for interviews was not preferred for this study. In this research, I chose the third way - the face-to-face method, of conducting interviews.

Researchers can choose from three interview types: semi-structured, structured, and unstructured (Magaldi & Berler, 2020). The structured interview method is limiting because it has a set of rigid questions, so the interviewer has no flexibility to probe for the elaboration of interviewee responses (Rogers, 2018). Given the subject under investigation and acknowledging the challenges mentioned in previous literature regarding expressing emotions, perceptions, and experiences in structured interviews, I concluded that this interview format was unsuitable for this study. I needed to ask

follow-up questions and guide the interviewees to elaborate on their views, feelings, and experiences to obtain more comprehensive and detailed information. As a result, I opted for a different approach that allowed for a more in-depth and rich exploration of the participants' insights.

In addition, unstructured interviews require the interviewer to be highly skilled to avoid losing focus of the research objectives (Gibbs, 2014; Turner & Hagstrom-Schmidt, 2022). Consequently, I was reluctant to conduct unstructured interviews due to the high possibility of deviating from the study's aim and objectives, which may be time-wasting, thus obstructing the collection of valuable information; therefore, I chose the semi-structured interviews. According to Roberts (2020:74), semi-structured interviews are:

> Qualitative tools for collecting spoken information through predetermined questions, where intriguing and unforeseen responses can guide the creation of follow-up questions to gain a deeper understanding of individuals' perceptions and experiences.

While some researchers only use interviews for data collection, for the current research, I conducted semi-structured interviews to supplement the questionnaire. Flick (2018) states, "Qualitative interview data often gather more in-depth insights on participant attitudes, thoughts, and actions." However, Mohajan (2020) believes that the small samples used in qualitative studies render the results difficult to generalise or replicate. I structured all the relevant questions in an open-ended style for all interviewees, which can be modified as the interview proceeds. The semi-structured interviews permitted me to probe participants' responses while giving the interviewees sufficient time to express themselves (Turner & Hagstrom-Schmidt, 2022). I formulated the interview questions according to the dimensions of the TAM (PU and PEOU) and the tenets of TPACK to understand science teachers' in-depth perceptions and experiences of using the VL (Magaldi & Berler, 2020). In support, Silverman (2020:12) agrees that interviews have the advantage of having "fewer incomplete responses, a higher rate of return, and a controlled sequence for answering questions." As Silverman (2020) observed, for this study, the participants exhibited a notable level of engagement and cooperation. Despite having the option to decline to

answer certain questions, they chose to respond to all the questions, indicating their commitment to engaging fully in the research process. This resulted in the absence of any incomplete answers, ensuring a comprehensive dataset for analysis. The use of semi-structured interviews also proved valuable, as they offered opportunities for in-depth exploration and clarification of responses. Through probing further and following up on specific answers, the researcher could extract more detailed and nuanced information, improving the thickness of the data.

Moreover, the semi-structured nature of the interviews allowed me to maintain some level of control over the conversations. This ensured that the discussions remained focused and aligned with the research objectives, preventing any deviations that might have led to irrelevant or tangential information. On the other hand, interviews can be time-consuming, anonymity cannot be guaranteed, and subjectivity is a potential issue from both researchers and participants (Roberts (2020). This was especially true in this research because I had to meet with each of the four participants in person. This meant that they had to be known to me and could not remain anonymous to me. To assuage their fears, I reassured them that I would strictly adhere to confidentiality and that their identities would not be revealed. Below is a detailed description of how the data were gathered.

4.8 DATA COLLECTION PROCEDURES

The following is how the data for this study were gathered: Phase 1's data were quantitative, and Phase 2's data were qualitative. This aligns with Hirose and Creswell (2022:21), who posit that "Sequential mixed methods data collection strategies entail gathering data in an iterative manner, where the information obtained in one phase informs and contributes to the data collected in the subsequent phase." The data collection processes for the two phases are discussed below.

4.8.1 Phase 1 Data Collection

Quantitative data pertaining to the perceptions and experiences of Life Sciences teachers concerning teaching with the aid of VL was collected using a questionnaire from the Life Sciences teachers in the EC Province. The questionnaire was the most appropriate tool in this quantitative phase because it was able to "offer a numeric or quantitative portrayal of trends, attitudes, perceptions, or opinions within a population

by examining a sample from that population." (Rose & Johnson, 2020:13). In support, Roberts (2020:232) maintains that "questionnaires continue to be the preferred method for gathering primary data when studying a population that is too extensive to be directly observed" and are suitable to "measure perceptions and experiences in a large population". In developing the questionnaire, I first examined multiple questionnaires from previous research studies to determine how best to formulate demographic questions before developing the rest. The questionnaire was critiqued by two PhD holders who provided feedback. One PhD holder specialising in research methods assessed the questionnaire from the perspective of a research expert, while the other specialising in science education evaluated the questionnaire from a science education perspective. In addition, a practising Life Sciences teacher reviewed the questionnaire regarding the validity of data collection instruments to ensure that what was supposed to be measured was what they were intended to measure (Hirose & Creswell, 2022). The practising science teacher evaluated the questionnaire from the participant's perspective. Based on these reviewers' feedback, I modified the questionnaire to improve content validity. I then distributed an e-mail with the questionnaire to all the Life Sciences teachers in the district. All the teachers in the district had technology tools with e-mail and internet access.

My initial plan was to email the questionnaire to all the Joe Gqabi District Life Sciences teachers, which I did. However, despite two reminders, the respondents only returned 67 out of the 200 expected questionnaires. I then printed 150 questionnaires, which I personally administered during the last week of the November/December 2022 Grade 12 National Senior Certificate marking session. I requested permission to carry out the survey from the Marking Centre management and Chief Marker. Unlike the electronic questionnaire data, the data from the hard copies were drawn from respondents who are knowledgeable teachers selected for marking from all districts in the province. Hence, I consider this quantitative data to be thick and representative of the Life Sciences teachers across the EC Province. Out of the 200 questionnaires that I sent out, 186 were usable, as the others had missing data. At the end of the questionnaire, I issued a link for the respondents to indicate their willingness to be interviewed in Phase 2.

4.8.2 Phase 2 Data Collection

According to the sequential explanatory design, the current study's qualitative method followed the quantitative method. This required that the participants for the qualitative approach (semi-structured interviews) should also have contributed to the first quantitative approach, ensuring that the qualitative results elaborate on the quantitative findings. Therefore, only those who expressed their views in the quantitative phase were part of the qualitative follow-up. I conducted semi-structured interviews in this phase to strengthen my insights gleaned from Phase 1 findings. As discussed earlier, I included an invitation towards the conclusion of the questionnaire for respondents to show their desire to participate in the interviews. Out of 27 respondents who demonstrated a desire to participate in the second phase, I used purposive sampling to select four (n = 4) from four different secondary schools in rural areas as participants in the semi-structured interviews. Selecting participants through purposive sampling allowed for identifying individuals who could provide a rich and nuanced perspective on the research topic. I e-mailed the interview recruitment (Appendix F) to four participants who had shown a disposition to be interviewed. Verbal consent was also confirmed before conducting face-to-face interviews. Table 4 below presents the interview participants' demographic characteristics to provide insight into their backgrounds and experiences.

Table 4: Semi-structured interview participants' demographics

Name (Pseudonym)	Age	Gender	Qualification	Teaching experience
LST1	33	Female	Bachelor of Education (Life Sciences)	8
LST2	38	Male	Bachelor of Science, Post Graduate Certificate in Education (Life Sciences & Natural Sciences)	14
LST3	49	Female	Bachelor of Education (Life Sciences & Agricultural Sciences)	23
LST4	28	Male	Bachelor of Education (Life Sciences & Mathematics)	5

I conducted the interviews at a convenient venue at a time suitable to both the interviewees and myself. Driven by the research objectives, the interview protocol allowed me to elicit detailed, thick data from interviewees. Thus, the interview data complemented the data elicited from the completed questionnaires to obtain incisive insights into the themes evident in the data.

I digitally recorded (with prior permission) the interviews and securely stored all information on a password-secured electronic file on my personal computer. I then transcribed and checked the data for accuracy. When recording and transcribing, I used pseudonyms instead of participants' names to protect identities. I destroyed the recordings when the thesis was completed. After interviewing each participant, I created participant summaries that I shared with them to verify that their views were authentically recorded. When preparing for data analysis, I uploaded the transcribed interview data onto the NVivo software, which aided me in organising and analysing the unstructured data using tools that classified, sorted, and arranged my data in ways that allowed me to identify themes and patterns.

Lastly, while the process of interviewing can provide greater depth of information, it is not without its shortcomings. These include the researcher as being the instrument (credibility is dependent on the researcher), reduced generalisability, inaccurate memory or recall error, unintentional bias, personal bias, degree of participant honesty, labour intensiveness, participant's emotional state, and it can be time-consuming (data collection and analysis) (Teddlie & Tashakkori, 2012; Turner & Hagstrom-Schmidt, 2022). Nonetheless, a well-thought-out and appropriate research design can reduce some of these limitations, although not completely. As the researcher, I addressed the limitations in terms of reflexivity and transparency. Additionally, I created a democratic, tranquil, and cordial interview environment such that the participant would feel at ease to answer all the questions. Also, I told them before the interview that they were not compelled to reply to any questions should they feel uncomfortable answering them. The following section articulates the process of data analysis that I followed.

4.9 DATA ANALYSIS

I analysed all collected data by means of a blend of quantitative and qualitative approaches, in line with the traditions of the mixed-methods approach as follows.

4.9.1 Phase 1 Data Analysis

The quantitative data of Phase 1 was statistically analysed. To reduce vast amounts of data into manageable quantities, I categorised the data into smaller statistical quantities that expressed the population or sample's main attributes. This was to comprehend better and make sense of the study's findings. Rogers (2018) agrees that researchers in the educational and social sciences are often confronted with massive data amounts that should be substantially reduced to manageable numbers before accurately interpreting the data. Accordingly, statistical procedures can be grouped into branches of descriptive and inferential statistics. I mainly employed descriptive statistics for this research, primarily for analysing and describing quantitative data (Shreffler & Huecker, 2022). This is beneficial when measuring characteristics of the available data as it focuses on a central tendency, frequency distribution, measures of association, and dispersion. In this phase, I utilised a Likert scale to gather data and determine surface standard deviations, means, and frequencies on Life Sciences teachers' perceptions and experiences of VL.

After receiving the completed questionnaires, I coded the quantitative data from the usable questionnaires and inputted it into a Microsoft Excel spreadsheet. Afterwards, I conducted an initial data inspection to check for missing values and the presence of outliers before transferring it to SPSS. Creswell and Creswell (2017) note that missing values occur when respondents fail to provide those values. In quantitative research, missing values are a significant statistical concern for various reasons. Firstly, missing values can compromise the validity of findings by reducing the performance of confidence intervals, resulting in biased parameter estimates (Lang & Little, 2018; Enders, 2022). Secondly, as missing values lead to less information, they can significantly decrease statistical power, resulting in inaccurate and invalid conclusions (Mathur & VanderWeele, 2020). This study excluded four cases with missing values (coded as -8) from statistical analysis.

After checking for missing values, I then inspected the database for outliers. Outliers are unusually extreme values that differ significantly from the majority (Koren, Koren & Peretz, 2023). Like missing values, outliers can significantly distort information such as the means and standard deviations of the distribution, affecting statistical analyses' validity (Blázquez-García et al., 2021). However, gross outliers were improbable in this research since the questionnaire responses were confined to a range between 1 and 5. I then transferred the Excel spreadsheet data to the SPSS Programme version 29 for descriptive and inferential statistical analysis. I then used the Phase 1 results to modify the interview protocol I used in Phase 2.

4.9.2 Phase 2 Data Analysis

In this phase, I employed a semi-structured interview protocol to gather qualitative and non-numerical data. Subsequently, I analysed this data using qualitative procedures. As Miles et al. (2018) suggest, qualitative data analysis procedures are particularly appropriate for conducting an in-depth exploration of the subject. This approach discloses salient themes, concepts, categories, relationships, and patterns entrenched in a particular text. For analysing the qualitative data, I utilised the thematic analysis approach. I applied this approach by following multiple steps, as Thompson (2022) recommends regarding coding practises. Thompson (2022:1417) states that "In qualitative research, a code typically represents a word or brief phrase that symbolically encapsulates a concise, notable, essence-capturing, and evocative attribute for a segment of language-based or visual data." In addition, Thompson (2022:1418) recognises what he calls 'first coding cycle' in which he explicates it as "one approach for initially summarising segments of data is pattern coding. In its second cycle, this method involves the consolidation of these initial summaries into a reduced set of categories, concepts, or themes." I began coding by reading each transcript repetitively to familiarise myself with the participants' voices. According to Miles' et al. (2018) recommendation, I completed the initial coding cycle by marking potential codes in purple and transcribing the names of preliminary codes in the transcripts' margins to differentiate distinct codes. I then scrutinised the codes and deliberated on them with my supervisor to ascertain their value and possibilities of alternative lines of interpretation.

Subsequently, I generated a codes' master list, which functioned as a reference point for the second coding phase, marking the conclusion of the initial coding process. I subsequently created a second set of codes and recorded the interviews. Then, I carefully looked at the connections among the codes to produce categories. I used the emerging categories to establish emerging themes from the data, after which I defined the themes and organised them by using the relevant quotes from interview transcripts. Once the second round of coding was completed, I proceeded to copy the verbatim quotes alongside the participant's pseudonym. These quotes were then pasted into the Microsoft Word program beneath their respective code names, effectively grouping them according to their designated codes.

While presenting the interview findings, I incorporated the participants' voices to enhance the results by directly quoting their exact words from the interview transcripts (Miles et al., 2018). To ensure alignment between the data analysis process and the theoretical framework, I used TAM constructs PU, PEOU, SI, BI, AU, and TPACK's knowledge domains TK, CK, PK, PCK, TPK, and TPACK as a guiding mirror to analyse the teachers' perceptions and experiences of teaching with VL. It was imperative for me to ensure a cohesive connection between the data analysis and the theoretical framework to establish a strong alignment between the empirical findings and the theoretical underpinnings, thus enriching the overall study. It is crucial to highlight that while PCK, PK, and CK are not inherently focused on technology use in teaching, I deliberately integrated them into the analysis. The rationale behind this inclusion was their integral role as components of the TPACK framework. Moreover, since the participants of this study are in-service teachers who can be expected to have developed high levels of PCK, PK, and CK, it was also crucial to include these knowledge domains in the analysis of the teachers' perceptions of VL.

Notably, during the data analysis phase, I employed various techniques to enhance internal validity, such as pattern matching, theme development, and construction of meanings and explanations derived from the themes. In addition, I used external validity to sharpen the theoretical focus of the present research, thus ensuring that the findings could be generalised to other cases or locations. To improve the reliability of the present investigation, I applied two of Yin's (2015) strategies for developing a case study database, including, first, a comprehensive literature review that solidified the

study's grounding in established theory and prior research. Second, a clear chain of evidence provided a transparent and rigorous account of how the data was collected, analysed, and interpreted. The following steps outline how I handled the qualitative data.

a. I recorded the semi-structured interview data using written field notes and a voice recorder.
b. I transcribed the semi-structured interview recordings from the recorder into a Microsoft Word Programme using the Dictate function of Microsoft Office 365.
c. I used open coding in the MS Word Programme to produce descriptions that generated themes or categories. I used CAPSLOCK for the codes and different font colours to highlight the codes next to the text in a transcript.
d. I analysed the emerging themes and descriptions by associating them with the research questions and quantitative data analysis.
e. I interpreted the qualitative findings with the "ultimate goal of unifying all data types so that they can be analysed as a single set" (Miles & Huberman, 1994:34).
f. I interpreted each case and presented it in contrast to each other, comparing them with the quantitative findings and literature.

As indicated above, I used the qualitative results to triangulate the quantitative phase findings, which I organised per research question (see Chapter 5). The subsequent section delves into the matters pertaining to the trustworthiness of the current study.

4.10 TRUSTWORTHINESS, VALIDITY AND RELIABILITY

Trustworthiness is "the readers' degree of trust or confidence in the study findings" (Rose & Johnson, 2020:41). A study's trustworthiness depends on the concepts of reliability and validity (Lemon & Hayes, 2020). According to Kyngäs et al. (2020), researchers ought to use triangulation principles to gather and analyse data to ensure data validity and reliability. In this research, I employed more than one data collection tool, including questionnaires and interviews (data triangulation), to ensure that the strengths of the other method complemented any weaknesses in the other. Furthermore, this study employed a mixed-methods approach (methodology triangulation) to secure results with depth and authenticity. Moreover, I used two

theoretical lenses (TAM and TPACK) - a theoretical triangulation - to investigate the research problems.

For the data extracted from the interviews, I requested the teacher participants to verify (member checking) the interview transcripts as their version of responses (Flick, 2018). After that, I only used the final transcript that the interviewees checked. Lastly, I utilised peer review sessions (Hays & McKibben, 2021) to ensure this study's trustworthiness. The Education Faculty of UFS conducts Title Defence seminars where I presented my work during its conception stages. The feedback and suggestions I received from experts in the field also ensured my research's trustworthiness.

On the other hand, trustworthiness is underpinned by research reliability and validity (Kyngäs et al., 2020). Aspers and Corte (2019:152) explain that the concept of validity describes whether a measurement instrument or assessment procedure yields results that align closely with the intended target or objective. In support, Hays and McKibben (2021) affirm that historically, validity has been viewed as a way of showing that a particular research instrument can measure that which it is intended to measure to generate meaningful discourse that accurately represents those characteristics it is supposed to theorise, explain, or describe. Recently, however, the notion of validity has become broad to include honesty, richness, and scope; that is, the depth and scope of the acquired data, the calibre of participants, the extent of triangulation, and the objectivity of the research were evaluated. (Taherdoost, 2016). Thus, to enhance validity, I subjected the questionnaire and interview questions to review by two experts: doctorate-level scholars and a serving Life Sciences teacher who helped address the ambiguity in questions. In addition, I subjected the research instruments to pilot studies, further refining and improving the question items. In research, the notion of validity encompasses both internal and external validity. Internal validity pertains to the research instrument's ability to accurately measure its intended constructs, a concern that was addressed through a pilot study (see section 4.12 on pilot studies). In contrast, external validity deals with to what extent can the research findings be transferred and generalised to other contexts. To guarantee external validity, I randomly sampled the participants for the study's first phase and during the conception stages of this research. When I presented this study's proposal to my peers and

experts in the field in our research group and during the faculty title registration defence, my “predispositions were examined, connotations were investigated, and the foundations of interpretation were elucidated” (Hays & McKibben, 2021:182). Hence, the feedback I received from my peers and experts helped validate this research.

In quantitative studies, reliability, on the other hand, is premised on the repeatability of findings (Hirose & Creswell, 2022). If research findings are to be deemed reliable, it would be a requirement that if the investigation were to be conducted on a comparable population in similar contexts, similar results would be produced. Reliability deals with the research findings’ replicability, consistency, and dependability. I guaranteed the questionnaire’s reliability by piloting it and eliminating all ambiguities and errors. I also exposed participants to the same question items.

Regarding qualitative research, reliability refers to the degree of consistency and dependability in the data captured by the researchers compared to what actually occurred in the research context from which the data was collected. It concerns the extent to which the data accurately represent the phenomena or experiences under investigation and whether they can be trusted as a faithful reflection of the participants’ perspectives or the observed events (Clark, 2019). Hence, reliability in qualitative research has to dwell more on the comprehensiveness of coverage and the level of accuracy. Member checking had to be executed to ensure reliability in this study’s qualitative phase. Member checking is a procedure in which researchers request one or more study participants to verify the accuracy of the provided account. (Hitchcock & Onwuegbuzie, 2020). I invited the participants to confirm whether the data represented an accurate narrative of their voices, whether the explanations were sufficient and satisfactory, and whether the interpretation represented their aspirations just and truthfully. Further, I also subjected the final thesis report to my peers, who critically perused the research’s findings and articulated the study’s strengths and weaknesses (Creswell, 2016). Notably, I presented this research at the UFS 5th Annual Postgraduate Research Conference before submitting the thesis for examination. The insights and recommendations that I gained from the conference helped strengthen the study’s validity. The following section outlines how I employed triangulation to strengthen the study’s validity.

4.11 TRIANGULATION

Triangulation stems from the need to explore and sufficiently describe the richness and complexity of people's actions by examining them from multiple viewpoints (Clark, 2019). This approach fosters data validation processes through cross-verification from various sources. I applied triangulation by utilising two data-gathering instruments: the questionnaire and the interview protocol (data triangulation) and two theories (theory triangulation). Flick (2018:31) suggests that "the key aspect of triangulation is not just the mere blending of diverse data types but the effort to interconnect them to mitigate the validity threats recognised within each dataset." The essence of triangulation for this research is that a single research tool cannot provide accurate or entirely reliable data for analysis. Thus, I employed triangulation to achieve cross-validation and augmentation of data from a different perspective. In the upcoming section, I detail the pilot-testing process employed for the research instruments.

4.12 PILOT STUDIES

Bell et al. (2018:153) advise "to avoid risks, conduct a pilot test first." One of the effective research approaches is thorough planning; pilot testing is usually an integral aspect of this planning. Lemon and Hayes (2020:608) maintain that "a pilot study is a small-scale preliminary investigation conducted before the main research to assess feasibility and enhance research design." In the current research, a pilot test was conducted to pre-test the research instruments in accordance with the method advocated by Bell et al. (2018). The pilot test's purpose was twofold: first, to ascertain the absence of ambiguity within the instruments, and second, to assess their effectiveness in gathering the intended data accurately. To achieve these objectives, I administered the two research instruments to a selected group of participants distinct from the main study's sample but still representative of an appropriate population. A crucial consideration in the pilot-testing approach was the deliberate choice to utilise individuals outside the main sample. This decision was taken to mitigate the potential influence of prior exposure to the research instruments on participants' responses, as pointed out by Taherdoost (2016). By employing a different cohort, the pilot test results remained independent and unaltered by any familiarity with the instruments. This ensured that the feedback obtained regarding their clarity and appropriateness remained unbiased and credible.

The pilot-testing phase was pivotal in refining the research instruments and identifying any shortcomings or issues that required rectification. This iterative process allowed for meticulous revisions, ensuring the instruments' validity and reliability were optimised prior to their implementation in the main research. Consequently, the rigorous pilot testing contributed to enhancing the overall quality and accuracy of the data collected in this research endeavour. The pilot study conducted in this research uncovered certain issues with the initial research instruments. Notably, overlaps were identified in specific questions, such as question 7 duplicating information already addressed in question 6. Consequently, the overlapping question 7 was removed after the pilot phase.

Additionally, a significant finding emerged from the pilot study, revealing that 56 questions in the original questionnaire lacked consideration for the context of the schools. This was particularly crucial as the study's theoretical framework incorporates TAM and TPACK, both of which emphasise the context-bound nature of technology acceptance and integration (Mishra, 2019). Following the pilot study, the questionnaire was expanded from 56 to 77 items. This expansion allowed the inclusion of questions specifically designed to capture vital contextual details related to the schools (refer to Appendix C, Section F). Notably, the interview protocol remained unaltered, as it effectively generated the desired data for the study. Overall, the pilot study was paramount in validating the final research methodology and ensuring the reliability of the instruments in gathering the requisite data.

On the other hand, while pilot studies are crucial in research, they also have flaws. First, the pilot-study findings may lead researchers to make incorrect assumptions or predictions. Pilot testing results can provide valuable insights into the expected response rate, magnitude, and preliminary outcomes. However, it is crucial to acknowledge their limitations because they lack a statistical basis. Pilot tests typically involve smaller sample sizes, making them less statistically representative than the main study. As a result, while pilot testing serves as a crucial step in refining research instruments and methodologies, its findings should be cautiously interpreted because they may not always guarantee the same level of statistical rigour as the main study. Therefore, while pilot testing provides essential information, the main study's results should be analysed with greater statistical confidence and significance (Bell et al.,

2018). Second, conducting a pilot study may have financial implications due to incurring extra funds, which may constrain researchers. Hence, in considering these disadvantages, piloting a study may not guarantee that it will succeed in the actual research, but it can help improve the prospects of success and, therefore, its use in this research. The subsequent section of this study focuses on the ethical considerations associated with the investigation.

4.13 ETHICAL CONSIDERATIONS

Ethics in research are "the moral values that govern research, from its inception to data collection, analysis, compilation, publication of results, and even beyond…" (Kyngäs et al., 2020:46). Research ethics binds all kinds of research and the present study is no exception as it involves human participants. In this study, I placed a strong emphasis on research ethics, which I ensured and implemented through ethics clearance from the UFS, obtaining permission from gatekeepers, securing consent for audio recording of responses, adhering to principles of voluntary participation, maintaining confidentiality and anonymity, obtaining informed consent from all participants, providing feedback to the participants, and acknowledging and informing traditional local authorities.

4.13.1 Ethics Clearance and Gatekeepers' Permission

Iphofen and Tolich (2018:43) suggest that "researchers applying for permission to study individuals in research ought to go through the approval process of an institution's ethics review committee". I complied with the requirements by applying for ethics clearance from the Faculty of Education's Ethics Committee at the UFS. I was granted clearance (Ethical Clearance Certificate number: UFS-HSD2022/1276) (see Appendix I). Oliver (2010:15) adds that "ethical procedures during data collection include obtaining consent from individuals in authority (gatekeepers) to gain access to study participants at research sites." Merriam and Tisdell (2015:324) define a gatekeeper as "an individual, whether officially designated or unofficial, who plays a role in granting access to a research site, aids researchers in locating study participants, and assists in identifying suitable areas for research." Accordingly, I sought permission to carry out this research in the four schools (research sites) from the ECDoE. The permission was granted (see Appendix H). Further, I used this letter from the ECDoE to request written authorisation from the school principals to access

the teacher participants at the research sites. As per Oliver (2010:214), "seeking permission before gathering data is not only a component of the informed consent process but also a fundamental ethical exercise," which aligns with my approach in this study. Thus, seeking permission from the ECDoE to carryout the investigation in the four schools (research sites) was an essential step to ensure informed consent and adherence to ethical guidelines. By obtaining proper authorisation, I aimed to uphold the principles of research ethics and demonstrate respect for the participants and the educational institutions involved.

4.13.2 Informed Consent and Voluntary Participation

Acknowledging the rights of the participants as outlined by Hays and McKibben (2021), I ensured that their voluntary participation was strictly upheld, safeguarding their confidentiality, anonymity, and the right to provide informed consent. Throughout the research process, I prioritised demonstrating respect, maintaining transparency, and ensuring the safety and well-being of all study participants. These ethical considerations were fundamental in conducting the research in an ethically responsible manner. In compliance with ethical guidelines, I informed all participants about their rights to voluntary participation, emphasising their autonomy to withdraw from the research at any stage without facing any disadvantages (Iphofen & Tolich, 2018). By providing this information, I aimed to ensure that the participants felt empowered and in control of their involvement in the study, fostering an atmosphere of openness and mutual respect throughout the research journey. These details were indicated verbally and on the consent form, which the participants signed to confirm their informed and voluntary participation. Before they signed the consent forms, I clarified in-depth the research's objectives, the research process, why they were involved, and how the study results would be used, among other finer details (Cohen et al., 2017) (see Appendix E).

4.13.3 Confidentiality, Privacy and Anonymity

I was obliged to guarantee that the participants' rights to confidentiality, privacy, and anonymity were always safeguarded (Cohen et al., 2017). Merriam and Tisdell (2015:87) emphasise that "the assurance of respondents' anonymity encourages them to share information more openly and readily." Accordingly, I did not divulge the participants' identities and all information elicited from them (Taherdoost, 2016). I

protected the questionnaire respondents' anonymity by allocating codes (numbers) to the completed (returned) questionnaires. I also invited the participants to suggest the pseudonyms they would prefer to maintain anonymity, and these were used alongside the participants' interview verbatim responses. I also informed the participants that they still had a right to identification when publishing this thesis should they choose to. Lastly, I treated the collected information as highly private and confidential. I stored all the information in an electronic password-protected file on my laptop, only to be accessed by myself and not to be shared with persons who were not part of this research.

4.13.4 Honesty, Respect, Transparency, and Integrity

I was committed to executing this research with transparency, honesty, integrity, and respect (Hamilton & Finley, 2020). To my best level, I honestly reported on the research methodology, data, and results. I safeguarded against fabricating, misrepresenting, and misconstruing information. A further guarantee was that this research was supervised by Professor T. Jita, who supervised all aspects of the study (see Appendix E). Further, I maintained integrity by always being punctual for appointments and meetings with the participants. Moreover, I executed the study with high levels of openness, integrity, dignity, and transparency by sharing all pertinent information and results with the participants while inviting critical suggestions. Also, in line with Shreffler and Huecker's (2022:137) recommendation, "researchers should maintain objectivity and make concerted efforts to prevent bias during the interpretation and analysis of data." Therefore, I vigorously attempted to be as objective as I could in line with the prescripts of data analysis. To uphold transparency and honesty, I invited some participants to proofread this thesis before its final submission. Given the disparity in cultural backgrounds between myself and the participants, I recognized the significance of cultural differences while engaging with their perceptions and lived experiences within their cultural context. Consequently, I consciously tried to set aside any preconceived research assumptions and embrace the participants' viewpoints to learn from their perspectives. Moreover, throughout the study, I deeply respected my participants' diverse ages, genders, races, nationalities, languages, colours, marital statuses, and customs. (Appendix C).

4.13.5 Providing feedback to the participants

After this research, I provided all the participants with details to access the thesis from the UFS electronic repository. In addition, I produced printed copies of the thesis for the ECDoE in line with the Department's ethical approval terms and conditions (see Appendix H).

4.13.6 Recognition of Traditional Local Authorities

The four research sites (schools) are situated in rural areas where traditional leaders hold significant recognition, such that almost all the schools are named after the Chiefs of the areas. In recognition of the traditional authorities, members of the School Governing Body (SGB) and I informed the Chiefs about this research in the schools. By adopting this approach, I aspired to ensure that the research is conducted with cultural sensitivity and garners the necessary support from the community, should the need arise. I now fold this chapter (4) in the following section.

4.14 SUMMARY

This chapter (4) discussed the methodology, including the paradigm, approach, design, research population, sampling techniques, instruments for data collection, and the data analysis process utilised in this research. Further, the justification and the adoption of particular methods were elaborated upon. Also, this chapter highlighted pertinent issues such as research validity and reliability and the related aspects of triangulation and pilot studies. This chapter (4) concluded by exploring how ethical considerations were addressed. The upcoming chapter (5) delved into the presentation, analysis, and interpretation of the collected data.

CHAPTER FIVE

DATA PRESENTATION, ANALYSIS, AND INTERPRETATION

5.1 INTRODUCTION

The purpose of this chapter is to present, analyse, and interpret the study's findings. The data presented in this section were collected through a closed-ended questionnaire and semi-structured interviews conducted in two distinct phases. The initial phase involved data collection over five weeks, spanning from the third week of November 2022 to the fourth week of December 2022. Subsequently, the second data collection phase occurred over twelve weeks between the last week of January 2023 and the last week of April 2023. Throughout the research, the study's theoretical framework and research questions guided the presentation, analysis, and interpretation of the results. It is important to note that I strictly adhered to all ethical requirements throughout the research process.

I deployed a mixed methods research approach using the sequential explanatory design to explore the perceptions and experiences of Life Sciences teachers on the integration of VL for rural teaching. This method involved initially gathering quantitative data, then collecting qualitative data, and then using the qualitative results to explain the quantitative findings from the first phase. After getting both data sets, I had to address issues regarding the priority and integration, or 'mixing', of the quantitative and qualitative findings to ensure a more nuanced and in-depth examination.

First, the issue of priority in mixed methodology relates to whether to give more attention to the qualitative or quantitative approach (Creswell & Creswell, 2017). As per the sequential explanatory design, priority can be given to either the quantitative or qualitative approach based on the specific research needs and objectives (Taherdoost, 2022). In this study, I deliberately prioritised the quantitative phase. By doing so, my primary goal was to obtain precise numerical insights and statistical information relevant to the research questions and the overall study objectives. Focusing on quantitative data collection and analysis allowed me to gather empirical data that I could quantify and analyse statistically. This approach provided a clear,

measurable perspective, revealing patterns, trends, and relationships between TAM and TPACK variables associated with Research Question 3.

Second, in the spirit of the sequential explanatory design, I had to handle integration, which involves merging or 'mixing' quantitative and qualitative findings at different stages, such as when designing the research, collecting the data, analysing the data, or presenting and interpreting the findings (Tashakkori & Teddlie, 2021). I 'mixed' this study's quantitative and qualitative results in three stages. The first 'mixing' of the findings occurred during the design phase, where I used the quantitative phase findings to develop the qualitative phase interview questions. This meant that I collected and analysed the quantitative data separately and then shaped the interview plan and the questions to be explored further (i.e., triangulation). The second 'mixing' of the results occurred during the presentation, analysis, and interpretation stage, and the third and final mixing occurred during the discussion of the results.

I used descriptive and inferential statistics involving percentages, frequencies, standard deviations, means, and coefficients in tables and graphs to analyse and interpret the quantitative findings. Additionally, and where necessary, I present the qualitative findings in a narrative form using excerpts or verbatim statements from the participants. Moving on to the subsequent section, I discuss the results from the quantitative and qualitative phases, commencing with an overview of the participants' demographics.

5.2 DEMOGRAPHICS OF THE PARTICIPANTS

A total of 186 respondents completed the questionnaire. The initial part of the questionnaire gathered demographic data from the participants. This step was crucial because demographic and personal characteristics tend to influence teachers' perceptions and experiences of novel technologies such as VL for teaching. Analysing this information provided opportunities to understand the contexts from which the Life Sciences teachers' perceptions and experiences of VL flowed. Furthermore, understanding the demographic profile of the participants plays a critical part in enhancing the interpretation of the findings. This section reports on four characteristics: age, gender, teaching experience, and level of education.

5.2.1 Gender of Respondents

The questionnaire requested the teachers to indicate their gender based on the following categories: (i) male, (ii) female, and (iii) other. Analysis of the SPSS descriptive statistics output confirmed that out of the 186 Life Sciences teachers who completed the questionnaire, 119 (64%) indicated that they were female, and 67 (36%) were male (see Figure 4 below).

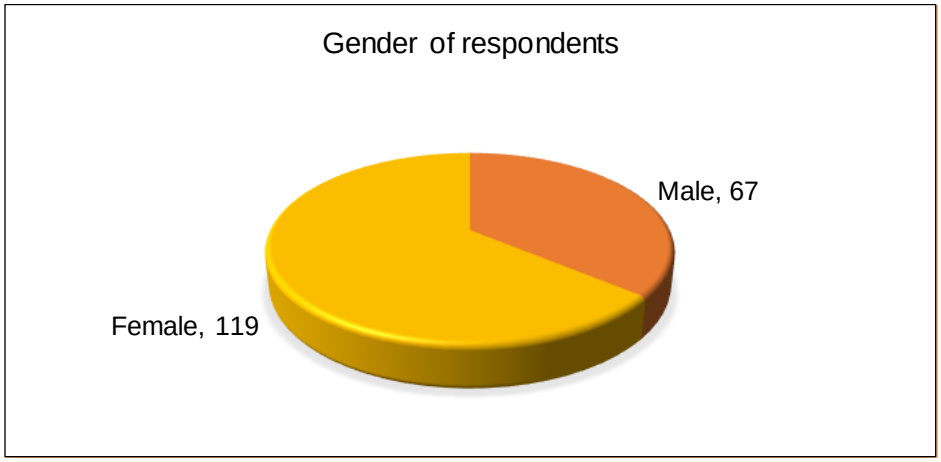

Figure 4: Gender of respondents

The results in Figure 4 above demonstrate a higher representation of female Life Sciences teachers (n = 119, 64%) compared to male teachers (n = 67, 36%). It is essential to highlight that the selection process for phase 1 participants was random, ensuring that both male and female Life Sciences teachers had equal opportunities for inclusion in the present study's sample. The results of this investigation align with the existing literature, such as the work by Moosa and Bhana (2023), which characterises the teaching profession in SA as predominantly female or feminised. These findings are further supported by the DBE (2022) statistics, which report a composition of 73.5% female teachers and 26.5% male teachers in SA, similar to the pattern observed in the present research. However, it is fundamental to clarify that this research did not specifically explore the influence of gender on VL acceptance and use, as it was beyond the scope of the research.

5.2.2 Age of Respondents

The questionnaire asked the teachers to show their ages according to the following groups: (i) 21 and under, (ii) 22-30, (iii) 31-40, (iv) 41-50, (v) 51-60, and (vi) 61 and above. Figure 5 shows the findings of the ages of the teachers.

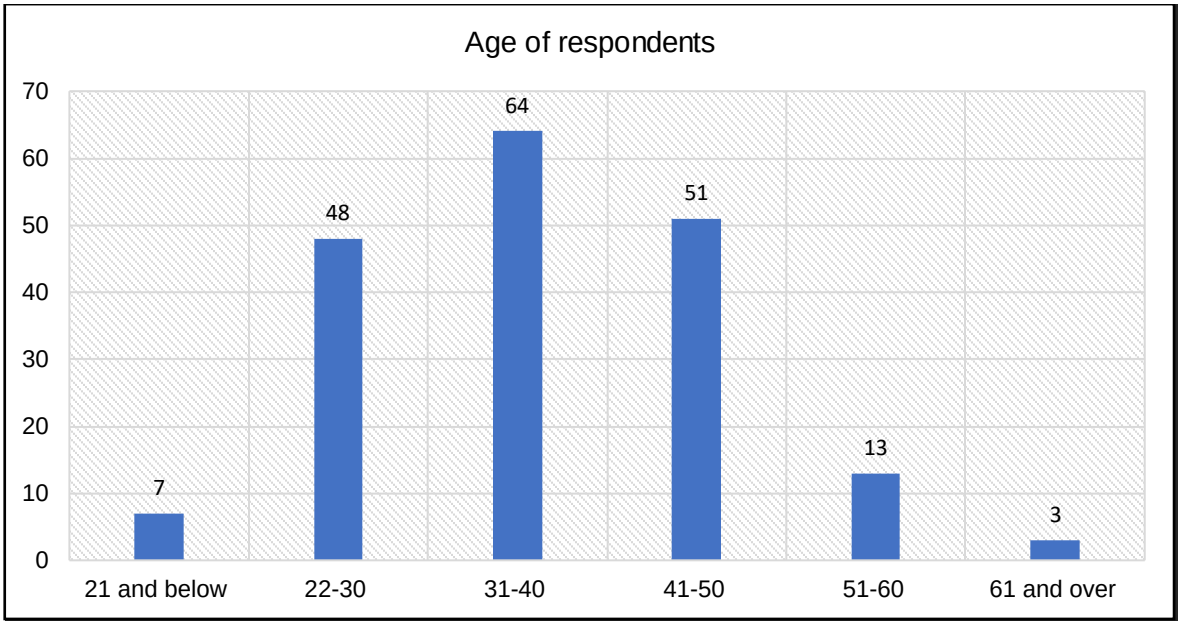

Figure 5: Age Distribution Reported by Life Sciences Teachers

Based on Figure 5, most teachers (n = 64, 34.4%) belonged to the 31–40-year age group, while the 41–50-year age group (n = 51, 27.4%) was the second largest. The smallest group was the 61 years and over category (n = 3, 1.6%). Therefore, most Life Sciences teachers in rural schools (n=115, 61.8%) fall within the 31-40 and 41-50 age groups. From these findings, it can be concluded that most Life Sciences teachers in rural schools (n = 115, 61.8%) belong to the 31-40 years and 41-50 years age groups. This finding suggests that Life Sciences teaching in the study area comprises teachers who are 50 years of age or younger. Also, it is possible that some of the older teachers, perhaps more averse to technology, might have opted out of the study sample. Notably, only three respondents (1.6%) reported being 61 or older, indicating fewer teachers in this age range. It is plausible that the small number of teachers over 60 is due to retirement, as most teachers in SA retire at 60 or earlier. Although it might be argued that differences in age impact teachers' experiences and perceptions of educational technologies and their acceptance, the literature review

conducted in the present research did not show significant correlations between age and technology use in the classroom.

5.2.3 Teaching Experience of Respondents

The questionnaire requested the teachers to indicate their teaching experience based on the categories: (i) 0-4 years, (ii) 5-10 years, (iii) 11-15 years, (iv) 16-20 years, (v) 21-25 years; and (vi) 26 or more years. Figure 6 below shows the results.

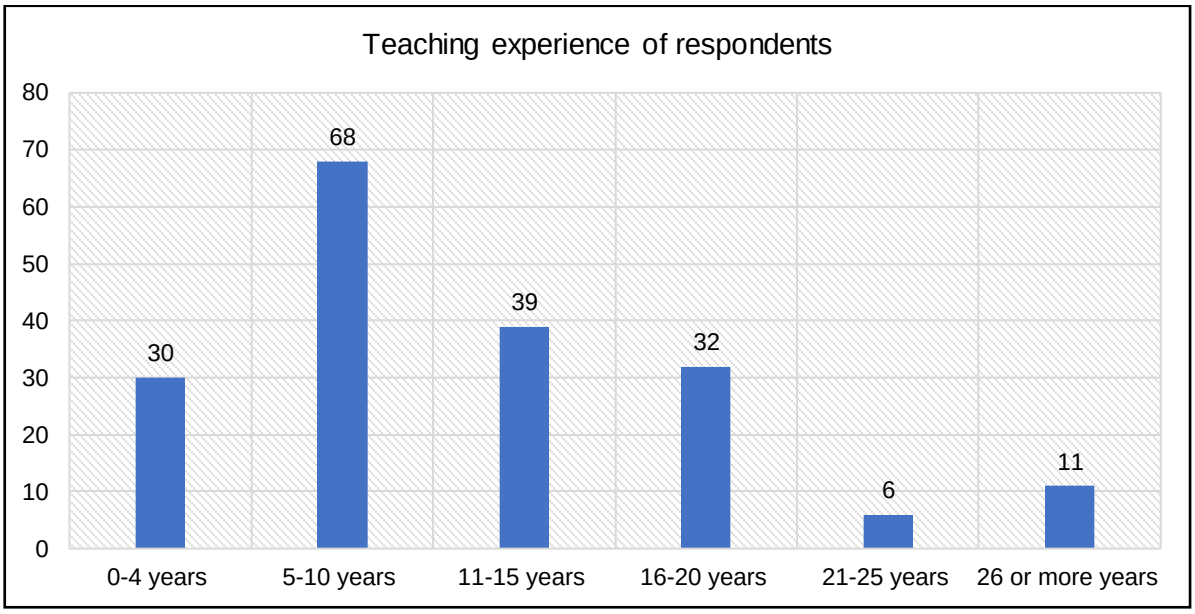

Figure 6: Teaching Experience reported by Life Sciences teachers (Years)

Figure 6 illustrates that the most substantial proportion (n = 68, 36.6%) of the surveyed Life Sciences teachers in the study possessed a teaching experience of 5-10 years. Following closely, the second most significant group (n = 39, 21.0%) comprised teachers with 11-15 years of experience in the profession. Altogether, most Life Sciences teachers in rural schools who participated in the study (n = 156, 83.9%) had over five years of teaching experience. From these findings, this study assumes that the surveyed Life Sciences teachers would hold positive perceptions towards using VL for rural science teaching. The basis for this assumption would be that more experienced teachers may be more inclined to appropriate technologies in their teaching than less experienced teachers due to several factors. Firstly, they may have greater familiarity with technology because of their personal and professional experiences. This familiarity could make them more comfortable using technology in

their teaching and may allow them to integrate it more seamlessly and effectively. Additionally, experienced Life Sciences teachers often have a more incisive understanding of teaching and learning, which could help them leverage technology more effectively to enhance their teaching.

Moreover, experienced Life Sciences teachers may have had more opportunities for professional development related to technology integration, attending conferences, workshops, or courses to stay updated with the latest trends and best practices. These opportunities could give them new ideas and strategies to try in their classrooms. While technology integration in classrooms is not solely determined by experience, I reckon that these factors contribute to why experienced Life Sciences teachers may be more likely to do so. Therefore, it is rational to presuppose that the Life Sciences teachers in this research would be more receptive to incorporating VL as a platform to augment their science teaching.

5.2.4 Level of Education

Regarding education level, the questionnaire asked the teachers to indicate which qualification they hold according to the following qualifications: (i) Bachelor's degree, (ii) Post-Graduate Certificate, (iii) Master's degree, (iv) Doctoral degree, and (v) other. Figure 7 below shows the Life Sciences teachers' education levels.

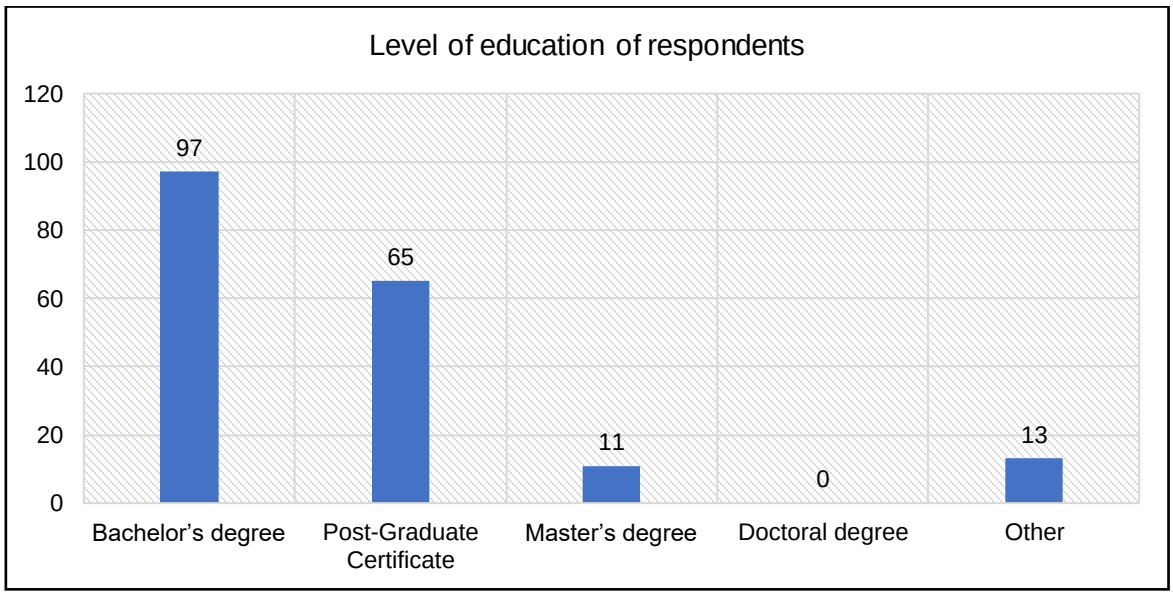

Figure 7: Level of Education reported by Life Sciences teachers.

Figure 7 shows that most Life Sciences teachers in rural schools (n = 97, 52.2%) stated they hold a Bachelor of Education degree. On the contrary, the smallest number of teachers (n = 11, 5.9%) reported having a Master's degree - the highest qualification among the surveyed teachers. It is noteworthy that there were no teachers who reported having a Doctoral degree. To account for respondents with qualifications not covered in the provided options, I included the category "other." A total of (n = 13, 7.0%) Life Sciences teachers indicated holding qualifications other than teaching-related ones. These are 'unqualified' teachers often recruited by private or public schools in instances of a shortage of qualified teachers, and they are not on the government payroll. From the findings, only 7.0% of the surveyed teachers can be regarded as 'unqualified' or underqualified if they hold a teaching diploma of less than seven in the National Qualifications Framework (NQF) rankings. This low percentage of unqualified teachers could be attributable to the fact that the SA government ceased to recruit individuals who did not have a formal teaching qualification around ten years ago. Hence, the pattern in Figure 9 above indicates that most Life Sciences teachers in rural schools (n = 173, 93.0%) have the required teaching qualifications. It is crucial to underscore that I included teachers with different qualifications in this study. The rationale was that regardless of their qualifications, all teachers would have perceptions and experiences concerning the integration of VL for teaching. The following section presents and analyses this study's findings per research question.

5.3 FINDINGS OF THE STUDY

I present the research findings by triangulating the quantitative findings with the qualitative results per research question. Furthermore, I analyse and interpret the results through the TAM and TPACK framework lens. To understand and explain the teachers' perceptions and experiences of VL, I utilised Fisher and Marshall's (2009) classification to interpret the mean scores of the five-point Likert scale. Table 5 below shows the mean score classification.

Table 5: Classification of mean scores

Mean score	Classification
1.0-1.79	Very low
1.8-2.59	Low
2.6-3.39	Medium/Neutral
3.4-4.19	High
4.2-5.0	Very high

5.3.1 RESEARCH QUESTION ONE (RQ1)

This section presents the results that aim to answer the question:

- What are rural Life Sciences teachers' views and understanding of the integration of Virtual Lab in classroom practice?

5.3.1.1 Life Sciences Teachers' Perceptions of VL for Rural Teaching

RQ1 aimed to understand and explain Life Sciences teachers' perceptions of VL for rural teaching. I addressed RQ1 using the three components of TAM, i.e., PEOU, PU, and BI of VL for rural science teaching. The quantitative data for RQ1 were generated using the close-ended questionnaire and triangulated with the qualitative semi-structured interview data. Table 6 below shows descriptive statistics results of the TAM variables related to the Life Sciences teachers' perceptions of VL.

Table 6: Descriptive statistics for TAM variables PEOU, PU, and BI

Factor	N	Mean	SD	Min	Max
PEOU	186	3.7581	0.7754	1.00	5.00
PU	186	3.8952	0.6476	2.00	5.00
BI	186	3.9651	0.5028	2.00	5.00

Table 6 displays the results of the statistical analyses, demonstrating that Life Sciences teachers held strong positive perceptions towards VL. This was evident in the mean scores of all individual items, which were consistently higher than (M = 3.7). Furthermore, the standard deviation of the individual items was low, ranging from (SD = 0.5028 to 0.7754), indicating a high level of agreement among teachers in their

perceptions. The high positive perceptions of the teachers toward Virtual Lab for all the TAM variables are encouraging as this may point to a higher probability of the successful adoption of VL in rural teaching. Of note, BI received the highest mean score and the lowest standard deviation (M = 3.9651, SD = 0.5028). The high mean value and low standard deviation for BI reveal a strong agreement among teachers that they are enthusiastic about using VL in their teaching. This finding suggests that Life Sciences teachers are eager to adopt VL into their classrooms.

Moreover, the computations in Table 6 above indicate that the PU of VL for rural science teaching received a higher mean rating (M = 3.8952, SD = 0.6476) compared to the PEOU (M = 3.7581, SD = 0.7754). This observation suggests that the Life Sciences teachers placed more value on the benefits of VL rather than its ease or difficulty of use. This finding indicates that the surveyed teachers in rural schools recognise the value of incorporating VL into their teaching as a science teaching-learning platform. Furthermore, the analysis revealed more significant agreement among teachers regarding the usefulness of VL (indicated by a lower standard deviation of PU with SD = 0.6476) compared to its ease of use (indicated by a higher standard deviation of PEOU with SD = 0.7754). This revelation highlights the importance of the PU of VL for successful adoption in rural schools. Overall, the statistical findings indicate that the Life Sciences teachers understood the potential benefits of VL and were motivated to adopt it into their classrooms, as demonstrated by their firm BI to use VL (M = 3.9651, SD = 0.5028). The subsequent sub-section presents descriptive statistics for each TAM factor (PEOU, PU, and BI), which are triangulated by the findings from the semi-structured interviews.

5.3.1.2 Perceived Ease of Use (PEOU)

The survey questionnaire included four Likert scale statements on PEOU. Table 7 below presents the findings for the statements.

Table 7: Descriptive statistics - Perceived ease of use (n=186)

Statement	Mean	SD	Min	Max
Learning how to teach with Virtual Laboratory is easy for me.	3.677	0.9260	1.0	5.0
I find it easy to teach Life Sciences experiments with Virtual Laboratory.	3.817	0.9235	2.0	5.0
I find it easy to become skilful in teaching with Virtual Laboratory.	3.801	0.9054	2.0	5.0
I find Virtual Laboratory easy to use.	3.737	0.9475	1.0	5.0

Overall mean (3.7581), Standard deviation (0.7754)

The analysis of PEOU statements sought to understand the degree to which Life Sciences teachers perceive VL to be user-friendly and intuitive for rural teaching. Of particular interest was how teachers perceived the learning curve for using VL to be manageable, as reflected by the high overall mean score for PEOU (M = 3.7581, SD = 0.7754). This finding is crucial because ease of use can be a critical predictor for teachers' willingness to adopt new educational technologies, such as VL. Analysis of the individual PEOU items indicates a strong positive perception (M = 3.677, SD = 0.9260) that "learning to teach with Virtual Laboratory is easy," despite high variability in responses away from the mean. When asked during the interviews, three out of the four teachers (excluding LST3) stated that learning to teach with VL is easy as the programme has step-by-step instructions, as reflected in the following statement:

> As a teacher, I appreciate the user-friendly nature of Virtual Lab with its easy-to-follow instructions and demonstrations. It makes it easy for me to teach experiments like food tests, where chemicals are not readily available at my school. With Virtual Lab, I could simply choose the experiment, and learners could observe real-time results, making the learning process much easier and more engaging. (LST1)

The perception by LST1 is noteworthy, as it suggests that the Life Sciences teachers in rural schools may be receptive to adopting VL for teaching purposes. Further analysis of the survey findings indicates that the greatest mean value (M = 3.817, SD

= 0.9235) was recorded for the statement, “I find it easy to teach Life Sciences experiments with Virtual Laboratory.” Although responses substantially varied, as reflected by the high standard deviation (SD = 0.9235), it is worth noting that most surveyed teachers did perceive that VL was easy to use and, in turn, perceived that it would make their teaching easier. The teachers’ PEOU of VL was investigated further during the interviews. Specifically, the teachers were asked if they perceive that using VL makes their teaching easier, with further probes on the VL ease of use. The interview data confirmed the questionnaire data, as evidenced by the following statements:

> The Virtual Lab is a lifesaver. Ours is a poor rural school deep in the rural, lacking science equipment. But with Virtual Lab, teaching science can be a breeze. The best part is that even the kids can get it [science concepts] faster. (LST4)

LST4 added that:

> So, I have been using this Virtual Lab thing to show some experiments to my learners, and it has been pretty awesome. They seem to get into it and are interested in what is happening. And when they are invested in the material, it is way easier for me to teach them the concepts I had planned. It is like magic! (LST4)

Examining the teachers’ interview responses reveals that their perception of VL’s ease of use was multi-dimensional. The teachers perceived VL was easy to use, translating to making their teaching easier in different ways. For example, LST2 perceived that VL enables the teaching of experiments that would be impossible to conduct because of the high cost of the equipment and chemicals required. He stated as follows:

> Virtual Lab makes teaching Life Sciences easier for me. My school is in a rural area with budget constraints, and physical science equipment is expensive. With Virtual Lab, all the equipment needed for experiments is available virtually, so my school does not need to buy any physical equipment. (LST2)

He further indicated that VL could make teaching easier due to its accessibility anywhere, anytime. This is in addition to the opportunity that learners can have to repeat experiments as many times as required for them to grasp the concepts:

> Virtual Lab is a valuable resource even when learners cannot attend school due to holidays or other circumstances. My learners can perform experiments remotely from home, making teaching more flexible and accessible. This also allows learners to repeat experiments at their own pace and location, leading to a better understanding of the concepts taught. (LST2)

Of interest was also a perception that the teachers “found Virtual Laboratory easy to use” (M = 3.737, SD = 0.9475), which garnered a slightly lower mean score but still suggested positive perceptions of ease of use. Furthermore, the survey findings showed that the teachers thought “they find it easy for them to become skilful in teaching with Virtual Laboratory” (M = 3.801, SD = 0.9054). The interview statements echoed the survey results in this aspect. For instance:

> I must say, Virtual Lab is pretty user-friendly, and I could figure it out without too much trouble for the stuff I was trained on. I am not an expert on all the bells and whistles of the platform, but I am pretty sure I could learn more and use it for teaching in different ways if I give myself some time to play around with it. (LST4)

Although most Life Sciences teachers perceived VL as easy to use, making it easier for them to teach, some in the interviews voiced that the technology was not as easy for them to use. For example, LST3 stated as follows:

> Navigating through the different experiments of Virtual Lab was difficult for me, and I had to spend some time figuring out how to use the software properly. (LST3)

Overall, the descriptive statistics for PEOU revealed a mean score of (M = 3.7581, SD = 0.7754), making PEOU the third most influential construct shaping Life Sciences

teachers' perceptions of VL for rural teaching. This indicates that the teachers perceive VL as user-friendly and easy to navigate. However, the SD value (0.7754) suggests some variability in teachers' perceptions, reflecting mixed perceptions of the PEOU items. This finding was not unexpected due to the newness of VL. Thus, while VL may be easy to use, some teachers felt they had limitations in terms of its optimal use. Taken together, the quantitative and qualitative findings suggest that to effectively promote the adoption of VL among Life Sciences teachers in rural schools, it will be essential to ensure that VL is perceived as easy to use and can boost teachers in becoming proficient users. In the subsequent sub-section, the focus shifts to exploring VL's perceived usefulness among teachers in rural teaching.

5.3.1.3 Perceived Usefulness (PU)

The teachers were requested to indicate their responses to four Likert scale statements for the perceived usefulness of VL. Table 8 below shows the results.

Table 8: Descriptive statistics: Perceived Usefulness (n=186)

Statements	Mean	SD	Min	Max
Using Virtual Laboratory enables me to teach lab practicals more quickly.	3.903	0.9072	1.0	5.0
Using Virtual Laboratory enhances the quality of my Life Sciences teaching.	3.876	0.8766	2.0	5.0
Using Virtual Laboratory makes it easier to do my work.	3.930	0.8256	1.0	5.0
I find Virtual Laboratory useful in my work as a Life Sciences teacher.	3.871	0.8412	2.0	5.0

Overall mean (3.8952), Standard deviation (0.6476)

Table 8 shows that the mean score for PU of VL (M = 3.8952, SD = 0.6476) was greater, on average, compared to that for PEOU (M = 3.7581, SD = 0.7754). As discussed earlier, this may suggest that the surveyed teachers valued the usefulness of VL more than its ease of use. Moreover, the lower standard deviation value of PU (SD = 0.6476) compared to PEOU (SD = 0.7754) indicates that teachers agreed more on the usefulness of VL in their teaching than on its ease of use. When examining the individual PU statements, it can be seen that the teachers agreed that "using Virtual

Laboratory makes it easier to do their work" (M = 3.930, SD = 0.8256) and "using Virtual Laboratory enables them to teach lab practicals more quickly" (M = 3.903, SD = 0.9072). This observation was corroborated by the interview findings when the teachers reported that VL could help use teaching time judiciously and facilitate quicker learning of science concepts. This was expressed, for example, by LST3's narrative below:

> Virtual Labs can be time-saving since physical labs require setup time for the apparatus before conducting experiments and cleaning up and packing after experiments. Virtual Lab eliminates these hassles, making them a more efficient use of time. (LST3)

Furthermore, when analysing the teachers' responses to PU questionnaire items 2 and 4, it becomes clear that they perceived VL as a platform that could augment the quality of their Life Sciences teaching. This observation is evidenced by the high mean scores for item 2, "Using Virtual Laboratory enhances the quality of my Life Sciences teaching" (M = 3.876, SD = 0.8766) and item 4, "I find Virtual Laboratory useful in my work as a Life Sciences teacher" (M = 3.871, SD = 0.8412). Therefore, the perceived usefulness of VL was an essential consideration for the teachers in deciding whether to use it in their classrooms. The statements below, extracted from the interviews, corroborate the survey findings, indicating that the teachers perceived VL as beneficial and valuable in enhancing their teaching.

> Virtual Lab saves teachers time by eliminating the need for one-on-one assistance. As learners become more familiar with the programme, it can provide instructions on its own, freeing up more time for assessment. This promotes learner motivation and more effective use of classroom time, resulting in better learning outcomes. (LST1)

While the interview questions' primary focus revolved around VL's usefulness in teaching, it is noteworthy that certain teachers also highlighted its advantages for learning purposes. This suggests that VL might positively influence not only the teaching process but also the overall learning experience for learners. This narrative is illuminated in LST1's statement below:

> Virtual Lab allows learners to repeat experiments as many times as needed to comprehend a particular concept, which is not always possible in physical labs due to limited resources. (LST3)

Furthermore, the following comments indicate that the teachers perceived VL as useful in resource-constrained rural schools.

> As teachers and learners from disadvantaged communities, we lack the resources for building and conducting experiments in traditional physical labs. However, with Virtual Lab, we can conduct experiments at a lower cost, using the laptops available in our schools and tablets provided to learners by the department. (LST2)

> Given that we teach in quintile one schools where we have limited funding to purchase adequate science teaching equipment, Virtual Lab proves invaluable as it offers a diverse range of opportunities for me to introduce my learners to practical experiments that would be otherwise impossible. (LST3)

According to LST1, VL's perceived usefulness centred around its ability to enable learning anywhere and anytime. She stated as follows:

> Another point is that the experiences of the COVID-19 pandemic have taught us that there are times when teaching and learning may be impossible within school premises. In such cases, I see Virtual Lab as useful for learning anywhere, anytime. (LST1)

On the other hand, LST1, LST2, and LST4 particularly perceived VL as a safe platform for conducting experiments, as shown by the statements below:

> I had a personal experience with an experiment that involved cutting an onion, and one of my learners accidentally cut themselves. This highlights a potential danger when conducting experiments in real-life settings. However, with Virtual Lab, such risks can be avoided altogether. (LST1)

> Virtual Lab is the coolest way to experiment without worrying about getting hurt. Say goodbye to the old-school labs with their spills and potential dangers. With Virtual Lab, you can get as wild and creative as you want without any worries. It is safer and more cost-effective than buying all the equipment yourself. It is a total win-win situation. (LST4)

> Virtual Lab accommodates different learning paces and styles, including disabled learners who may find it easier to use as everything is accessible in one place. (LST2)

The above teacher narratives highlight their perceptions of the usefulness of VL as a safe environment for learners to conduct experiments. Furthermore, the modern-day learner is presented with a plethora of choices, primarily due to the ubiquitous presence of smartphones and tablets. This allows them to manage their learning time in formal face-to-face settings, such as the classroom, and in non-traditional environments, such as private and public spaces. The following quotations substantiate this paradigm shift:

> Lots of learners nowadays have smartphones and tablets. And with Wi-Fi being available in so many public places, they can use their devices to run experiments even when not in school. It is pretty cool that they have more learning time outside of regular class hours if they want it. (LST4)

Overall, the teachers rated the PU of VL for rural teaching (M = 3.8952, SD = 0.6476) as important. This view led PU to receive the second-highest score, behind BI. The teachers' responses to the PU statements showed little difference, with mean scores for each statement being very close and standard deviation scores ranging from (SD = 0.8256 to 0.9072). Furthermore, the perceived ability of VL to enable the teachers to "teach lab practicals more quickly" was the second most crucial determinant for the teachers' adoption of VL. The teachers seemed to understand that the less time spent making learners understand concepts, the more productive the lesson. Thus, Life Sciences teachers in rural schools may be inclined to adopt VL as an efficient platform that needs less time to realise the pedagogical objectives of the lesson.

The combination of the questionnaire and interview results indicates that Life Sciences teachers in rural schools view VL as crucial for improving their work. They recognise that VL helps them complete tasks more efficiently and enhances their teaching. Based on this result, PU of VL stands out as the foremost determinant that predicts BI toward adopting the technology. This finding endorses the notion that the PU of VL is a robust indicator of Life Sciences teachers' inclination to adopt this technology into their future pedagogical practices. Notably, this investigation did not seek to explore the actual efficacy of VL in teaching, which could be a promising avenue for future research. The subsequent subsection presents the results concerning the behavioural intention of Life Sciences teachers to employ VL for rural teaching.

5.3.1.4 Behavioural Intention (BI)

Table 9 below presents the findings for the respondents' behavioural intention to use VL.

Table 9: Descriptive statistics: Behavioural Intention to use Virtual Lab (n=186)

Statement	Mean	SD	Min	Max
I intend to use Virtual Laboratory more when teaching Life sciences through experiments.	3.871	0.6932	2.0	5.0
I would like to use Virtual Laboratory in all my experiments.	3.935	0.7249	2.0	5.0
I would recommend using Virtual Laboratory to others.	4.043	0.6883	2.0	5.0
I intend to use Virtual Laboratory more to enhance my Life sciences teaching.	4.011	0.6896	2.0	5.0

Overall mean (3.9651), Standard deviation (0.5028)

Table 9 reveals that the Life Sciences teachers in rural schools rated the BI construct as the most significant among the three constructs for teacher perceptions, garnering an overall mean score (M = 3.9651, SD = 0.5028). The high overall mean score for BI suggests a solid intention to adopt Virtual Lab by the teachers in their future lessons. Specifically, the BI item "I intend to use Virtual Laboratory more to enhance my Life Sciences teaching" was the most robust indicator of the teachers' willingness to continue using VL, with the greatest mean rating (M = 4.011, SD = 0.6896). The

descriptive statistics also show high agreement among the intentions to use VL. When explored through semi-structured interviews, all the teachers articulated a willingness to use VL in their future lessons. The teachers were specifically asked whether they think they will use VL in the future, and the interview findings were consistent with the questionnaire results on BI. The following interview comments highlight the teachers' intention to use VL.

> I think I will use Virtual Lab going forward. You see, as a poor community, we need alternative ways of exposing our learners to those scientific experiments. Conducting experiments with our kids is a necessity. So far, Virtual Lab seems to be our only option. Besides, technology has come to stay, so we must embrace it. (LST3)

Perhaps a more exciting response to whether she intends to use VL came from LST1, who stated as follows:

> I would say it is even late. Based on my experience with Virtual Lab, I feel it should have been here long ago. I say this because I see the limitless opportunities that Virtual Lab can offer in helping teachers to teach science more meaningfully. (LST1)

In addition, to LST1's views, LST2 added as follow:

> Virtual Lab can potentially transform science education, especially in rural schools where resource limitations often prevent learners from developing a strong foundation in the subject. By providing learners with access to a wider range of scientific experiences, Virtual Lab could inspire more learners to pursue science-related careers. (LST2)

The quotes above indicate that the Life Sciences teachers in rural schools firmly intend to adopt VL. Furthermore, analysis of the BI items also shows a very high mean score for the item "I would recommend using Virtual Laboratory to others" ($M = 4.043$, $SD = 0.6883$). A narrow range of perceptions was also reflected in the high agreement among the teachers in their intention to recommend VL to others, as indicated by the

standard deviation value (SD = 0.6883). In attempting to investigate the degree of the teachers' intention to use VL, I posed a question during the semi-structured interviews: "Based on your experience with VL, do you encourage all Life Sciences teachers to consider using it?" In this regard, the following teacher narratives illustrated their intention to encourage others to adopt VL.

> I strongly encourage teachers, especially those working in resource-poor schools like mine, to adopt Virtual Lab. This will enable learners in these schools to conduct experiments and gain exposure to scientific concepts that may not have been otherwise accessible due to a lack of physical laboratory resources. With Virtual Lab, even schools without actual labs can offer their learners similar learning opportunities as those with fully equipped laboratories. (LST3)

> And then this Virtual Lab is very cost-effective, captures learners' interest in science, and I believe it can make a huge difference in effective science teaching. (LST1)

> I highly encourage teachers to utilise Virtual Lab in their teaching. The potential for Virtual Lab to improve learners' performance is immense, as it enables students to gain exposure to scientific investigations, which can help them answer exam questions related to experiments. I strongly encourage using Virtual Lab, especially in resource-constrained rural schools like mine. (LST2)

Other BI items, such as "I would like to use Virtual Laboratory in all my experiments" (M = 3.935, SD = 0.7249) and "I intend to use Virtual Laboratory more when teaching Life Sciences through experiments" (M = 3.871, SD = 0.6932), also received high levels of agreement among the teachers. Notably, most Life Sciences teachers expressed a firm view that VL represents the future of science education in rural schools. They demonstrated a solid intention to incorporate VL into their future classrooms, with a clear behavioural commitment to using it for the benefit of their learners. The teachers' opinions were notably optimistic in this regard, as they firmly

believed in the potential advantages of VL for enhancing the learning experiences of their learners:

> Yes, using a Virtual Lab would be awesome. It is not the only way to learn, but it is cool because you can do so much with it. You could get kids involved by giving them tablets or laptops and letting them experiment and develop their own ideas. It is great because they can learn a lot by doing things themselves rather than just reading about them in a book. That is how the world is going - more and more toward technology. (LST4)

The above statements suggest that the teachers' positive BI towards using VL can positively influence their integration of the tool in their classrooms. Therefore, from these findings, the successful adoption of VL into rural science teaching can be anticipated. However, whether the Life Sciences teachers' positive behavioural intentions would translate into using VL in their teaching was outside the scope of this investigation but would be a future research area of interest. The subsequent section presents the findings that specifically addressed Research Question 2.

5.3.2 RESEARCH QUESTION TWO

This section's results addressed the question:

- What are rural Life Sciences teachers' experiences concerning the integration of Virtual Lab into science teaching?

5.3.2.1 Life Sciences Teachers' Experiences of Virtual Lab

RQ2 sought to examine the experiences of Life Sciences teachers in using VL for rural teaching, focusing on three TAM factors: social influence (SI), facilitating conditions (FC), actual usage (AU), and the factors impacting the use of VL in rural schools. By investigating the three determinants of TAM, I aimed to explore the factors that can shape rural Life Sciences teachers' acceptance and successful adoption of VL in teaching. I triangulated quantitative and qualitative results to acquire a nuanced and comprehensive analysis of the lived and reported experiences of the Life Sciences teachers when using VL in rural schools. Table 10 below shows the computed

descriptive statistics for SI, FC, and AU constructs and factors impacting the use of VL.

Table 10: Descriptive statistics for TAM with four variables

Factor	N	Mean	SD	Min	Max
SI	186	3.6172	0.6212	2.00	5.00
FC	186	3.0672	0.8835	1.00	4.00
AU	186	2.4796	0.9312	1.00	4.00
Factors Impacting the Use of Virtual Laboratory	186	3.4183	0.5200	2.00	5.00

The results presented in Table 10 demonstrate a wide range of responses from the surveyed Life Sciences teachers regarding their experiences of using VL, with mean scores spanning from (M = 2.4796 to 3.6172). The standard deviations also varied, ranging from (SD = 0.5200 to 0.9312). The investigation uncovered that SI garnered the highest mean value (M = 3.6172, SD = 0.6212), highlighting its perceived significance in facilitating successful VL adoption. This noteworthy finding suggests that the perceptions of those in the teacher's social network, including family, friends, and parents of learners, play a vital role in promoting effective VL integration into teaching. Future research could shed light on parents' perceptions of VL in their children's learning, as parents' views are often missing in the teaching-learning discourse.

Furthermore, the second-highest mean score was associated with the factors impacting the use of VL for rural science teaching (M = 3.4183, SD = 0.5200), indicating that teachers encountered multiple factors that impacted their use of VL. More so, the lowest standard deviation value was recorded for the factors influencing the use of VL (SD = 0.5200), suggesting that most teachers agreed with the impact of the factors, with only a few expressing differing opinions. Regarding FC, the teachers responded neutrally (M = 3.0672, SD = 0.8835), indicating that they most probably did not feel that their school's conditions were conducive to effectively integrating VL into teaching. Of the four variables investigated under teachers' experiences of VL, AU registered the lowest mean score (M = 2.4796, SD = 0.9312), showing that most

surveyed teachers did not agree that they used VL. This outcome was not surprising, given that VL is an emerging technology that has yet to be widely adopted and used.

Notably, although AU had the lowest mean score (M = 2.4796), some teachers used Virtual Lab in their teaching without guidelines from the DBE, indicating that advancement is being made in this area. More so, the high standard deviation value for AU (SD = 0.9312) suggests a broad range of experiences regarding Virtual Lab usage for rural science teaching. The upcoming sub-section provides the descriptive statistics of the statements for each variable (SI, FC, AU, and the factors influencing VL use for rural science teaching), along with the semi-structured interview findings.

5.3.2.2 Social Influence (SI)

In this study, SI refers to the impact of interpersonal relationships and social norms on the teachers' perceptions and behaviours towards adopting VL. Specifically, for this study, I report on the influence of colleagues, learners, school managers, and the teachers' families and friends on the acceptance and use of VL. By understanding the social dynamics and support systems within rural school communities, I aimed to uncover the role of SI in how the encouragement and endorsement of VL by peers and school leaders can foster a positive environment for its adoption and usage. The results are shown in Table 11 below.

Table 11: Descriptive statistics: Social influence (n=186)

Statements	Mean	SD	Min	Max
My peers think that I should teach with Virtual Laboratory.	3.651	0.8130	1.0	5.0
My family and friends think that I should teach with Virtual Laboratory.	3.790	0.7527	2.0	5.0
My learners think that I should teach with Virtual Laboratory.	3.742	0.9053	1.0	5.0
My School Management Team think that I should teach with Virtual Laboratory.	3.554	0.8882	1.0	5.0
My school community generally supports teaching with Virtual Laboratory.	3.349	0.9191	1.0	5.0

Overall mean (3.6172), Standard deviation (0.6212)

The computed descriptive statistics in Table 11 above show that SI was the most crucial factor in the teachers' experiences with VL, as demonstrated by the high mean score of (M = 3.6172, SD = 0.6212). Surprisingly, the item "My school community generally supports teaching with Virtual Laboratory" received the lowest score, with most teachers indicating neutrality towards it, possibly due to the novelty of the technology. However, the fact that VL is still in its infancy in SA suggests that this rating might shift in future research. In contrast, the high mean score (M = 3.790, SD = 0.7527) recorded for "my family and friends think that I should teach with Virtual Laboratory" implies that teachers might have discussed VL with those close to them, which suggests that people tend to share similar views when something is perceived as useful.

Furthermore, the second high-ranked mean (M = 3.742, SD = 0.9053) recorded for "My learners think that I should teach with Virtual Laboratory" is noteworthy. This result highlights learners' influence in shaping the teachers' decisions to adopt VL in their teaching. Since learners are the focal point of all teaching initiatives, all technology-related interventions should aim to facilitate effective learning in classrooms. However, this research did not seek to explore learners' perceptions and experiences of learning with VL, but this could be a worthy future research area. During the interviews, most

Life Sciences teachers cited that the most social influence they experienced was from their learners. This observation corroborated the survey findings in which the item “My learners think that I should teach with Virtual Laboratory” received a high mean score (M = 3.742, SD = 0.9053), as I indicated earlier. The teachers responded to a specific interview follow-up question, “What was the atmosphere or the feedback from your learners in the class after you exposed them to Virtual Lab? The teachers responded as follows:

> My learners were very enthusiastic about using Virtual Lab as it is a novel platform. They were keen to explore and understand how to conduct experiments using it. They are even eager to see me teach them using this technology. (LST3)

> My learners found it [Virtual Lab] very interesting because they were experiencing it for the first time, so it excited them, and they said they wanted to learn more with it. (LST1)

In addition to the learners’ interest in VL, LST2 revealed another crucial aspect, i.e., learner motivation. He stated as follows:

> My learners were very excited and motivated because they had never conducted experiments in a real lab. Using Virtual Lab has given them a new perspective on learning science, and they want me to use it in my teaching. (LST2)

Surprisingly, further analysis of the individual items “My peers and colleagues think I should teach with Virtual Laboratory” (M = 3.651, SD = 0.8130) and “My School Management Team think that I should teach with Virtual Laboratory” (M = 3.554, SD = 0.8882) received lower ratings than “My family and friends think that I should teach with Virtual Laboratory” (M = 3.790, SD = 0.7527). This finding challenged my initial expectation that colleagues and SMTs would be more knowledgeable about VL and provide more support to their peers. This observation highlights the potential role of family and friends in successfully adopting new technologies. It could also indicate a lack of support from colleagues and SMTs in adopting new technologies.

While there seems to be congruency between quantitative and qualitative findings regarding the learners' influence on the teachers to use VL, there was a divergence between the quantitative and qualitative results in that family and friends' influence did not come out in the interview. This is despite the item "My family and friends think that I should teach with Virtual Laboratory", which received the highest mean rating (M = 3.790, SD = 0.7527) in the questionnaire. One possible reason for this non-convergence could be attributed to sampling. It is most probable that most participants whom family and friends influenced, as captured in the survey, might not have been the ones that were sampled for the semi-structured interviews.

Moreover, similar to the survey findings were "My School Management Team think that I should teach with Virtual Laboratory" (M = 3.554, SD = 0.8882) and "My school community generally supports teaching with Virtual Laboratory" (M = 3.349, SD = 0.9191) received the lowest mean ratings of the SI items, none in the interviews mentioned any form of influence from within the school other than their learners. This is an important finding that shows that most teachers draw their inspiration and motivation from seeing their learners showing interest in their efforts. On the other, the discovery reveals a need to involve all staff members in a school when new initiatives are being introduced to ensure peer support. The following sub-section delves deeper into the facilitating conditions for VL in teaching.

5.3.2.3 Facilitating Conditions (FC)

The present research views FC as the presence of the necessary support, resources, and infrastructure for using VL effectively. Considering the resource constraints often encountered in rural schools, I sought to identify the factors that encourage or hamper the use of VL in teaching, such as access to reliable internet connectivity, availability of devices, technical support, and professional development opportunities. By exploring these facilitating conditions, I aspired to understand the practical considerations influencing the teachers' experiences with VL. I included four Likert scale statements on FC in the questionnaire, as shown in Table 12 below.

Table 12: Descriptive statistics: Facilitating Conditions (n=186)

Statement	Mean	SD	Min	Max
The necessary resources (e.g., computer hardware and software) are available for me.	3.349	1.0457	1.0	5.0
I can access the Internet very quickly within my school.	3.027	1.1645	1.0	5.0
Guidance is available to me to effectively teach with Virtual Laboratory.	2.919	0.9636	1.0	5.0
A particular person (or group) is available for assistance when teaching using Virtual Laboratory.	2.973	1.1267	1.0	5.0

Overall mean (3.0672), Standard deviation (0.8835)

The descriptive statistics in Table 12 show that the overall mean score for FC was (M = 3.0672, SD = 0.8835), suggesting that most teachers answered neutrally to the FC items statements. This finding indicates that most Life Sciences teachers in rural schools may be uncertain about which factors can enable or constrain teaching with VL. This result is not unexpected because as VL is a new technology in SA, most teachers would not have been conversant with factors that impact its use. When analysing the mean scores of the individual FC items, one can see a wide range of mean scores from (M = 2.919 to 3.349). This finding suggests a diverse range of experiences among teachers regarding the conditions that facilitate or hinder the successful adoption of VL in rural schools. Furthermore, the analysis of standard deviations revealed that most SD values were greater than 1, indicating high variability in the teachers' responses per statement, which is expected due to the novelty of the technology.

Specifically, the statement "The necessary resources (e.g., computer hardware and software) are available for me" recorded the highest mean value of (M = 3.349, SD = 1.0457). This observation is unsurprising since the ECDoE provided all schools with technology tools, such as computers, which most teachers can access. During the interviews, the teachers expressed more detailed and elaborative responses regarding their experiences with the facilitating conditions. The teachers were explicitly answering the question: "Based on your experience of teaching with VL, what factors

do you believe can either encourage or hinder the use of Virtual Lab by teachers?" The teachers provided the following responses:

> Having enough resources is the most important of all. (LST1)

> Teachers must be provided with all the necessary equipment. They should get all the support from the [school] management. (LST3)

In addition to the need for adequate resource provisioning, LST4 and LST2 further highlighted the need for suitable training. They stated as follows:

> There is a potential roadblock we need to watch out for - some teachers might not be tech-savvy, and that could hold them back. To overcome this, these teachers will need to get trained on using Virtual Lab platform. (LST4)

> The teachers should have adequate training to conduct these experiments. (LST2)

Furthermore, questionnaire items such as "Guidance is available to me to effectively teach with Virtual Laboratory" (M = 2.919, SD = 0.9636) and "A specific person is available for assistance when teaching with Virtual Laboratory" (M = 2.973, SD = 1.1267) had the lowest mean scores. These findings indicate that most Life Sciences teachers in rural schools lack adequate guidance and support when using VL. The teachers also affirmed the importance of receiving administrative and technical guidance and support. The following quotes exemplify their perspective:

> It is an embarrassment when you are all set to use the technology for your class, but they always have technical issues. That is why it is important to have technical support available at the school to address these problems. (LST4)

> Technology glitches can be a major setback, causing a loss of teaching time. So, while technology is useful, it can also be problematic. (LST1)

> I struggled with certain aspects of using Virtual Lab, and my learners could often tell that I was having difficulty. Unfortunately, no one was available to assist me with these challenges at school. (LST2)

The lack of support, as indicated by the interview excerpts, could be attributed to the novelty of the technology, where many teachers still require training and guidance to use VL effectively. Since VL is a relatively new tool in education, it is natural for teachers in rural schools to face challenges when incorporating it into their teaching. Nonetheless, the absence of people with the requisite expertise to support teachers' VL use is a crucial factor that requires attention if VL integration is to be a success. Therefore, this study's findings underscore the notion that schools that lack adequate technical and administrative support and the necessary resources will face challenges in successfully adopting VL.

In sum, one can argue that if teachers have a positive perception of VL and have the necessary resources and support to use it, they are likelier to adopt and use it effectively. Furthermore, the findings for FC suggest that Life Sciences teachers in rural schools require a robust support network to help them navigate the challenges they experience as they integrate VL into their teaching. The following sub-section presents findings on Life Sciences teachers' actual usage of VL.

5.3.2.4 Actual Usage (AU)

For this study, AU examines the extent to which Life Sciences engage with and utilise VL in their teaching. I aimed to investigate usage patterns and provide insights into the alignment or misalignment between perceived benefits and realised outcomes. The questionnaire included five Likert scale statements on AU of VL. The statements are shown in Table 13 below.

Table 13: Descriptive statistics: Actual usage of Virtual Lab for rural teaching (n=186)

Statements	Mean	SD	Min	Max
I use the Virtual Laboratory when teaching Life sciences experiments.	2.220	1.0133	1.0	4.0
I use the Virtual Laboratory when preparing my lessons.	2.414	1.1743	1.0	5.0
I use the Virtual Laboratory to enhance my Life sciences teaching.	2.435	1.0997	1.0	5.0
I use Email for student contact and to give my advice	2.253	1.1129	1.0	5.0
I tend to use the Virtual Laboratory for as long as is necessary.	3.075	1.2454	1.0	5.0

Overall mean (2.4796), Standard deviation (0.9312)

The statistics in Table 13 above represent the distribution of responses to items about the AU of VL. The item “I use Virtual Laboratory when teaching Life sciences experiments” recorded a mean score of (M = 2.220, SD = 1.0133), indicating that, on average, the teachers disagreed with the statement. This finding suggests that most teachers have not used VL. However, while most teachers reported not using VL, some indicated they had experience with the technology. This finding was confirmed by the high standard deviation (SD = 1.0133), demonstrating a high degree of variability in the teachers’ responses.

In contrast, the item “I use Virtual Laboratory when preparing my lessons” and “I use the Virtual Laboratory to enhance my Life sciences teaching” received mean scores of (M = 2.414, SD = 1.1743) and (M = 2.435, SD = 1.0997), respectively. These findings further suggest the Life Sciences teachers’ lack of usage of Virtual Lab. However, the variability of their responses is slightly higher than the former statement, indicating that some teachers used VL to prepare their lessons but not necessarily during teaching. Furthermore, the statement “I use Email for student contact and to give my advice” received a low mean score of (M = 2.253, SD = 0.1129), with some variation in responses, suggesting a disagreement among the Life Sciences teachers. This finding indicates that while some teachers use email to communicate with learners, others prefer other methods, such as WhatsApp or face-to-face interactions.

Finally, for the statement “I tend to use the Virtual Laboratory for as long as is necessary,” the teachers appear neutral on average, with a relatively high degree of variation in their responses, as indicated by a mean score of (M = 3.075, SD = 1.2454). This finding suggests that Life Sciences teachers are flexible in using VL, with some considering using it only when necessary and others using it more frequently.

During the interviews, there was a diversity of viewpoints among the teachers’ experiences regarding VL usage as a teaching tool. While certain teachers, such as LST2, reported the tool to be exceptionally useful in stimulating learner engagement and understanding of complex concepts:

> I have tried to teach with Virtual Lab, which has helped me demonstrate experiments I would not have managed in our school context. (LST2)

Notably, most teachers had reservations about its effectiveness and limitations. They expressed difficulties navigating the tool and noted that it did not always offer the desired level of interactivity and feedback. For example, LST3 reported as follows:

> Since the time I got trained in teaching with Virtual Lab, I never really got to use it in my teaching. I still find it difficult, but with time and more training, I think I will use it more. (LST3)

The low usage of VL, which was also reflected in the survey findings, was not unexpected. This is because VL is a new technology in SA that still has to be diffused into the teaching spaces. Nonetheless, the teachers acknowledged the potential advantages of using VL and understood the requirement for additional support and adjustments to optimise its efficacy. The next sub-section discusses the factors that impact the use of VL for teaching.

5.3.2.5 Factors Impacting the Use of Virtual Lab

The questionnaire included eleven Likert scale items to explore the contextual factors impacting VL use in rural schools. It was critical to investigate the contextual factors to provide nuanced insight into the multifaceted nature of teaching with technology. Factors such as infrastructure and technical support can influence the effectiveness

of VL integration. By considering these factors, I hoped to construct and offer a better understanding and explanations concerning the use of VL for rural science teaching. Additionally, considering contextual factors can help identify how VL can address specific teaching challenges or opportunities unique to those contexts, in this case, the rural settings. Table 14 below shows the results for factors impacting VL.

Table 14: Descriptive statistics: Factors impacting the use of Virtual Lab (n=186)

Statement	Mean	SD	Min	Max
Lack of skills/experience	3.806	0.9445	1.0	5.0
Confidence	3.796	0.8518	1.0	5.0
Insufficient pedagogy and content	2.129	0.8017	1.0	4.0
Lack of professional development/Insufficient training	3.801	0.8563	2.0	5.0
Lack of support	4.027	0.7948	2.0	5.0
Insufficient access to or maintenance of technology	3.194	1.2586	1.0	5.0
Restrictions in educational environment or curriculum	3.000	1.1991	1.0	5.0
Insufficient time	2.876	1.1488	1.0	5.0
Lack of a school-based technician	3.387	1.4221	1.0	5.0
Limited supply of electricity	4.167	0.7705	2.0	5.0
Limited access to high-speed internet	3.511	1.3764	1.0	5.0

Overall mean score (3.4183), Standard deviation (0.5200)

From the questionnaire responses, four factors had the greatest impact on Virtual Lab use: “Limited electricity supply” (M = 4.167, SD = 0.7705), “Lack of support” (M = 4.027, SD = 0.7948), “Lack of skills/experience” (M = 3.806, SD = 0.9445), and “Lack of professional development” (M = 3.801, SD = 0.8563). Of these factors, limited electricity supply emerged during the survey as the most critical constraint to teaching with VL in rural schools. This finding was corroborated by the teachers during the interviews as follows:

> Our country is currently experiencing power cuts, which is a significant challenge for us. Since Virtual Lab relies on electronic devices that require electricity, the lack of power negatively impacts our ability to teach effectively. (LST2)

During load-shedding in SA, the irregular electricity supply may cause some teachers to abandon using VL in teaching. The present study suggests that a reliable electricity supply must be ensured for successful VL integration. Related to the challenge caused by the unstable electricity supply, the teachers also cited “Limited access to high-speed internet” (M = 3.511, SD = 1.3764).

> My school has no Wi-Fi, making it impossible to utilise Virtual Lab meaningfully. (LST3)

> Getting online these days can be a pain, and I think it is partly because of this load-shedding. On top of that, my school does not provide us with any data, so we must use our own data for school stuff. That can get pretty expensive, and we cannot always afford it. (LST4)

> The Internet connection at my school is slow and disappointing, and this problem worsens during those times when there is no electricity. This gives me a big challenge in using Virtual Lab. (LST2)

The excerpts from the interview transcripts shown above demonstrate that the teachers acknowledged facing a plethora of challenges related to a lack of resources. Moreover, lack of support was rated as another crucial factor that impacted the use of VL in teaching (M = 4.027, SD = 0.7948). In particular, pedagogical and technical support distinguished themselves as necessities for successfully adopting VL in rural schools. Furthermore, lack of skills/experience (M = 3.806, SD = 0.9445) and lack of professional development (M = 3.801, SD = 0.8563) were also important factors that impacted VL use. More so, the teachers felt that continuous teacher development (TD) workshops on using VL in teaching should be provided. The interview findings mirrored the survey findings regarding “lack of professional development/insufficient training” (M = 3.801, SD = 0.8563), as shown by the following statements:

> My training was not adequate because there is more that I still need to learn about how to teach using Virtual Lab. Although the training opened my eyes, and I can conduct basic experiments, I feel like there is so much that I need to learn, so I need more. (LST1)

> Virtual Lab can only be effective if all the teachers are given suitable training and professional development so that teachers can integrate the technology in the classroom meaningfully. (LST3)

> Virtual labs show that technology is evolving rapidly, and without ongoing professional development, teachers will struggle to integrate it into their classes. Despite attending technology training, I have found it insufficient to cover everything that needs to be done. (LST2)

Based on the interview excerpts, adequate VL training will be crucial for successfully adopting this technology. On the other hand, “insufficient access to or maintenance of technology” (M = 3.194, SD = 1.2586), “restrictions in the educational environment or curriculum” (M = 3.000, SD = 1.1991), “insufficient time” (M = 2.876, SD = 1.1488), and “insufficient pedagogy and content” (M = 2.129, SD = 0.8017) had lower mean scores in the survey findings. These findings indicate that these factors were less critical to using VL for rural teaching. However, the high variability in the teachers’ responses showed that some teachers’ opinions differed from most of the group. The survey findings indicated that insufficient time was not a significant concern for the teachers. The teachers disagreed that time was a setback (M = 2.129, SD = 0.8017). However, during the interviews, worry about time emerged from one teacher:

> I may be able to utilise Virtual Lab during class if I have more spare time, which is a rarity for me. (LST3)

Overall, “insufficient pedagogy and content” was rated as the least important factor when using VL because the teachers believed in their content and pedagogical knowledge competency. These knowledge types did not limit their adoption of VL in teaching. This finding is not surprising considering that most of this study’s participants had five years of teaching experience and would have significantly developed their pedagogy and content knowledge.

Furthermore, the surveyed teachers agreed they experienced “insufficient access to or maintenance of technology” (M = 3.194, SD = 1.2586). This result was supported by the interview findings where teachers reported a shortage of computers for use by

learners in the classrooms, as shown by the following statements, which exemplify the contexts in most rural schools.

> All that teachers and learners need is access to adequate and suitable technologies for every classroom. We do not have enough computers for all learners, which remains challenging. (LST2)

The statement above indicates that computer shortages and other related tools for learners can negatively affect the adoption of VL in rural schools. The teachers acknowledged that while they have been provided laptops by the ECDoE, the learners do not have access to them, which poses a challenge. Therefore, the availability of adequate computers becomes a critical factor in inspiring teachers to use VL. The following section responds to research question three.

5.3.3 RESEARCH QUESTION THREE

This section's results aimed to address the following question:

- How can rural Life Sciences teachers' perceptions and experiences of the integration of Virtual Lab be understood and explained?

5.3.3.1 Explaining teachers' perceptions and experiences of Virtual Lab

RQ3 sought to explain Life Sciences teachers' perceptions and experiences of VL by considering the influence of teachers' knowledge, i.e., TPACK, on their intention to adopt and use Virtual Lab in their teaching. Considering teachers' TPACK was crucial because although teachers might have positive perceptions of technology, meaningful adoption of such a technology may be affected due to a lack of knowledge and skills to teach with it. Thus, TPACK highlights the importance of acquiring knowledge for teachers to successfully integrate VL in their teaching by emphasizing the interrelationship between content, pedagogy and technology knowledge and the need for teachers to understand how these domains interact. Below are the descriptive statistics for each TPACK domain.

Table 15: Descriptive statistics: TPACK domains

Domain	N	Mean	SD	Min	Max
TK	186	3.4427	1.0000	1.00	5.00
CK	186	4.3091	0.4623	2.00	5.00
PK	186	4.2520	0.3832	2.00	5.00
PCK	186	3.8796	0.6841	1.00	5.00
TPK	186	2.9875	1.0377	1.00	5.00
TPACK	186	3.0269	0.9648	1.00	4.00

Table 15 shows the mean, SD, minimum and maximum values for the six TPACK domains, divided into two groups: three domains related to non-technology topics and three related to technology. The non-technology domains exhibited higher mean scores, all above 3.8, including CK (M = 4.3091, SD = 0.4623), PK (M = 4.2520, SD = 0.3832), and PCK (M = 3.8796, SD = 0.6841). In addition, the standard deviations for these domains were lower, indicating that Life Sciences teachers possessed a more comprehensive knowledge of the subject content and pedagogy. On the other hand, the technology-related TPACK domains had lower mean scores than the non-technology ones, with TK (M = 3.4427, SD = 1.0000), TPK (M = 2.9875, SD = 1.0377), and TPACK (M = 3.0269, SD = 0.9648). This implies that Life Sciences teachers may need to enhance their TK and technology-related pedagogical skills. Figure 8 below provides a graphical representation of the TPACK domains' descriptive statistics. The purpose of the table is to offer a more precise visualisation and facilitate a comparative analysis of the prominence of different knowledge domains.

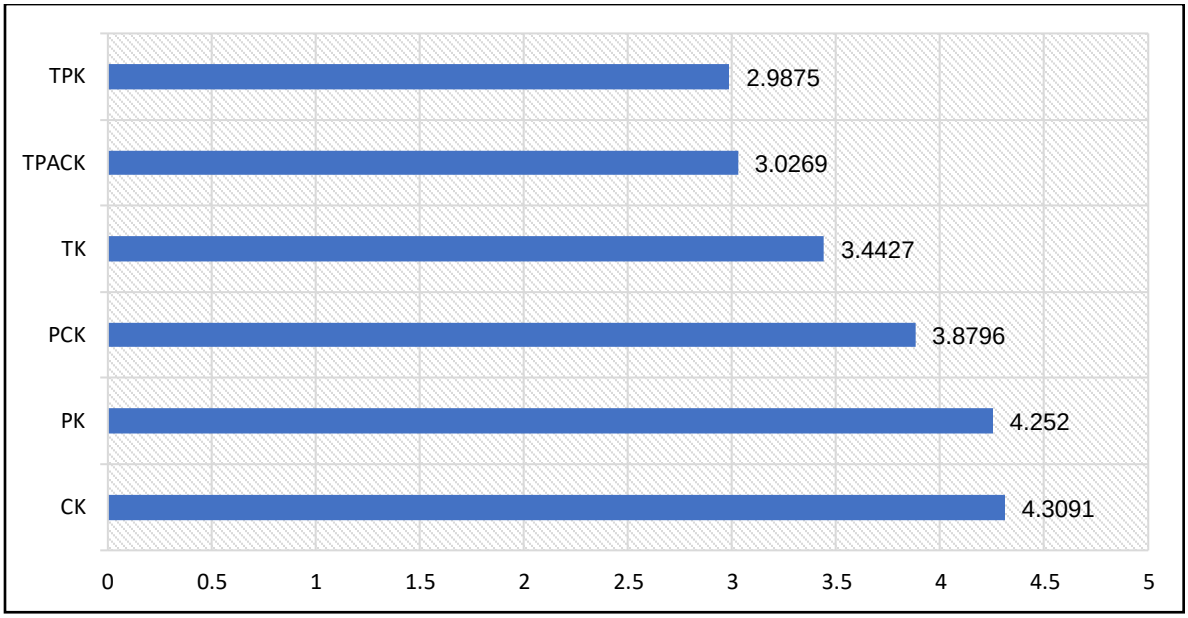

Figure 8. Descriptive statistics. TPACK domains (n = 186)

Notably, the Life Sciences teachers' TK domain was high (M = 3.4427, SD = 1.0000) but dropped when amalgamated with the other two knowledge constructs to form TPK (M = 2.9875, SD = 1.0377) and TPACK (M = 3.0269, SD = 0.9648). These findings suggest that Life Sciences teachers are stronger in their PK and CK than their proficiency in other knowledge domains. This finding underscores the significance of subject content expertise and its effective delivery to learners, highlighting a lower confidence level in their TK. One potential explanation for their high level of CK may stem from the SA education system's emphasis on subject specialisation. As section 5.2 of the study indicates, teachers in SA schools must have a degree in their subjects, equipping them with in-depth CK of their respective fields. Moreover, the focus on improving pedagogical skills during continuous professional teacher development programs may have contributed to their superior PK. Further, the continuous professional teacher development programmes prioritise the content and pedagogical knowledge domains, potentially contributing to the Life Sciences teachers' advanced knowledge in these areas.

Furthermore, the higher TK mean compared to other technology-related domains highlights the importance of TK in particular and its impact on the Life Sciences teachers' use of VL. As discussed earlier, the teachers may benefit from professional development programs that focus on developing their TK and skills to keep up with the

continuous introduction of new technology tools in education. I included non-technology domains CK, PK, and PCK in this study because introducing TK in the teacher knowledge to form TPACK should be grounded in strong CK, PK and PCK. To fully comprehend the Life Sciences teachers' knowledge of technology, content, and pedagogy (TPACK), I analysed each TPACK domain and triangulated the findings with the qualitative results presented in the following sub-sections.

5.3.3.2 Technological Knowledge

The questionnaire asked the participants to respond to the seven items for TK. These statements are shown in Table 16 below.

Table 16: Descriptive statistics: Technological Knowledge (n=186)

Factor	Mean	SD	Min	Max
I can learn to use educational technologies easily.	3.823	1.0218	1.00	5.00
I can teach with the use of different technologies.	3.306	1.1331	1.00	5.00
I often play around with technology tools.	3.387	1.1858	1.00	5.00
I know of a lot of different technology tools.	3.134	1.2426	1.00	5.00
I keep up with important emerging technologies.	3.661	1.0231	1.00	5.00
I know which technologies would work best for my Life sciences teaching.	3.344	1.2169	1.00	4.00

Overall mean score (3.4427), Standard deviation (1.0000)

According to the statistical data presented in Table 16, the Life Sciences teachers in rural schools exhibit high levels of TK based on the mean ratings of all the individual items. Notably, the statement that scored the highest mean rating was related to the teachers' "ability to learn technology easily" (M = 3.823, SD = 1.0218), implying that they possess a certain level of adaptability and willingness to explore new technological tools in their classrooms. This finding was corroborated by the semi-structured interviews in which teachers highlighted the ongoing necessity to stay current with technological advancements in education:

> Staying abreast of new technological advancements is crucial for teachers. Therefore, I must continually educate myself on the latest technology trends to effectively leverage tools like Virtual Lab and ensure that learning remains pertinent for today's learners. (LST2)

> Oh man, have you noticed how many new educational technologies keep popping up these days? Just when you think you have the hang of one, they introduce a new one! It is tough to keep up with the latest trends, so you got to make sure you are always updating yourself. (LST4)

LST2 and LST4 indicate that teachers recognise the importance of staying up to date through ongoing self-development. Furthermore, the survey findings suggest that the Life Sciences teachers hold a high degree of comfort in utilising various technologies in their teaching, as reflected in the similar scores obtained for the items "I frequently play around with technologies" (M = 3.387, SD = 1.1858), "I know which technologies would work best for my Life sciences teaching" (M = 3.306, SD = 1.1331), and "I can teach with the use of different technologies" (M = 3.306, SD = 1.1331). These results suggest that the teachers possess self-assurance in their technological capabilities and are well-equipped to use educational technologies in their pedagogical approaches.

However, the questionnaire findings also demonstrated that the teachers' knowledge of "a lot of different technologies" registered the lowest mean score (M = 3.134, SD = 1.2426), suggesting that some teachers may lack confidence in their familiarity with various technological tools. The high standard deviation for this item (SD = 1.2426) indicates a considerable variance in teachers' levels of TK, with some exhibiting greater proficiency than others. The semi-structured interviews also captured the lower mean score for the teachers' "knowledge of a lot of different technologies" (M = 3.134, SD = 1.2426). Some teachers indicated that they lacked basic technology skills to operate various technologies, as reflected in the following statements:

> Teachers may not know how to use digital tools effectively for teaching purposes, including how to implement them and share information on widely available platforms. (LST3)

The remarks by LST3 reinforce the notion that a sound foundation in TK is a crucial basis for other knowledge domain areas involving technology, such as TPK and TPACK. This finding implies that teachers who frequently employ technology may still require the acquisition of skills necessary to remain abreast of emerging technology tools and their uses in the teaching-learning spaces. Lamentably, this study's findings suggest that the technology training teachers receive is inadequate. This inadequacy is frequently attributable to training that fails to emphasise integrating pedagogy, content, and technology knowledge for teaching. As such, teachers must receive training to develop their TK, enabling them to utilise technology as an essential tool to support learning confidently.

Further, when examined through the interviews, the present study found that all four Life Sciences teachers in rural schools desire training programmes that prioritise integrating technology into pedagogy to enhance learning outcomes. In addition to learning about the most up-to-date technological tools, such as VL, the teacher participants emphasised the importance of knowing how to incorporate these tools into the Life Sciences subject area so that they could create impactful and engaging technology-based teaching experiences for their learners. The Life Sciences teachers' emphasis on the need for ongoing professional development is reflected in the following quotes.

> Teachers require support and training in utilising technology for teaching in addition to their existing pedagogical knowledge. (LST1)

Overall, the statistical analysis shows that Life Sciences teachers in rural schools exhibit a high level of technological knowledge and can effectively work with various technologies. The overall mean rating (M = 3.4427, SD = 1.0000) indicates that the teachers are well-versed in technological tools. These results are encouraging and suggest that these teachers are well-prepared to meet the technological demands of contemporary teaching practices such as those involving VL. The next sub-section presents the survey findings for content knowledge.

5.3.3.3 Content Knowledge

The questionnaire asked the participants to respond to the six question items concerning their content knowledge. Table 17 below displays the findings.

Table 17: Descriptive statistics: Content Knowledge (n = 186)

Factor	Mean	SD	Min	Max
I possess sufficient Life sciences knowledge to teach the subject.	4.274	0.6368	2.00	5.00
I can use a scientific way of thinking.	4.242	0.6243	2.00	5.00
I have many ways and approaches of increasing my own Life Sciences understanding.	4.167	0.5190	3.00	5.00
I am familiar with the Life Sciences content that is prescribed by CAPS.	4.462	0.5314	3.00	5.00
I understand and can explain the concept of the scientific method.	4.333	0.6033	2.00	5.00
I have sufficient knowledge to answer most learners' Life Sciences questions.	4.376	0.5679	3.00	4.00

Overall mean score (4.3091), Standard deviation (0.4623)

The computations presented in Table 17 above show the Life Sciences teachers' responses regarding their content knowledge. The teachers rated the highest mean value for the item "I am familiar with the Life sciences content that CAPS prescribes" (M = 4.462, SD = 0.5314), showing that the teachers possess a strong familiarity with the subject matter outlined in the CAPS. This was followed by the teachers' "sufficient knowledge to answer most learners' Life Sciences questions" (M = 4.376, SD = 0.5679), suggesting that the teachers feel confident in their ability to address learners' queries related to the subject. On the contrary, the statement with the lowest mean rating was "I have various ways and strategies of developing my own Life Sciences understanding" (M = 4.167, SD = 0.5190). The low standard deviation for this item (SD = 0.5190) indicates that the teachers had a firm agreement regarding their level of proficiency in developing their understanding of Life Sciences content through various methods and strategies.

Overall, the findings suggest that the Life Sciences teachers regard themselves as highly knowledgeable in their subject content, as evidenced by the individual items' mean scores exceeding 4. The standard deviation values ranging from (SD = 0.5190 to 0.6368) also suggest high agreement levels among the teachers' responses to the items. The CK construct had a very high mean rating (M = 4.3091) and an SD value (0.4623), signifying that the Life Sciences teachers' CK level was high and that most teachers responded similarly. It is worth noting that these findings are not surprising, given that subject specialisation is a prerequisite for Life Sciences teachers to graduate from their initial teacher training courses. Therefore, it is commonly understood that a competent Life Sciences teacher must have a firm grasp of the subject content they teach. However, it is essential to recognise that there may be a mismatch between the teachers' self-reported levels of their CK and their actual competency in the subject content. Future studies may explore the teachers' actual content knowledge using objective measures to afford a more comprehensive understanding of their competencies. The next sub-section presents the survey findings for pedagogical knowledge.

5.3.3.4 Pedagogical Knowledge

The questionnaire asked the participants to respond to the eight question items concerning their pedagogical Knowledge, and Table 18 below displays the results.

Table 18 Descriptive statistics: Pedagogical Knowledge (n = 186)

Factor	Mean	SD	Min	Max
I can assess learners' performance in Life sciences, including knowledge of different cognitive levels, degrees of question difficulty and the concept of a 'reasonable learner'.	4.102	0.5554	3.00	5.00
I know how to adapt my teaching depending on what learners understand or do not understand.	4.226	0.5527	2.00	5.00
I know how to assess learning in multiple ways.	4.204	0.5800	2.00	5.00
I can adapt my teaching style to different learners.	4.290	0.5004	3.00	5.00
I can use various teaching approaches in my Life Sciences class.	4.263	0.4882	3.00	5.00
I am familiar with common learners' understandings and misconceptions of Life Sciences	4.237	0.5281	3.00	5.00
I can organise and maintain class management and control.	4.409	0.5833	3.00	5.00
I am familiar with the prescribed Life Sciences textbooks and other learning resources used in most South African classrooms.	4.285	0.5877	2.00	5.00

Overall mean (4.2520), Standard deviation (0.3832)

Table 18 provides insight into the Life Sciences teachers' PK domain. As seen from the table above, the mean ratings for all the PK statements were above 4, which suggests that the teachers held high regard for their aptitude to direct learners in adopting suitable learning approaches and supervising their learning progress. Notably, the item "I know how to organise and maintain class management and control" recorded the highest mean rating (M = 4.409, SD = 0.5833), emphasising the importance of effective class management and control as a basis for successful teaching. Additionally, the teachers strongly perceived that "they are familiar with the prescribed Life Sciences textbooks and other learning resources used in most South African classrooms" (M = 4.285, SD = 0.5877). However, the lowest mean value on the PK scale was for the item "knowing how to assess learners' performance in Life Sciences, including knowledge of different cognitive levels, degrees of question

difficulty and the concept of a 'reasonable learner'" (M = 4.102, SD = 0.5554). This finding, nevertheless, demonstrates that the teachers believed they could assess learners' performance in Life Sciences. In sum, the teachers reported very high PK levels, with an overall mean value of (M = 4.2520) along a very high agreement level for all the individual items in this knowledge domain (SD = 0.3832). Furthermore, the high mean scores for PK indicate that the teachers believed they could stretch their learners' thinking by crafting challenging activities. In sum, the Life Sciences teachers' PK levels were overwhelmingly positive, indicating a high level of certainty in their aptitude to teach Life Sciences effectively. The subsequent sub-section goes into the Life Sciences teachers' pedagogical content knowledge.

5.3.3.5 Pedagogical Content Knowledge

The questionnaire requested the teachers to respond to the five PCK items, and Table 19 below displays the results.

Table 19 Descriptive statistics: Pedagogical content knowledge (n = 186)

Factor	Mean	SD	Min	Max
I can teach specific Life Sciences concepts/topics using specific Virtual Lab experiments.	3.855	0.9616	1.00	5.00
I know which Life sciences concepts/topics to teach using simulations.	3.876	0.8059	1.00	5.00
I have the knowledge to teach Life sciences using videos and audio, e.g., from YouTube.	4.145	0.7465	2.00	5.00
I have the knowledge to teach Life sciences using Virtual Labs on mobile devices such as cell phones, Tablets, and iPads.	3.645	1.0413	1.00	5.00
I have the knowledge to teach Life sciences using digital boards, e.g., data projectors and Smartboards.	3.876	1.0031	1.00	5.00

Overall mean (3.8796), Standard deviation (0.6841)

The descriptive statistics in Table 19 comprehensively analyse the mean ratings and SD values of the Life Sciences teachers' PCK levels. A closer examination of the individual item mean ratings demonstrated that all the mean values exceeded 3.5,

revealing high levels of the teachers' PCK. Specifically, the statement with the highest mean score was "teachers' knowledge to teach Life Sciences using audios and videos, e.g., from YouTube" (M = 4.145, SD = 0.7465), highlighting the importance of multimedia resources in Life Sciences teaching from the teachers' perspectives. This was followed closely by three items that had similar means; "I know which Life Sciences concepts/topics to teach using simulations" (M = 3.876, SD = 0.8059), "I know how to teach Life Sciences using digital boards, e.g., Smartboard, data projector" (M = 3.876, SD = 1.0031), and "I know how to teach specific Life Sciences concepts/topics using specific Virtual Lab experiments" (M = 3.855, SD = 0.9616). All these three items had mean scores above 3.8, indicating very high teachers' self-reported PCK levels.

Contrary to the above, the lowest mean rating was recorded for the statement, "I can teach Life sciences using Virtual Laboratories in mobile devices such as cell phones, Tablets, and iPads" (M = 3.645, SD = 1.0413). A similar pattern emerged during the semi-structured interviews: two teachers reported low abilities to teach with VL. For example, LST3 commented:

> While I believe that Virtual Lab can simplify my teaching, the challenge lies in its unfamiliarity to many of us. As a result, there are numerous complexities that I have encountered, and we need to put time into comprehending how to use them in teaching. (LST3)

The above statement highlights a need for teacher training in utilising VL, even on mobile devices, to enhance learning. Generally, the PCK mean score was high (M = 3.8796, SD = 0.6841), suggesting that the teachers in this study possess the requisite knowledge and skills to connect pedagogy and content knowledge to provide their learners with diverse learning opportunities. The results imply that the Life Sciences teachers in rural schools know various teaching strategies and resources to improve their learners' learning outcomes in Life Sciences. However, there is still room for improvement in some areas of teacher knowledge, such as incorporating VLs in teaching. The following sub-section discusses the Life Sciences teachers' TPK.

5.3.3.6 Technological Pedagogical Knowledge

The questionnaire requested the teachers to respond to the three TPK items, and Table 20 below shows the results.

Table 20: Descriptive statistics. Technological pedagogical knowledge (n = 186)

Factor	Mean	SD	Min	Max
I can select technologies that enhance my teaching strategies for a lesson.	3.070	1.2260	1.00	5.00
I can select technologies that enhance learners' understanding of a lesson.	3.102	1.1509	1.00	5.00
I always think critically about how to use Virtual Lab in my Life Sciences class.	2.790	1.1266	1.00	5.00

Overall mean (2.9875), Standard deviation (1.0377)

The statistical analysis findings of the six TPACK constructs reveal that the lowest mean score (M = 2.9875, SD = 1.0377) is attributed to TPK. This indicates that Life Sciences teachers responded neutrally to disagree with the TPK items. The teachers' responses are evidence of their poor TPK levels to use VL as a pedagogical tool. To delve deeper into TPK, Table 21 above displays the results of the three individual TPK items. The mean values for the individual items ranged from (M = 2.790 - 3.102), signifying that teachers' confidence in integrating VL into their pedagogy was low to moderate. In particular, the item "I can choose technologies that enhance learners' understanding for a lesson." (M = 3.102, SD = 1.1509) recorded the highest mean value compared to other items. However, the high standard deviation suggests a broad range of perceptions by the teachers.

The teacher's ability to select technologies that enhance learners' comprehension was directly raised with the teachers during the interviews. All the teachers indicated that technology could be a useful aid in making learners understand those topics that they may typically struggle with. Specifically, two teachers shared that incorporating VL can help learners better grasp complex or abstract concepts. LST2 and LST4 both conveyed this sentiment in the following statements:

> Virtual Lab has helped me teach complex biology concepts more effectively. Its visual aids create a realistic and tangible learning experience for my learners. Specifically, topics like accommodation and breathing movement are easier to understand with the help of Virtual Lab. It enables learners to interact and visualise with these concepts, leading to better retention and comprehension. (LST2)

> Virtual Lab has a bunch of cool experiments that can help you teach abstract stuff in Life Sciences class. (LST4)

These teachers are forward-thinking and actively seek strategies to enhance the teaching of complex or abstract concepts for the learners' benefit.

Further scrutiny of the individual TPK statements shows that the lowest mean rating (M = 2.790, SD = 1.1266) was observed for the item "I always think critically about how to use VL in my Life Sciences class." This suggests that most rural Life Sciences teachers were either unsure or lacked confidence in their ability to "think critically about using VL in their teaching". Moreover, the high standard deviation (SD = 1.1266) suggests significant variation in teachers' responses.

Following the above survey findings, I probed the teachers during the semi-structured interviews about what they think should be done to help them achieve higher TPK levels. The teachers responded that technology training should not only focus on a technology tool's technical and operational aspects but should encompass how that tool can be incorporated into effective teaching. This is evident from the excerpts below, where the Life Sciences teachers articulated their desire for professional teacher development opportunities that prioritise integrating technology into pedagogy.

> Virtual Lab aims to enhance the accessibility, interactivity, and engagement of science education. As part of teacher professional development, there should be a deliberate focus on integrating technology into teaching. (LST3)

> Professional development programs should focus on developing technical competencies for using technology tools and utilising technology to enhance pedagogy. This approach will ensure that teachers are capacitated to use technology for teaching, both now and in the future. (LST2)

The overall TPK mean score (M = 2.9875, SD = 1.0377) signifies low levels of the teachers' ability to choose which aspects of VL experiments can enhance their teaching. These results are not unexpected given the novelty of VL, where much is yet to be known about VL's potential to improve teaching. Thus, it can be concluded that with more widespread adoption and use of VL, most Life Sciences teachers in rural schools will develop higher TPK levels required to use this tool for teaching effectively. Below, I discuss the Life Sciences teachers' TPACK.

5.3.3.7 Technological Pedagogical Content Knowledge

The questionnaire asked the participants to respond to the three TPACK items, and Table 21 below shows the results.

Table 21: Descriptive statistics: Technological pedagogical content knowledge (n = 186)

Factor	Mean	SD	Min	Max
I can adapt and use particular experiments in Virtual Lab to meet my different learners' learning capabilities.	3.011	1.0449	1.00	5.00
I can teach Life Sciences concepts/topics that appropriately combine the content with technology skills using science experiments in a Virtual Lab.	3.032	1.0076	1.00	4.00
I can teach Life Sciences concepts/topics that appropriately combine the content with different teaching strategies using science experiments in a Virtual Lab.	3.038	0.9884	1.00	5.00

Overall mean (3.0269), Standard deviation (0.9648)

The statistical analysis reveals that the overall mean rating for TPACK was (M = 3.0269, SD = 0.9648) and that mean scores for all the individual TPACK items

exceeded 3.0, indicating moderate to high TPACK levels. This finding shows that the Life Sciences teachers were moderately confident in their ability to "teach Life Sciences concepts/topics that appropriately combine the content with different teaching strategies using science experiments in Virtual Lab" (M = 3.038, SD = 0.9884). It also indicates that teachers can "teach Life Sciences concepts/topics that appropriately combine the content with technology skills using science experiments in Virtual Lab" (M = 3.032, SD = 1.0076). When explored through semi-structured interviews, the teachers were specifically asked what informs their decision on which experiments in VL to use and at what point they choose to do so. The teachers' responses included the following:

> I can say I am able to choose the experiments that can specifically help reinforce [learners'] understanding of a certain topic. (LST1)

> I think proper lesson planning is key to teaching well. So, before my lessons, I try out a bunch of experiments in Virtual Lab to find the ones that are just right for my students. Some of them can be too hard, but I check the CAPS document to see which ones are suitable for their level. (LST4)

The above statements highlight the teachers' confidence in their TPACK levels in teaching with VL. LST1's response, which reveals some pedagogical intent to use VL evident during lesson planning, is fascinating. Moreover, the survey findings and the interview responses indicate that the teachers further concurred that they could "adapt and use particular experiments in VL to meet their different learners' learning capabilities" (M = 3.011, SD = 1.0449). The interview response that corroborated this survey finding is as follows:

> I really appreciate the flexibility of Virtual Lab because it allows me to modify and customise experiments better to fit the needs and abilities of my students. I can simplify or add more complexity as necessary, and it's all in one convenient platform. (LST2)

Moreover, analysis of the standard deviation values for the TPACK items indicates that they were above 1.0, suggesting more variation in the teachers' responses.

Notably, when compared with other technology-related domains, the overall TPACK domain mean (M = 3.0269, SD = 0.9648) slightly exceeded that for TPK (M = 2.9875, SD = 1.0377) but was lower than the TK mean score (M = 3.4427, SD = 1.0000). This is an exciting finding as it suggested that the teachers in this research held that they could integrate VL in their classrooms despite their competence in their ability to utilise it being lower.

In summary, the above findings reveal that Life Sciences teachers' levels of their non-technology-related domains (PK, CK and PCK) were higher than the technology-related constructs (TK, TPK and TPACK). Among the technology-related domains, the highest knowledge level was reported in the teachers' TK compared to TPK and TPACK, though lower than CK, PK and PCK. The high TK levels imply that most Life Sciences teachers in rural schools have high regard concerning their TK in applying diverse technology tools to teach Life Sciences.

However, the finding also reveals that introducing content and pedagogical domains to technology concepts further lowers their knowledge levels, as demonstrated by the inclination towards lower mean scores for the TPK and TPACK domain questions. Consequently, because the efficacy of technology integration in teaching hinges on the notion that TK is amalgamated into existing pedagogy, professional development must focus on technology usage and the learning output and how technologies aid in their growth. The following section explores the relationships between TAM and TPACK constructs.

5.4 RELATIONSHIP BETWEEN TAM AND TPACK CONSTRUCTS

To answer RQ3, 'How can rural Life Sciences teachers' perceptions and experiences of the integration of the Virtual Lab be understood and explained?', I further conducted correlation and regression analyses to establish the relationship between TAM and TPACK tenets to explain the teachers' perceptions and experiences of VL in their classrooms. This undertaking was crucial because TAM is a model that articulates how Life Sciences teachers adopt and use VL. It concentrates on the teachers' perception of VL's usefulness and ease of use. On the contrary, TPACK is a model that explains how pedagogy, content, and technology knowledge work together in teaching with VL. TPACK can also be useful in guiding the development of effective

VL integration strategies that consider the unique context of a particular teaching-learning situation. In this case, it is the rural teaching context.

While TAM and TPACK address different aspects of technology integration, they can complement each other in educational technology research. This research expected that TAM would help understand the factors that influence VL adoption and use by the Life Sciences teachers in rural schools, while TPACK would help provide insight into how VL can be effectively integrated into teaching. By combining these two models, I hoped to understand better the complex practices involved in VL integration in teaching. To the researchers' knowledge, very few studies have investigated technology integration from the lenses of TAM and TPACK, and here lies a new methodological contribution to research on technology integration in rural science education.

In answering RQ3, I first studied the correlations between the aggregate means of PEOU, PU, SI, FC, BI, AU, and TK, CK, PK, PCK, TPK, and TPACK. I relied on quantitative statistical analysis to develop insight to adequately address the question of how the teachers' perceptions and experiences of VL can be understood and explained. I deployed the Pearson correlation technique to investigate relationships among the TAM and TPACK constructs. I analysed the TAM variables amongst themselves and with the TPACK variables. Then, I cross-correlated the TAM and TPACK variables with each other to uncover any interrelationships between the variables. Given my desire to understand and explain the teachers' perceptions and experiences of VL, I preferred the Pearson correlation approach over the Spearman correlation coefficient. This was because the Pearson correlation coefficient measures the degree to which a linear function can explain the correlation between two variables. In contrast, using a monotonic function based on data value ranks, the Spearman correlation coefficient measures how well the correlation between two variables can be explained.

Furthermore, due to the considerable sample size (n = 186), the Pearson and Spearman correlation coefficients were congruent, prompting me to use the conventional Pearson correlation coefficients to report the results. I harnessed correlation analysis as a crucial tool to evaluate the robustness of the relationships

between the variables. Notably, the correlation coefficient is bounded between -1 and +1, with a value of +1 signifying a strong positive correlation, with -1 indicating a negative correlation, and a 0 implying no relationship. Thus, the degree of the correlation coefficient signals the potency of the relationships between variables, with a higher coefficient value suggesting a more positively strong relationship. To summarise, the Pearson correlation technique proved to be a salient approach for discerning plausible relationships among the variables in this investigation, while correlation analysis gave me insights into the strength of these relationships. Later in the analysis, I conducted multiple linear regression analyses to predict the correlation between specific TPACK and specific TAM components.

The following specific questions guided the Pearson correlation analysis:

- To what extent do the TAM variables explain the Life Sciences teachers' perceptions and experiences of Virtual Lab for rural teaching?
- To what extent do the TPACK variables explain the Life Sciences teachers' perceptions and experiences of Virtual Lab for rural teaching?
- To what extent do the TAM and TPACK models offer opportunities to understand and explain the Life Sciences teachers' perceptions and experiences of Virtual Lab for rural teaching?
- Which factors of the TAM and TPACK frameworks have the greatest impact on the decision of teachers to use (or not) Virtual Lab?

Table 22 presents the findings from the correlation analysis.

Table 22: Pearson correlation coefficients (r-values), n=186. TAM and TPACK constructs

		PU	PEOU	SI	FC	BI	AU	TK	CK	PK	PCK	TPK	TPACK
PU	Pearson Correlation	1	.549**	.344**	.078	.436**	.428**	.454**	.426**	.262**	.347**	.292**	.385**
	Sig. (2-tailed)		.000	.000	.290	.000	.000	.000	.000	.000	.000	.000	.000
	N	186	186	186	186	186	186	186	186	186	186	186	186
PEOU	Pearson Correlation	.549**	1	.210**	.108	.226**	.379**	.283**	.231**	.166*	.270**	.182*	.263**
	Sig. (2-tailed)	.000		.004	.142	.002	.000	.000	.002	.023	.000	.013	.000
	N	186	186	186	186	186	186	186	186	186	186	186	186
SI	Pearson Correlation	.344**	.210**	1	.213**	.248**	.301**	.106	.125	.164*	.276**	.048	.172*
	Sig. (2-tailed)	.000	.004		.004	.001	.000	.148	.089	.025	.000	.512	.019
	N	186	186	186	186	186	186	186	186	186	186	186	186
FC	Pearson Correlation	.078	.108	.213**	1	.078	.379**	.169*	.118	-.127	.125	.086	.247**
	Sig. (2-tailed)	.290	.142	.004		.293	.000	.021	.110	.084	.088	.241	.001
	N	186	186	186	186	186	186	186	186	186	186	186	186
BI	Pearson Correlation	.436**	.226**	.248**	.078	1	.238**	.385**	.331**	.296**	.238**	.164*	.185*
	Sig. (2-tailed)	.000	.002	.001	.293		.001	.000	.000	.000	.001	.025	.012
	N	186	186	186	186	186	186	186	186	186	186	186	186
AU	Pearson Correlation	.428**	.379**	.301**	.379**	.238**	1	.451**	.333**	-.042	.376**	.225**	.613**
	Sig. (2-tailed)	.000	.000	.000	.000	.001		.000	.000	.568	.000	.002	.000
	N	186	186	186	186	186	186	186	186	186	186	186	186
TK	Pearson Correlation	.454**	.283**	.106	.169*	.385**	.451**	1	.544**	.131	.652**	.424**	.637**
	Sig. (2-tailed)	.000	.000	.148	.021	.000	.000		.000	.074	.000	.000	.000
	N	186	186	186	186	186	186	186	186	186	186	186	186
CK	Pearson Correlation	.426**	.231**	.125	.118	.331**	.333**	.544**	1	.607**	.465**	.272**	.368**
	Sig. (2-tailed)	.000	.002	.089	.110	.000	.000	.000		.000	.000	.000	.000
	N	186	186	186	186	186	186	186	186	186	186	186	186

PK	Pearson Correlation	.262**	.166*	.164*	-.127	.296**	-.042	.131	.607**	1	.229**	.229**	.072
	Sig. (2-tailed)	.000	.023	.025	.084	.000	.568	.074	.000		.002	.002	.331
	N	186	186	186	186	186	186	186	186	186	186	186	186
PCK	Pearson Correlation	.347**	.270**	.276**	.125	.238**	.376**	.652**	.465**	.229**	1	.354**	.515**
	Sig. (2-tailed)	.000	.000	.000	.088	.001	.000	.000	.000	.002		.000	.000
	N	186	186	186	186	186	186	186	186	186	186	186	186
TPK	Pearson Correlation	.292**	.182*	.048	.086	.164*	.225**	.424**	.272**	.229**	.354**	1	.491**
	Sig. (2-tailed)	.000	.013	.512	.241	.025	.002	.000	.000	.002	.000		.000
	N	186	186	186	186	186	186	186	186	186	186	186	186
TPACK	Pearson Correlation	.385**	.263**	.172*	.247**	.185*	.613**	.637**	.368**	.072	.515**	.491**	1
	Sig. (2-tailed)	.000	.000	.019	.001	.012	.000	.000	.000	.331	.000	.000	
	N	186	186	186	186	186	186	186	186	186	186	186	186

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 22 above presents Pearson correlation coefficients (r-values) between different TAM and TPACK construct pairs, including PU, PEOU, SI, FC, BI, AU, TK, CK, PK, TPK, and TPACK. Arising from this table, the following sub-sections cast a torchlight on specific correlations as discussed below.

5.4.1. Correlation analysis: Perceived Usefulness (PU)

The Pearson correlation coefficients in Table 22 above display a positive correlation between PU and all the TPACK domains, as shown by the correlation coefficient values (r) that ranged from (r = 0.262 - 0.454). In this study, I view PU as the degree to which Life Sciences teachers in rural schools perceive that utilising VL is useful in teaching. A closer look at the correlation coefficients reveals that although a positive relationship exists between the PU and TPACK domains, these are weak positive relationships. The constructs are not strongly related since correlation coefficient values from (r = 0.262 - 0.454) are not close to +1. Nonetheless, the findings show that when Life Sciences teachers have higher TPACK levels, then they tend to perceive VL as useful in their teaching. Specifically, the present research found that the strongest positive correlation between TPACK and TAM constructs is between PU and TK (r = 0.454). This finding highlights the importance of TK as a foundation for teachers to develop positive perceptions of VL's usefulness in teaching.

When examining the correlations between PU and the other TAM constructs, it emerges that PU has a strong positive relationship with PEOU (r = 0.549). This finding demonstrates that when Life Sciences teachers believe that VL is user-friendly or easy to use, they perceive it as useful in their teaching. In addition, Table 22 above shows that PU has a weak positive relationship with SI (r = 0.344) compared with other TAM constructs, suggesting that SI from peers and family wields the least influence on the teachers' perceived usefulness of VL. Furthermore, a weak correlation between PU and FC emerged (r = 0.078). This discovery is surprising in that the presence (or not) of facilitating conditions does not seem to affect the Life Sciences teachers' perceptions of VL usefulness in rural schools. One would have assumed that the presence of facilitating conditions would significantly influence the teachers' PU of VL because the facilitating conditions may be requisite for effective VL use. One possible reason for the finding could be that since VL is new, most Life Sciences teachers may be unsure how and which facilitating conditions may impact VL use.

Further analysis of the correlation coefficients between PU and the other TAM variables reveals a robust positive relationship between PU and BI (r = 0.436). This result shows that PU strongly influences the Life Sciences teachers' BI to use VL. The positive relationship between PU and BI is crucial because Table 22 above further shows a positive relationship between PU and AU (r = 0.428). Thus, this finding suggests that when the usefulness of VL for rural science teaching is established, Life Sciences teachers would be more likely to adopt the technology in their teaching. In fact, there is a positive relationship between the TAM constructs in the following path: PU → BI → AU. Conversely, it must be noted that if VL's perceived usefulness is not recognised, the teachers simply abandon the technology and look for more useful alternatives. It is also essential to realise that although a positive relationship exists between PU and AU of VL, that relationship is weak (r = 0.428). One probable explanation of this result is that most respondents (n = 186) had low experience with VL. Therefore, the correlation between PU and AU could be higher for more experienced teachers. Nonetheless, the present research results support the notion that a strong and positive PU of VL positively influences the Life Sciences teachers' AU of the technology in rural schools.

5.4.2 Correlation analysis: Perceived Ease of Use (PEOU)

Second, it was also essential to analyse the relation between the PEOU of VL and the TPACK and other TAM constructs. The Pearson correlation coefficients analysis showed that PEOU has positive correlations with all the TPACK constructs, with the weakest positive relationship with PK (r = 0.166) and TPK (r = 0.182). This finding suggests that PK and TPK do not strongly influence the Life Sciences teachers' PEOU of VL for rural teaching. On the contrary, PEOU has the most positive relationship with TK (r = 0.283) when compared to all the other TPACK constructs, i.e., CK (r = 0.231), PK (r = 0.166), PCK (r = 0.270), TPK (r = 0.182) and TPACK (r = 0.263). Therefore, the positive relationship between PEOU and TK is crucial as it indicates that Life Sciences teachers with higher TK levels perceive VL as easy to use. This relationship is not unexpected because the more knowledgeable a user is in using a particular technology, the easier they find it to use the technology.

Further analysis reveals that TPACK is positively related to PEOU (r = 0.263). However, the correlation coefficient (r = 0.263) represents a weak positive association

between PEOU and TPACK. This correlation between PEOU and TPACK is weaker than that between PU and TPACK (r = 0.385), suggesting a stronger positive relationship between PU and TPACK. When analysing the association between PEOU and the other TAM variables, the findings reveal positive relationships between PEOU and all the variables. However, the most positive relationship is between PEOU and AU (r = 0.379). Therefore, one could argue that Life Sciences teachers who perceive VL as easy to use actually use it in their classrooms.

Furthermore, one of the most exciting results from the correlation analyses is a strong positive association between PEOU and Life Sciences teachers' BI to use VL. This finding reveals that if teachers perceive VL as easy to use, it raises their positive intentions. This observation underscores the importance of PEOU in the context of VL in SA. Since VL is a relatively new technology in the country, it is unsurprising that ease of use plays a vital part in shaping teachers' intention to use it. As such, it may be necessary to provide support and training to teachers to flatten the learning curve in using VL.

Overall, the correlation coefficient findings suggest that improving PEOU could be an effective strategy for increasing Life Sciences teachers' adoption and use of VL in rural schools. By addressing any usability issues and providing adequate training and support, it may be possible to enhance teachers' perception of ease of use and, in turn, increase their inclination to integrate VL in their classrooms. This result shows that when Life Sciences teachers in rural schools perceive VL as easy to use, they can perceive it as useful. In other words, Life Sciences teachers prefer that VL requires minimum effort, enhancing their perception of its usefulness. This behaviour is justifiable because an easy-to-use VL saves the teachers' effort and time and shortens the learning curve by allowing them to learn it more quickly, effectively, and efficiently. Therefore, this research supports the idea that VL's strong PEOU helps increase the Life Sciences teachers' BI in rural schools.

5.4.3 Correlation analysis: Social Influence (SI)

Third, the correlation between SI and the TPACK domains are positively related, i.e., PK (r = 0.164), PCK (r = 0.276), and TPACK (r = 0.172). However, SI has weak positive relationships with all the TPACK variables. Moreover, a weak positive

relationship exists between SI and TK (r = 0.106), CK (r = 0.125), and TPK (r = 0.048). This result implies that SI has little impact on TPACK as knowledge for teaching. Conversely, SI has a stronger positive relationship with AU (r = 0.301) when compared with the other TAM variables. This finding underscores the positive impact of SI on the Life Sciences teachers' BI and AU of VL (r = 0.248).

5.4.4 Correlation Analysis: Facilitating Conditions (FC)

Fourth, when examining the relationship between FC and the TPACK constructs, one can observe weak positive correlations with most TPACK constructs. The only significant positive relationship is between FC and the technology-related constructs TK (r = 0.169) and TPACK (r = 0.247). This result suggests that FC have a minimum impact on the Life Sciences teachers' overall knowledge of teaching using VL. However, when analysing the correlations between FC and the other TAM variables, there is evidence that FC has a significant positive relationship with AU (r = 0.379). One possible explanation could be that there must be facilitating conditions for Life Sciences teachers to use VL. Thus, one can argue that the absence of facilitating conditions can reduce the Life Sciences teachers' actual use of VL in rural schools.

5.4.5 Correlation analysis: Behavioural Intention (BI)

Fifth, I further explored the association between BI and the TPACK variables and the other TAM tenets. For this study, I defined BI as the Life Sciences teachers' plans or aims to use VL for rural teaching. The correlation coefficients in Table 22 above reveal positive correlations between BI and all the TPACK constructs. In particular, TK had the most significant relationship with BI (r = 0.385), suggesting that high levels of TK increase the Life Sciences teachers' intentions to use VL in teaching. Like the TPACK constructs, BI also positively correlates with all the TAM variables. Specifically, BI has a direct positive influence on the teachers' AU of VL. This finding indicates that when Life Sciences teachers in rural schools are strongly willing to use VL, they are more likely to use it. However, as I explained earlier, simply stating an intention to use technology, such as VL, particularly after participating in a study that emphasises the technology's effectiveness as a teaching platform, differs significantly from implementing the technology in teaching. Moreover, despite the weak positive relationship between BI and AU (r = 0.238), this relationship contributes to

understanding the perceptions that Life Sciences teachers in rural schools hold when deciding to adopt VL in teaching.

5.4.6 Correlation analysis: Actual Usage (AU)

I also investigated the relationship between the AU of VL, the TPACK constructs, and the other TAM variables. The relationships between AU and the other TAM variables have been explained in the preceding sub-sections above. Table 22 displays positive correlations between AU and all the TPACK constructs. AU and TPACK exhibited the strongest positive correlation ($r = 0.613$). This finding is interesting as it highlights the apex of using two theories to explain teacher perceptions and experiences of VL. Thus, it can be argued that TPACK directly influences AU and that when Life Sciences teachers have high TPACK levels, then they actually use VL.

In summary, the correlation coefficients and p-values in Table 22 above indicate the significance and strength of the relationship between each pair of constructs with the following key findings:

- PU and PEOU are positively correlated ($r=0.549$, $p<0.001$).
- AU and BI are positively correlated ($r=0.428$, $p<0.001$).
- TK, PK, CK, PCK, TPK, and TPACK are all positively correlated with each other, with correlation coefficients that ranged from ($r = 0.272$ to 0.652) and all p-values ($p<0.001$).
- FC has positive correlations with BI ($r = 0.379$, $p<0.001$) and AU ($r = 0.379$, $p<0.001$) but not with PEOU ($r = 0.108$, $p = 0.142$) or PU ($r = 0.078$, $p = 0.290$).
- SI has positive correlations with BI ($r = 0.248$, $p = 0.001$), AU ($r = 0.301$, $p<0.001$), and PCK ($r = 0.276$, $p<0.001$) but not with PU ($r = 0.344$, $p = 0.004$) or PEOU ($r = 0.210$, $p = 0.004$).

Overall, the results suggest that the TAM and TPACK constructs are positively correlated, indicating that they are related and may influence each other. Mainly, it emerged that PU and TK have the greatest influence on teachers' decisions to adopt VL. Therefore, combining these two theories can afford a nuanced and comprehensive analysis and discourse about teacher perceptions of VL for rural

teaching. The following sub-section delves deeper into the analyses of the Pearson correlation coefficients using the individual items of each TAM variable against the TPACK constructs.

5.5. CORRELATIONS BETWEEN TAM INDIVIDUAL ITEMS AND TPACK CONSTRUCTS

5.5.1 PU items and TPACK constructs

Table 23 Pearson correlation coefficients (r-values), n=186. PU items and TPACK constructs

	PU1	PU2	PU3	PU4	TK	CK	PK	PCK	TPK	TPACK
PU1	1									
PU2	0.311	1.000								
PU3	0.446	0.459	1.000							
PU4	0.387	0.455	0.462	1.000						
TK	0.350	0.301	0.349	0.365	1.000					
CK	0.272	0.313	0.369	0.330	0.544	1.000				
PK	0.216	0.208	0.233	0.127	0.131	0.607	1.000			
PCK	0.185	0.269	0.282	0.313	0.652	0.465	0.229	1.000		
TPK	0.288	0.125	0.230	0.231	0.424	0.272	0.229	0.354	1.000	
TPACK	0.404	0.162	0.265	0.322	0.637	0.368	0.072	0.515	0.491	1.000

The table above shows the pairwise correlations among the PU items and TPACK constructs. Each column and row represents a variable, and the values in the cells represent the correlation coefficient between those variables. The computations show that all the PU items positively correlate with all the TPACK constructs. However, these relationships between PU items and the TPACK constructs are weak to moderate. It can be seen that the correlation between responses to all the PU items was strongest with TK than any other TPACK construct and decreased with the addition of other TPACK domains such as CK and PK. When analysing the relationship between TPACK and the PU items, the highest correlations are observed between PU1 and TPACK (r = 0.404) and PU4 and TPACK (r = 0.322). These correlations appear to indicate that Life Sciences teachers put more consideration that “Virtual Lab enables them to teach lab practicals more quickly” (PU1) as well as that they find the “Virtual Laboratory useful in their work as Life Sciences teachers” (PU4). The low TPACK correlation coefficients suggest that the blending of pedagogy, technology, and content was minimal among the teachers.

5.5.2 PEOU items and TPACK constructs

Table 24 Pearson correlation coefficients (r-values), n=186. PEOU items and TPACK constructs

	PEOU1	POEU2	PEOU3	PEOU4	TK	CK	PK	PCK	TPK	TPACK
PEOU1	1.00									
POEU2	0.57	1.00								
PEOU3	0.57	0.64	1.00							
PEOU4	0.61	0.60	0.63	1.00						
TK	0.26	0.25	0.24	0.21	1.00					
CK	0.21	0.23	0.13	0.20	0.54	1.00				
PK	0.10	0.22	0.12	0.12	0.13	0.61	1.00			
PCK	0.30	0.24	0.25	0.13	0.65	0.47	0.23	1.00		
TPK	0.10	0.17	0.17	0.17	0.42	0.27	0.23	0.35	1.00	
TPACK	0.25	0.17	0.26	0.20	0.64	0.37	0.07	0.52	0.49	1.00

The correlation matrix above shows positive relationships between all the PEOU items and TPACK constructs. This observation suggests that Life Sciences teachers perceive VL as easy to use and enhance their effective teaching ability. However, the lack of a significant correlation between PK and TPK with PEOU items may suggest that teachers may not feel confident in their content and pedagogical knowledge when using VL in the classrooms. This observation could be due to inadequate support and training in VL integration or a lack of familiarity with the technology. Overall, the weak positive correlations between PEOU items and the TPACK constructs suggest that teachers perceive technology as a useful tool for teaching and are willing to utilise it but may require additional training and support to fully integrate it into their practice.

5.5.3 SI items and TPACK constructs

Table 25: Pearson correlation coefficients (r-values), n=186. SI items and TPACK constructs

	SI1	SI2	SI3	SI4	SI5	TK	CK	PK	PCK	TPK	TPACK
SI1	1.00										
SI2	0.58	1.00									
SI3	0.54	0.54	1.00								
SI4	0.20	0.26	0.47	1.00							
SI5	0.24	0.31	0.34	0.60	1.00						
TK	0.13	-0.05	0.13	0.09	0.07	1.00					
CK	0.08	0.00	0.17	0.14	0.05	0.54	1.00				
PK	0.06	0.05	0.25	0.17	0.05	0.13	0.61	1.00			
PCK	0.20	0.07	0.26	0.24	0.21	0.65	0.47	0.23	1.00		
TPK	-0.04	-0.06	-0.03	0.13	0.16	0.42	0.27	0.23	0.35	1.00	
TPACK	0.12	0.07	0.08	0.13	0.21	0.64	0.37	0.07	0.52	0.49	1.00

The findings above suggest that most SI items have weak positive correlations with the TPACK constructs, which may indicate that the social influence of peers and colleagues does not strongly impact the TPACK knowledge of Life Sciences teachers, which, consequently, has no impact on the teachers' use of VL in the classrooms. Furthermore, the correlation matrix indicates that the social influence item SI2, "my peers think that I should teach with the Virtual Lab," has a negative correlation with TK and TPK ($r = -0.05$ and $r = -0.06$), respectively. This outcome suggests that the social influence of peers may even be detrimental to the development of certain aspects of TPACK knowledge, particularly TK and TPK. The negative correlation may be because peers' perceived pressure or influence to use VL may not align with the Life Sciences teacher's teaching practices using the technology. This may be so because teachers have unique teaching styles and preferences developed over time. When faced with pressure from peers to use VL, the Life Sciences teacher may resist due to differences in teaching methods and beliefs. If the teacher relies heavily on physical laboratory experiments or other interactive activities, they may view VL as a departure from their preferred approach. They may feel that it lacks the hands-on experience, face-to-face interaction, or depth of understanding provided by traditional experiments. Additionally, lacking familiarity or confidence in using VL may influence the teacher's hesitation. Learning and implementing a new tool can be time-consuming and require additional training and preparation. These factors contribute

to a perceived mismatch between the pressure to use VL and the teacher's teaching practices, resulting in a negative correlation. In sum, the statement suggests that while social influence may have some weak positive correlations with TPACK constructs, it is crucial to be mindful of social pressure's potential adverse effects and ensure that pedagogical decisions are grounded in effective teaching practices and principles.

5.5.4 FC items and TPACK constructs

Table 26: Pearson correlation coefficients (r-values), n=186. FC items and TPACK constructs

	FC1	FC2	FC3	FC4	TK	CK	PK	PCK	TPK	TPACK
FC1	1.00									
FC2	0.40	1.00								
FC3	0.43	0.58	1.00							
FC4	0.52	0.68	0.78	1.00						
TK	0.04	0.20	0.21	0.11	1.00					
CK	0.08	0.09	0.15	0.08	0.54	1.00				
PK	0.17	-0.28	-0.11	-0.17	0.13	0.61	1.00			
PCK	0.06	0.15	0.13	0.07	0.65	0.47	0.23	1.00		
TPK	0.13	0.03	0.08	0.05	0.42	0.27	0.23	0.35	1.00	
TPACK	0.12	0.20	0.28	0.22	0.64	0.37	0.07	0.52	0.49	1.00

According to the above correlation matrix, all the FC items have weak positive correlations with all the TPACK constructs. Furthermore, most FC items have negative correlations with PK. These findings indicate that while FC may have some impact on Life Sciences teachers' TPACK, this influence is weak, and FC may be more closely linked to other aspects of TPACK than PK. The negative correlations between FC items FC2 (r = -0.28), FC3 (r = -0.11), and FC4 (r = -0.17) and PK may indicate that certain FCs may be less supportive of pedagogical approaches that heavily rely on CK. It is essential to note that correlation does not rule out other factors that may have contributed to the nature of the relationship between FC and TPACK. These factors include infrastructure limitations such as low access to reliable internet and outdated technology, a lack of quality professional development opportunities focused on TPACK and technology integration, time constraints and heavy workloads, and socioeconomic factors affecting access to technology outside of school. Nevertheless, the correlation matrix provides insight into the connections between these constructs and implies that FC may play a role in shaping teachers' TPACK, primarily concerning PK.

5.5.5 BI items and TPACK constructs

Table 27 Pearson correlation coefficients (r-values), n=186. BI items and TPACK constructs

	BI1	BI2	BI3	BI4	TK	CK	PK	PCK	TPK	TPACK
BI1	1									
BI2	0.231	1.000								
BI3	0.284	0.374	1.000							
BI4	0.184	0.520	0.546	1.000						
TK	0.325	0.174	0.369	0.246	1.000					
CK	0.190	0.208	0.332	0.224	0.544	1.000				
PK	0.176	0.256	0.351	0.066	0.131	0.607	1.000			
PCK	0.211	0.076	0.231	0.170	0.652	0.465	0.229	1.000		
TPK	0.193	0.073	0.140	0.068	0.424	0.272	0.229	0.354	1.000	
TPACK	0.038	0.044	0.234	0.222	0.637	0.368	0.072	0.515	0.491	1.000

The table above shows the correlations between BI items and TPACK constructs. The matrix shows that all BI items (BI1, BI2, BI3, and BI4) positively correlate with all the TPACK domains (TK, PK, CK, PCK, TPK, TPACK). This observation suggests that teachers possessing higher TPACK levels are likelier to demonstrate positive BI towards using Virtual Lab. The highest positive correlation appears between BI3, “I intend to use the Virtual Laboratory in the near future,” and PCK (r = 0.231). This finding suggests that teachers having higher PCK levels are more willing to use Virtual Lab in the future. The positive association between PCK and BI in adopting VL is not surprising. While PCK only focuses on pedagogy and content knowledge without including the technology component, the present study reveals it plays a vital role in adopting and using VL. This is because successful technology integration relies heavily on a strong foundation of PCK. That is, when teachers combine TK with a solid PCK, it leads to higher levels of TPACK, which is essential for meaningfully incorporating VL into teaching. As a result, it can be inferred that teachers with higher PCK levels are likelier to embrace and adopt VL in their teaching. This conclusion is premised on the understanding that PCK encompasses the skills and knowledge necessary to design and deliver effective pedagogical strategies that align with specific content domains. When teachers deeply understand how to teach a particular content or a Life Science concept, they can more readily recognise how technology, such as VL, can enhance their teaching. Furthermore, it is also crucial to underscore that there are some correlations between the TPACK constructs themselves. For

example, CK and PK have a positive correlation of (r = 0.607), suggesting that teachers with higher CK levels are also likely to exhibit superior PK levels.

5.5.6 AU items and TPACK constructs

Table 28: Pearson correlation coefficients (r-values), n=186. AU items and TPACK constructs

	AU1	AU2	AU3	AU4	AU5	TK	CK	PK	PCK	TPK	TPACK
AU1	1.00										
AU2	0.78	1.00									
AU3	0.67	0.85	1.00								
AU4	0.74	0.57	0.45	1.00							
AU5	0.47	0.54	0.55	0.43	1.00						
TK	0.36	0.49	0.48	0.25	0.28	1.00					
CK	0.24	0.28	0.22	0.28	0.33	0.54	1.00				
PK	-0.14	-0.06	-0.03	-0.09	0.12	0.13	0.61	1.00			
PCK	0.27	0.41	0.39	0.26	0.23	0.65	0.47	0.23	1.00		
TPK	0.17	0.23	0.23	0.22	0.09	0.42	0.27	0.23	0.35	1.00	
TPACK	0.52	0.61	0.65	0.39	0.37	0.64	0.37	0.07	0.52	0.49	1.00

Based on the correlation matrix above, several significant positive correlations exist between the AU items and the TPACK constructs. Specifically, all AU items (AU1, AU2, AU3, AU4, AU5) have positive correlations with all TPACK constructs (TK, CK, PK, PCK, TPK), with correlation coefficients that ranged from (r = 0.060 to 0.781). Additionally, the overall TPACK score (TPACK) has positive correlations with all TPACK constructs ranging from (r = 0.072 to 0.637) and with all AU items ranging from (r = 0.386 to 0.651). This finding indicates that individuals with higher TPACK levels also exhibit positive user acceptance towards using VL in teaching, possibly due to several reasons. For example, the teachers' comprehension of the interconnectedness between pedagogy, content, and technology knowledge can allow them to envision the benefits of VL within their rural teaching context. With expertise in integrating VL effectively, they can maximize its potential for enhancing teaching and learning experiences.

Moreover, individuals with higher TPACK may be more adaptable, open to innovation, and value continuous professional development. Their proactive inclination towards growth, coupled with their skills and willingness to embrace new technologies, can contribute to their positive acceptance of VL as a pedagogical tool. Overall, their

comprehensive understanding, expertise, adaptability, and growth mindset play key roles in fostering positive user acceptance of VL in teaching. However, some negative correlations are also present in the matrix, specifically between PK and AU1, AU2, AU3, and AU4, with correlation coefficients ranging from (r = -0.139 to -0.090). This finding indicates a negative linear relationship between these variables, suggesting that individuals with higher PK scores may be less likely to accept VL in their teaching. The following section presents findings from the multiple linear regression analysis.

5.6 MULTIPLE LINEAR REGRESSION (MLR) ANALYSIS

MLR analysis was conducted to ascertain the relationships between the Life Sciences teachers' perceptions of VL and their TPACK. It is essential to clarify upfront that I chose to employ MLR analysis with the purpose of examining the collective impact on the dependent variables, which are the TPACK components (CK, PK, PCK, TK, TPK, TPACK), and their influence on the dependent variables (PU, PEOU, BI, AU). As I indicated earlier, the application of MLR analysis is specifically tailored to address RQ3. RQ3 aims to attain a more profound comprehension and provide insights into teachers' perceptions and experiences related to the adoption of VL. More precisely, RQ3 is focused on untangling the complex combined effects of multiple independent variables (TPACK components) on several dependent variables (PU, PEOU, BI, AU). Given the complexity of these relationships, employing a method like MLR is well-suited due to its ability to manage such intricate interactions effectively. This rationale aligns with the perspective of Cohen et al. (2017:664), which asserts that MLR analysis "enables prediction and evaluates the relationship between two or more explanatory independent variables and a dependent variable." Reduced to its simplest terms, I used MLR analysis to explore the extent to which teacher knowledge could explain the teacher perceptions with the assumption that strong positive perceptions of VL flow from higher TPACK levels.

I commenced MLR analysis regression by computing the average scores of the TAM constructs PEOU, PU, BI, and AU. I considered these TAM constructs as dependent variables and were regressed with the independent variables PK, TK, CK, PCK, TPK, and TPACK. Each regression analysis provides a coefficient of determination (r-value) and a (p-value) for each independent variable, indicating how strong and statistically significant a relationship is between an independent and a dependent variable. The r-

value shows the degree to which the independent variable can account for the variability within the dependent variable. A higher r-value signifies a robust relationship between these two variables and accentuates their degree of association. In contrast, the p-value assumes the responsibility of ascertaining the significance of the independent variable's impact on the dependent variable. For example, a p-value lower than 0.05 ($p<0.05$) proves the independent variable's statistical significance, indicating that the likelihood of obtaining such outcomes by mere chance is less than 5%. For this investigation, the designated threshold for statistical significance is established at $p<0.05$.

I conducted multiple linear regression analyses to answer the following specific questions:

- To what extent do the TPACK constructs offer opportunities to understand and explain the Life Sciences teachers' perceived usefulness of VL for rural teaching?
- To what extent do the TPACK constructs offer opportunities to understand and explain the Life Sciences teachers' perceived ease of use of VL for rural teaching?
- To what extent do the TPACK constructs offer opportunities to understand and explain the Life Sciences teachers' behavioural intention to use VL for rural teaching?
- To what extent do the TPACK constructs offer opportunities to understand and explain the Life Sciences teachers' actual use of VL for rural teaching?

Table 29 below presents a detailed summary of the results of MLR analysis on the independent and dependent variables and uncovers unexpected connections between distinct variables. To the researcher's knowledge, little research has utilised theory triangulation involving TPACK and TAM.

Table 29 TPACK constructs as predictors of PU, PEOU, BI, and AU of Virtual Lab.

Independent variables		Dependent variables			
		PU	PEOU	BI	AU
TK	r-value	0.156	0.096	0.236	-0.034
	p-value	**0.022***	0.289	**0.000***	0.693
CK	r-value	0.229	0.002	-0.026	0.592
	p-value	0.104	0.992	0.819	**0.001***
PK	r-value	0.184	0.236	0.364	-0.614
	p-value	0.211	0.226	**0.002***	**0.001***
PCK	r-value	-0.001	0.110	-0.053	0.088
	p-value	0.992	0.313	0.428	0.402
TPK	r-value	0.033	0.007	-0.015	-0.066
	p-value	0.495	0.916	0.698	0.273
TPACK	r-value	0.093	0.097	-0.038	0.530
	p-value	0.121	0.219	0.435	**0.000***

***p<0.05**

The tabulated results offer a comprehensive look into the complex interplay between independent variables (TK, CK, PK, PCK, TPK, and TPACK) and the dependent variables (PU, PEOU, BI, and AU). The findings indicate a modest positive and statistically significant relationship between TK and PU of VL (r = 0.156, p = 0.022*), suggesting that teachers with higher TK tend to view VL as more useful for their teaching. Similarly, there is a positive and statistically significant association between TK and BI (r = 0.236, p = 0.000*), indicating that as teachers' TK increases, their intention to use VL for teaching purposes also tends to increase. However, no statistically significant correlations exist between TK and PEOU (r = 0.096, p = 0.289) or AU (r = -0.034, p = 0.693). In other words, the level of TK does not seem to have much influence on the ease with which teachers perceive the use of VL, nor does it seem to have much influence on their actual use of VL in the classroom.

Furthermore, a noteworthy positive correlation between CK and AU of VL emerges (r = 0.592, p = 0.001*), emphasising that Life Sciences teachers in rural schools with high CK are more inclined to use VL in their teaching. This correlation underscores the

practical application of subject expertise in embracing innovative technology tools, such as VL. However, it is crucial to recognise that the relationship between CK and other dimensions of VL adoption is nuanced. While there exists a positive correlation between CK and PU of VL ($r = 0.229$), the associated p-value ($p = 0.104$) indicates that this link is not statistically significant. This implies that although a trend suggests that teachers with more solid CK might perceive VL as more useful, this observation does not reach a level of statistical certainty. Interestingly, the correlation between CK and PEOU of VL is very close to zero ($r = 0.002$), and the p-value is exceptionally high ($p = 0.992$), indicating no relationship between these two variables. This finding indicates that teachers' CK does not significantly impact their perception of the ease of using VL. Similarly, the absence of a statistically significant correlation between CK and BI to use VL ($r = -0.026$, $p = 0.819$) suggests that CK might not substantially influence teachers' intentions toward adopting VL. In essence, the absence of a significant correlation between CK and BI to use VL suggests that CK alone might not strongly determine teachers' intentions. It underscores the intricate interplay of various attitudinal, practical, and contextual factors that collectively influence teachers' decisions to adopt VL.

In addition, the MLR analysis shows a positive association between PK and PEOU, supported by an r-value of 0.236 and a p-value of 0.226. This finding signifies that Life Sciences teachers in rural schools who possess a robust pedagogical foundation are more likely to perceive technology as intuitive and accessible. This insight highlights the potential synergy between effective teaching practices and the use of VL, indicating that a solid pedagogical grounding can facilitate a smoother use of novel technology tools such as VL in teaching strategies. More so, the positive association between PK and BI ($r = 0.364$; $p = 0.002$*) offers an intriguing perspective on teachers' intentions to use VL in their teaching. From this finding, one can argue that teachers with advanced pedagogical expertise express a stronger inclination to embrace VL as a pedagogical tool. This alignment between pedagogical proficiency and VL adoption intentions suggests that teachers who deeply understand effective teaching methods recognise the potential benefits of VL as an enhancement to their teaching toolkit. In contrast, the most intriguing finding emerges from the negative correlation between PK and AU of VL ($r = -0.614$; $p = 0.001$*). This phenomenon highlights a significant disconnection between teachers' intentions and their practical use of VL. While the

Life Sciences teachers with substantial PK express a higher intention to use VL, its tangible use in their teaching remains lower than expected. This discrepancy raises questions about potential barriers, challenges, or factors that hinder the translation of intention into action.

Moreover, the correlations for PCK are non-significant across all dependent variables. This suggests that, in this study, the influence of pedagogical content knowledge might be less pronounced when shaping teachers' perceptions, intentions, and behaviours related to VL use in teaching. Similarly, TPK shows minimal correlations with the dependent variables that do not reach statistical significance. TPK's non-significant correlations suggest that it might not strongly relate to teachers' perceptions, intentions, or behaviours regarding VL use. Regarding TPACK, the present research shows that it does not significantly correlate with PU ($r = 0.093$, $p = 0.121$), PEOU ($r = 0.097$, $p = 0.219$), or BI ($r = -0.038$, $p = 0.435$). However, a noteworthy finding is the correlation between TPACK and AU of VL, which is the strongest ($r = 0.613$) compared to other TAM variables. This association is also statistically significant ($p = 0.000$), suggesting that TPACK exerts the most significant influence on Life Sciences teachers' use of VL. Based on this finding, one can conclude that TPACK is a strong predictor for Life Sciences teachers' adoption and use of VL, and here lies the new knowledge for perceptions of VL for science teaching in SA rural schools. Overall, the MLR analyses reveal a statistically significant linear association between the TPACK and TAM constructs. Thus, it can be predicted that when Life Sciences teachers develop higher TPACK levels, then the chance of having positive perceptions of VL also increases. In contrast, if teachers have low TPACK levels, then they develop negative perceptions of VL for rural teaching. Therefore, TPACK levels can be directly linked to the teachers' perceptions of VL. The next section accounts for the divergence between specific quantitative and qualitative results reported in this research.

5.7 DIVERGENCE BETWEEN QUANTITATIVE AND QUALITATIVE FINDINGS

When I employed the mixed methodology, I aspired to achieve convergence in the findings, which refers to combining all the findings in an organised way to enhance the validity of the present study (Zhou & Wu, 2022). However, lack of convergence, as I experienced in this study, does not necessarily indicate a defect in the research, as non-convergence can occur due to a variety of reasons, such as differences in the

sample size or sampling technique or discrepancies in the research design or methodology (Zhou & Wu, 2022). Furthermore, Mayoh and Onwuegbuzie (2015) argue that conflicting results can actually uncover new theories and insights, leading to in-depth insights into the phenomenon being investigated. Similarly, Headley and Plano Clark (2020) suggest that divergence between quantitative and qualitative results can unearth deeper perspectives, as researchers would have an opportunity to explore and explain why the results are different.

Mixed methods research allows for a deeper understanding of an enquiry by combining quantitative and qualitative data. However, as Headley and Plano Clark (2020) found, insufficient use of questionnaires can result in divergent results in mixed methods studies. In addition, Shannon-Baker (2016) suggests that sampling can be a design issue that can give rise to divergent findings between quantitative and qualitative approaches in mixed methods studies. Furthermore, each approach's focus can differ as quantitative methods aim to achieve adequate statistical power while qualitative approaches aim to attain conceptual or theoretical saturation (Mayoh & Onwuegbuzie, 2015; Headley & Plano Clark, 2020; Taherdoost, 2022). In this study, there were instances where the quantitative and qualitative results were in contradiction. For example, the quantitative findings indicated that the Life Sciences teachers had the TK required to use VL for teaching. At the same time, the qualitative interview participants reported low levels of TK. Furthermore, while the quantitative findings revealed that teachers believed their SMTs ($M = 3.554$, $SD = 0.8882$) and school communities ($M = 3.349$, $SD = 0.9191$) supported teaching with VL, none of the qualitative interview participants mentioned such influence.

Therefore, the study's quantitative and qualitative results showed a divergence, which could be attributed to the sampling technique employed when selecting the participants. I used a purposive sampling approach to invite survey respondents keen to participate in the follow-up interviews. I purposively selected only four from the 27 questionnaire respondents willing to be interviewed. The disparity in the number of participants in the two approaches might have caused the observed discrepancy, as participants' tech-savviness and interest in implementing VL in their teaching could differ between the two groups. Besides, methodological differences between the qualitative and quantitative phases could have contributed to the observed

divergence. Since the second qualitative phase of the research can only be developed after completing the first quantitative phase in a sequential explanatory mixed methods design, there was a time lapse between data gathering for the two phases, which might have influenced the results.

Furthermore, the survey's quantitative results were not obtained through questions that were explicit or tailored to each individual. In contrast, the qualitative semi-structured interview questions allowed teachers to express and elaborate more comprehensively on their perceptions and experiences of VL. In other words, the survey questionnaire could not capture the depth and richness of the teachers' experiences with VL as captured qualitatively. As a result, I suggest that the discrepancy between the quantitative and qualitative results could be attributed to the limited ability of the quantitative questionnaire to capture the intricate experiences that were reported through qualitative means. The following section folds the study.

5.8 SUMMARY

The present chapter provided the study's findings, which aimed to probe Life Sciences teachers' perceptions and experiences of using VL for rural teaching. Most participants were female (64%) and fell within the 31-40 and 41-50 age groups. Most surveyed teachers had 5-10 years of teaching experience and a Bachelor of Education degree.

The findings demonstrated that the teachers held positive perceptions of VL and voiced strong intentions to use it. Social influence, particularly from learners, significantly influenced the teachers' decision to adopt VL. However, the technology at conception limited its actual usage, and negative factors like lack of support, skills, and limited electricity supply were identified. Despite these challenges, the teachers found VL useful in facilitating their teaching. The participants had high mean ratings for all the TPACK domains, indicating high competence in their knowledge in these areas (CK, PK, and PCK). However, the teachers' TPACK to use VL was poor to moderate, with TPK having the lowest mean score. Positive correlations between TPACK and the TAM constructs were also found, indicating that higher levels of TPACK are linked with the actual use of VL. MLR analysis revealed that TPACK significantly influenced the Life Sciences teachers' perceptions of VL for rural teaching.

This study revealed some crucial findings:

a) The usefulness of VL is more important than its ease of use in terms of encouraging its adoption.
b) Positive correlations exist between the TAM and TPACK constructs.
c) Using a blend of the TAM and TPACK framework can help explain Life Sciences teachers' perceptions and experiences of VL for rural teaching.
d) Teachers' TPACK level significantly impacts their perceptions of VL.

Therefore, professional teacher development should highlight the features of VL that make it a suitable science teaching platform to generate interest among teachers and explore how VL can fit into different pedagogical approaches. Although enhancing teachers' TK and exposing them to the technical operations of VL is critical, it may be less valuable than focusing on the approaches mentioned above. Overall, the study provided valuable insights into Life Sciences teachers' perceptions and experiences regarding the use of VL for rural teaching. The present study's findings may have important implications for science teachers and researchers who aim to advocate using VL in teaching-learning spaces, as discussed in the next chapter. The subsequent chapter is the final segment of the investigation. Its primary objective is to present a summary of the research, emphasising the most significant findings. Furthermore, the limitations or challenges confronted while conducting the study will be highlighted. Additionally, the chapter suggests recommendations based on the study's insights and discoveries and indicates potential lines for further research.

CHAPTER SIX

DISCUSSION OF FINDINGS AND CONCLUSIONS

6.1 INTRODUCTION

This final chapter summarises this study's key findings, highlighting the most essential insights from the research. The summary of the findings serves as a snapshot of the study's main contributions concerning the research questions. In this chapter, I discuss the findings related to each research question, drawing upon relevant literature and the theoretical underpinnings presented in chapter two as lenses to ascertain the significance of the findings. Considering the findings from the present study, I formulated recommendations and suggestions for future studies in this chapter. The chapter starts with a brief overview of the investigation. It then summarises the findings, highlighting the new knowledge generated. This is followed by the recommendations, areas for further research, and conclusions.

6.1.1 An Overview of the Research

The present study was carried out in South Africa when the global call to utilise virtual learning platforms was louder than ever before due to the COVID-19 experiences. As VL is a new technology in the country, user acceptance issues inevitably arise, and these have to be interrogated. A literature search yielded few studies that investigate perceptions of virtual learning spaces in SA. These studies, including those done by Zhane'Solomon (2018), concentrated on lecturers' perceptions of using Virtual Realities (VR) for teaching, while Ramnarain and Penn (2019) explored university students' attitudes toward science learning on virtual platforms. Similarly, Jantjies and Matome (2021) examined student perceptions of VR in universities. What distinguishes the present study from the rest is that they were all conducted in university contexts using lectures and students, and none in secondary schools using teachers, particularly in rural schools. Thus, this study's unique contribution is that it is the first to explore teacher perceptions and experiences of VL in rural secondary schools in SA. Consequently, this research bridges the gap and complements prior research by contributing new insights to understanding how secondary science teachers in rural school contexts perceive VLs in SA. Specifically, the study is directed by the following research questions:

- What are rural Life Sciences teachers' views and understanding of the integration of VL in classroom practice?
- What are rural Life Sciences teachers' experiences concerning the integration of VL into science teaching?
- How can rural Life Sciences teachers' perceptions and experiences of the integration of the VL be understood and explained?

6.2 DISCUSSION OF KEY FINDINGS

The discussion of findings is structured into sections that align with the three research questions. This structured approach aims to improve the clarity and coherence of the discussion by ensuring a logical flow of information, allowing each section to focus on a specific aspect of the research.

6.2.1 RESEARCH QUESTION ONE

In this section, I discuss the findings related to the first research question:

- What are rural Life Sciences teachers' views and understanding of the integration of VL in classroom practice?

6.2.1.1 Teacher Perceptions on the Integration of VL

The teachers' perceptions of integrating VL were examined through two different lenses in RQ1 and RQ3. Specifically, RQ1 illuminates the teacher perceptions with respect to the three fundamental components of the TAM: PU, PEOU, and BI. This inquiry aims to discern how teachers perceive the potential benefits of VL integration, their perception of the ease with which they can employ the technology, and their intentions to utilise it in their teaching. On the other hand, RQ3 provides insights into the teacher's self-reported knowledge on integrating VL in teaching, analysed through the TPACK framework lens (PK, CK, TK, PCK, TPK, TPACK). By exploring the teachers' TPACK, RQ3 aimed to ascertain the degree to which the teachers feel equipped to leverage VL into teaching effectively. The findings of the research questions yielded intriguing insights, suggesting a positive stride toward the acceptance and integration of VL in rural classrooms. In summary, the answer to RQ1 is that the Life Sciences teachers in rural secondary schools demonstrated positive perceptions toward integrating VL for teaching.

6.2.1.1.1 Perceived Usefulness of Virtual Lab

In this study, I view PU as the degree to which Life Sciences teachers in rural schools perceive that utilising VL is useful in teaching. This study's findings provided compelling evidence that Life Sciences teachers in rural schools perceive VL as a valuable tool for teaching science through experiments. For example, the high mean score for the PU of VL (see Section 5.3.1.2) indicates that teachers acknowledge the benefits of incorporating this technology in teaching. Notably, the mean score for PU was higher than PEOU, showing that teachers prioritise the benefits of teaching with VL over its ease or difficulty of use. This finding aligns with prior research, which has highlighted the benefits of adopting virtual learning environments into science education (Tatli & Ayas, 2012; Ambusadi et al., 2015; Ramnarain & Penn, 2021). However, it is noteworthy that previous studies did not specifically investigate teachers' perspectives on integrating VL in rural secondary schools. Therefore, this study contributes a unique perspective by demonstrating that teachers in resource-constrained settings also recognise the value of VL as a science teaching-learning environment.

In addition to quantitative data, qualitative insights from semi-structured interviews further support the teachers' positive perceptions of VL. The interviews revealed that teachers appreciated VL's usefulness in several ways, such as saving time and facilitating quicker learning of science concepts. These findings corroborate past research (Pyatt & Sims, 2012; Jaradat, 2020) and endorse the assertion by Engel et al. (2023:5) that "VL is useful in supporting running experiments by cutting time spent on work such as setting up and calibration of equipment, freeing up time available for teaching and learning."

Furthermore, the study uncovered a perception that VL could be a viable alternative platform for conducting experiments, particularly in schools with limited resources. This finding contributes a novel perspective of SA Life Sciences teachers, as it is the first study conducted in rural schools. Another important finding is that teachers perceived VL as a safe platform for conducting experiments, avoiding physical dangers associated with traditional labs. For instance, the risk of learners accidentally cutting themselves during experiments involving cutting objects can be mitigated in VL. Previous studies have reported similar findings (Afgan, 2015; Kapilan, 2021;

Chen, 2022), highlighting the safety advantages of using VL. Additionally, while this study focused on teaching, the teacher participants also acknowledged the usefulness of VL for learning. The teachers perceived VL as a means to enable learning anywhere and anytime, including when physical laboratories are unavailable. This finding aligns with findings by Davenport et al. (2018) and Makarova et al. (2023) that VL transcends the limitations of physical proximity, allowing learners from remote areas or underserved communities to conduct experiments and access science learning opportunities that were previously inaccessible to them.

Collectively, the above findings demonstrate that Life Sciences teachers in rural schools perceive VL as an essential tool for optimising their work. This finding supports the notion that the PU of VL is a robust indicator of teachers' inclination to adopt this technology into their future pedagogical practices. It is worthwhile that although this study reports a positive relationship between PU and BI to adopt VL, the association is weak (see Section 5.4). However, this positive relationship is crucial, as it suggests that when the usefulness of VL for rural science teaching is established, teachers are likelier to adopt the technology for teaching. Conversely, if the perceived usefulness of VL is not recognised, teachers may abandon the technology and seek more useful alternatives. Based on the above findings, the present research supports the notion held by several other researchers (Davis (1989; Ertmer, 2005; Kriek & Stols, 2010; Larijani & Abedi, 2021) that a strong and positive perception of the usefulness of technology is an essential predictor of its acceptance and successful integration in teaching. Therefore, the present study's findings regarding VL's usefulness are promising, solidifying its potential cutting-edge technology for rural science teaching.

6.2.1.1.2 Perceived Ease of Use of Virtual Lab

In this research, I discuss PEOU as the teachers' subjective perception of how effortless VL is for rural teaching. One noteworthy finding from this investigation is that the Life Sciences teachers overwhelmingly perceived VL as user-friendly, easy to use, and intuitive for rural teaching, as shown by the high mean score for PEOU (see Section 5.3.1.3). Furthermore, the individual PEOU items analysis revealed a strong positive perception among teachers that "learning to teach with Virtual Laboratory is easy." Moreover, during the semi-structured interviews, the teachers further confirmed that VL provides step-by-step instructions, making the learning process

straightforward and seamless. Such findings underscore the user-friendly nature of VL and its ability to facilitate a smooth learning curve for teachers in rural schools. On the contrary, it is essential to note that while most Life Sciences teachers perceived VL as easy to use, a significant number equally expressed that VL could not be as easy for them to use. This finding is expected due to the novelty of the technology and unsurprising in the early stages of adopting any new technology.

Furthermore, this study presents evidence of a robust positive relationship between PU and PEOU regarding VL. This research firmly establishes that teachers' intention to adopt VL in their future teaching approaches is significantly tied to their perception of its ease of use and usefulness. This establishment flows from the fact that in teaching with technologies, teachers unequivocally prefer a technology that minimises effort and maximises efficiency. This is a crucial insight, as ease of use is a pivotal influencer for teachers' willingness to adopt new educational technologies, including VL. Therefore, the present study concurs with Davis (1986), emphasising that the perception of ease of use favourably impacts the adoption of new technologies in teaching. Therefore, teachers must perceive VL as intuitive and easy to use, thus alleviating the burden on teachers and saving them valuable time and energy.

Notably, the key takeaway from this research is that, from the teachers' perspectives, a user-friendly VL holds tremendous potential to facilitate its seamless integration into rural schools. This finding underscores the notion by Davis (1989) and Ertmer (2005) that teachers are more inclined to embrace and incorporate educational technologies when they perceive them as both easy to use and useful. This research, thus, supports prior studies by Kriek and Stols (2010), Carver (2016), and Zeichner (2021) and reinforces the significance of PU and PEOU as crucial predictors of teachers' intention to adopt VL. Moreover, the positive correlation established in this study between PU and PEOU (see Section 4.4) aligns with the broader literature on technology adoption in education (Romiszowski, 2004; Zhane'Solomon, 2018). More specifically, Nelson et al. (2019) asserted that teachers' positive perceptions are essential for meaningful technology integration. Likewise, Davis (1989:23) observed that "user acceptance is pivotal in determining the success or failure of any technology." However, what makes this research particularly noteworthy is that it addresses a relatively unexplored area within the field of science education in SA - the perspective of teachers in rural schools

on integrating VL. By focusing on this specific rural school context, this study provides fresh insights into the teachers' perceptions and experiences of VL in rural settings. This effort could be a first step towards positioning VL as a game-changer in enhancing science teaching, particularly in rural secondary schools facing limited science resources and infrastructure.

6.2.1.1.3 Behavioural Intention of Virtual Lab

In this study, BI refers to the teachers' willingness, inclination, or motivation to integrate VL for teaching in rural schools. The present study unveiled exciting findings concerning the Life Sciences teachers' desire to adopt VL in rural schools. Notably, among the three constructs examined for teacher perceptions, i.e., PU, PEOU, and BI, the construct BI registered the highest mean score, indicating a solid inclination by most teachers to adopt VL into their future lessons (see Section 5.3.1.4). The strong tendency and intention of Life Sciences teachers in rural and under-resourced schools to adopt VL into their future lessons challenge the notion by Squire (2003), Pyatt and Sims (2012), Pellas (2014), Davenport (2018), and Falade (2020) that technology adoption is primarily driven by resource abundance or urban school environments. Instead, this finding highlights the agency, agility, and adaptability of the present teacher cohort in rural schools, who recognise the potential of technology to overcome resource limitations and enrich their science teaching. Therefore, the positive perceptions and intentions expressed by the teachers in this study signify a significant shift in mindset towards embracing technology as a viable alternative and solution to resource constraints.

More so, the teachers' keenness and commitment to adopt VL in rural schools was stressed by the high mean score for the item "I intend to use Virtual Laboratory more to enhance my Life Sciences teaching" (see Section 5.3.1.4). Despite working in resource-poor environments, the teacher participants were eager to explore and leverage the innovative VL to enhance their science teaching. This finding corroborates Zeichner's (2021) notion that teachers with a firm intention to integrate technology into their teaching will likely incorporate it into their pedagogy. Specifically, the individual BI questionnaire items analysis revealed a notably high mean score for the item "I would recommend using Virtual Laboratory to others" (see Section 5.3.1.4). The finding that Life Sciences teachers in rural schools express a solid intention to

recommend VL to their peers signifies the role of these teachers as change agents within their school communities, fostering a culture of knowledge sharing and collaboration. This aspect could be particularly significant in rural settings, such as the context of this research, where teachers have limited access to professional development opportunities. Moreover, the teachers' endorsement of VL can enhance their practice and encourage their colleagues to explore and adopt technology-driven teaching strategies. From this finding, this research contends that the future of VL integration in rural schools looks bright.

More interestingly, the present research identified a positive association between BI and AU of VL (see section 5.4). This finding suggests that when the teachers in rural schools are willing to adopt VL, they are likely to follow through and utilise it. This discovery corroborates previous studies that found that AU is inherently tied to BI (Kriek & Stols, 2010; Carver, 2016; Zeichner, 2021). Although the correlation between BI and AU was relatively weak in this study, this relationship contributes to an understanding of the perceptions held by Life Sciences teachers in rural schools when making decisions about adopting VL in their teaching. It is essential to acknowledge that this study did not directly explore whether the positive BI of the teachers would indeed translate into AU of VL in teaching. While the expressed intention to adopt VL is encouraging, it is crucial to understand that intention alone differs significantly from implementation. This view aligns with Ajzen (1985) and Larijani and Abedi (2021), who caution that an intent to use technology may not necessarily translate into its widespread adoption and consistent usage. This suggests that while there is a strong inclination and intention among Life Sciences teachers in rural SA schools to adopt VL, there are potential challenges to consider in the actual implementation process.

In summary, this pioneering study reveals Life Sciences teachers' strong inclination and intention in rural schools in SA to adopt VL as a valuable tool for augmenting their teaching practices. The teachers' positive BI and willingness to recommend VL to others indicate a promising start. The teachers appear open to embracing VL, and their endorsement could pave the way for its successful integration into their classrooms. However, it is crucial to recognise that while intentions are positive, the translation into actual practice is a multifaceted process that may face challenges, leading to a disconnect between the initial intent and the actual execution. These

challenges could include technological barriers, resource constraints, resistance to change, and the need for training and support. Nonetheless, from the promising outlook of the teachers' solid intention to use and recommend VL to others, the successful adoption of this technology into rural science teaching can be anticipated. The next section presents a discussion of the results of RQ2.

6.2.2 RESEARCH QUESTION TWO

This section discusses the findings related to the Research Question 2:

- What are rural Life Sciences teachers' experiences concerning the integration of VL into science teaching?

6.2.2.1 Teachers' Experiences of Virtual Lab

Positive perceptions towards technology play a crucial role in shaping users' experiences, as highlighted by Carver (2016). In this study, the positive perceptions expressed by the Life Sciences teachers in rural schools towards VL set the stage for a potentially positive teaching experience with the technology. Nevertheless, perceptions do not always align with lived experiences, and there might be tensions between the intended use of VL and its actual use in the classroom. The discussion in this section draws on three elements of TAM, i.e., SI, FC, and AU, alongside exploring the contextual factors impacting the use of VL in rural schools. By investigating the above components, I aimed to understand the issues that can influence the rural Life Sciences teachers' acceptance and successful adoption of VL in teaching in rural secondary schools.

6.2.2.1.1 Social Influence Regarding Virtual Lab

SI in the present investigation refers to the influence of interpersonal and social factors on VL acceptance and use in rural secondary schools. The study findings on SI in adopting VL in rural schools yielded some unexpected and intriguing results. Surprisingly, the analysis of the questionnaire items related to SI revealed that peers, colleagues, and SMTs received lower mean ratings compared to family and friends regarding advocating for and supporting the use of VL (see Section 5.3.2.2). This finding challenges my initial assumption that colleagues and SMTs, presumed to exert more influence on adopting innovative technologies such as VL in schools, would

provide more substantial support for its integration. Moreover, during the interviews, the lack of support from fellow teachers and SMTs was also exposed, where no teacher participants mentioned any form of influence from within the school, apart from the learners. This absence of positive influence from other staff members in the school found in this study raises a concern regarding peer support when introducing new initiatives. When reduced to its elements, the lack of support by colleagues for innovative technology adoption efforts points to a culture of lack of school-based support networks. Based on this finding, like Zeichner (2021), this study cautions that if colleagues and SMTs are not supportive of new technologies, it could hinder the willingness of teachers to incorporate these technologies into their classrooms. Furthermore, this finding demonstrates that to ensure successful technology adoption, it becomes imperative to involve all staff members in the school and foster a culture of peer-to-peer support, and sharing of experiences, best practices, and challenges.

In addition, another intriguing observation that emerged from the present research regards the influence of learners on teachers' adoption of VL. The survey results revealed a high mean score for "My learners think I should teach with Virtual Laboratory" (Section 5.3.2.2). This finding is even more noteworthy because none of the interviewed teachers mentioned any other form of influence from within the school apart from their learners. One teacher, LST3, specifically emphasized that witnessing their learners' motivation and excitement about using VL significantly influenced their decision to adopt it into future lessons. This finding provides valuable insights into a less-known source of teacher motivation: the enthusiasm and interest exhibited by their learners. This study found that teachers draw inspiration and derive motivation from their learners' keen engagement with VL. In other words, when learners demonstrate a keen interest in a particular educational tool, it can be a powerful incentive for teachers to adopt and integrate it into their teaching. Therefore, the present study's emphasis on learner enthusiasm and interest as a driving force for teacher adoption of technology represents another vital contribution to the existing knowledge base, as no such findings were reported in the studies reviewed in this investigation. This is because this study's revelation that teachers draw inspiration and motivation from their learners' interest in new technologies challenges previous assumptions about the primary sources of teacher motivation in the adoption of educational innovations reported in previous research (Tobin, 1986; Ertmer, 2005; Cox

& Graham, 2009; Burić & Moe, 2020). For example, Tobin's (1986) research focused on the factors influencing teacher adoption of educational technology. His findings highlighted teacher training programmes and institutional support as key to encouraging technology adoption in teaching. Moreover, Ertmer's work (2005) delved into the concept of 'self-efficacy' among teachers, which relates to their belief in their ability to integrate technology into their teaching successfully. Her findings suggest that teachers with higher self-efficacy are more inclined to adopt technology in their classrooms. She also identified the role of external factors, such as professional development and supportive administrators, in enhancing self-efficacy. In addition, Cox and Graham (2009) identified barriers such as a lack of time, resources, and technical support in integrating technology into education, stressing the necessity of overcoming these obstacles to promote technology adoption among teachers. More so, Burić and Moe (2020) report pedagogical beliefs as a crucial factor in determining the adoption of educational technology. Therefore, while these previous studies highlighted factors like training, self-efficacy, institutional support, and pedagogical beliefs, the current research introduces a novel perspective. The present study reveals that when learners exhibit a strong interest in a specific educational tool (VL), it is a potent motivator for teachers to adopt the technology into their teaching, even without extensive training or high self-efficacy. This (re)interpretation contradicts the established wisdom that these traditional factors are the primary drivers of technology adoption among teachers. Instead, it underscores the pivotal influence of learner enthusiasm, offering a fresh perspective for future research and practice in educational technology adoption, thus steering clear of mere repetition of existing research.

Moreover, the most unexpected finding was the highest mean score for the SI item "My family and friends think that I should teach with Virtual Laboratory." (see Section 5.3.2.2). The revelation that family and friends can significantly support VL adoption in rural schools is another novel and noteworthy finding from the present study. This recognition of the influence of personal relationships outside the school environment represents a departure from traditional perspectives that primarily focused on the support received from colleagues and SMTs. Prior research by Samancıoğlu et al. (2015), Gürfidan and Koç (2016), Kabra, Ghosh, and Joshi (2023), and Kulaksız and Karaca (2023) has predominantly emphasised the vital role of peer support, collaboration among colleagues, and the guidance of SMTs in facilitating the adoption

of innovative tools like VL. Specifically, Samancıoğlu et al. (2015) herald the significance of professional learning communities in technology adoption. On the other hand, Gürfidan and Koç (2016) stress the importance of peer networks, while Kulaksız and Karaca (2023) underline the role of school leadership and administrative support. While the existing literature accentuates the significance of professional relationships within the school environment, the current study illuminates a novel dimension that personal networks outside the school, particularly friends and family, can also substantially support teachers in adopting innovative tools, such as VL. This innovative perspective challenges conventional assumptions and broadens the understanding of the multifaceted influences on technology adoption in educational settings. By surfacing the role of family and friends, this research opens new avenues for research, highlighting the potential interplay between personal and professional networks in technology adoption among teachers, particularly in rural school contexts.

6.2.2.1.2 Facilitating Conditions of Virtual Lab

In this context, FC refers to the Life Sciences teachers' perceived availability of technical, infrastructural, and institutional support to facilitate VL adoption and use in teaching. The present research findings shed light on the FC for adopting VL in rural schools and provided valuable insights into teachers' challenges and opportunities in integrating this new technology. Notably, the overall mean score for FC indicates that teachers in rural schools expressed uncertainty regarding the factors that can enable or hinder effective teaching with VL (see section 5.3.2.3). One possible explanation for the finding could be that VL is a relatively new technology in SA. As such, many teachers may not have had prior experience or familiarity with the factors influencing its successful adoption and use. This finding is consistent with the broader literature on technology adoption in education, which underscores the pivotal role of familiarity and prior experience. For instance, Stumbrienė, Jevsikova and Kontvainė (2023), in their exploration of digital learning tools adoption, found that teachers' previous experience with technology significantly influenced their ability to adapt to new digital teaching tools. The current study findings align with this, stressing that many SA teachers in rural schools may not have had substantial prior exposure to VL technologies, which then might lead to uncertainty regarding the facilitating conditions for successful VL adoption.

Interestingly, while the current study highlights the uncertainty regarding facilitating conditions for VL adoption and use, its survey findings revealed that the availability of necessary resources, including computer hardware and software, received the highest mean score, suggesting high access to the requisite technology tools (see Section 5.3.2.3). This finding suggests that the question of technology access is no longer a significant barrier to technology adoption in rural schools. This observation contradicts prior studies that consistently depicted rural schooling as hindered by a lack of access to technology, mainly due to the absence of necessary technology tools. Such previous studies include Van Dijk and Van Deursen's (2020) systematic literature review of empirical studies from 35 countries, including China, India and the USA.

Precisely, the current study's findings represent a direct challenge to previous research that reported low technology access in the EC province (SA). For example, Mthembu's (2014) qualitative investigation of three schools identified limited technology access as a significant obstacle to technology adoption in rural EC schools. Likewise, a quantitative study by Mwapwele et al. (2019), which examined ICT adoption among 240 teachers, reported a lack of technology tools in rural EC schools. The significant increase in technology access observed in the present research can be attributed to the initiatives of the SA government and many other governments globally. These initiatives, prompted by the challenges posed by the COVID-19 pandemic, involved equipping teachers and schools with technological resources. Consequently, the majority of teachers now have widespread access to these resources. Therefore, the current study asserts that technology access no longer poses a significant barrier to technology adoption in rural schools, particularly in SA.

Furthermore, similar to the findings under SI, the questionnaire items related to guidance and assistance from within the school received the lowest mean scores (see Section 5.3.2.3), indicating that teachers in rural schools do not feel adequately supported in their efforts to adopt and use VL. The questionnaire findings were confirmed during the semi-structured interviews, where teachers lamented the lack of technical guidance and administrative support. In this study, the lack of support may be attributed to the novelty of the technology, which is inevitably characterised by the absence of individuals with the necessary expertise to support VL lab integration. Similar findings were reported by Yazici and Nakıboğlu (2023) in their examination of

factors affecting Chemistry teachers' VL use in Turkey. This alignment between the two studies in different contexts strengthens the idea that the newness of VL may be the primary reason for the lack of guidance and support when adopting VL in schools. This observation is supported by several other scholars in the literature (Arista & Kuswanto, 2018; Falade et al., 2020; Polat & Ekren, 2023). Taken together, the survey and interview findings underscore the need for comprehensive technical and administrative support in rural schools to facilitate the successful adoption and use of VL. While the need for technical and organisational support has been widely reported in past research on technology integration (Ertmer, 2005; Cox & Graham, 2009; Burić & Moe, 2020), this study's findings contribute to the current literature by adding the perspectives of rural secondary school Life Sciences teachers on the integration of VL.

6.2.2.1.3 Actual Usage of Virtual Lab

The present study's findings indicate a clear pattern and current low usage of VL among Life Sciences teachers in rural secondary schools in SA. The mean scores for all the individual AU items were consistently low, suggesting that most teachers have not extensively used VL in their classrooms (see Section 5.3.2.4). This observation aligns with the current study's understanding that VL is a relatively new technology in SA, and its integration into teaching is yet to gain traction. These findings confirm earlier observations made by Oloruntegbe and Alam (2010) in Malaysia, Aliyu and Talib (2019) in Nigeria, Kapici, Akcay, and Cakir (2022), and Yazici and Nakıboğlu (2023) in Turkey that the integration of VL in teaching is still in the early stages of conception in many countries. The low usage of VL, as indicated by both the present study's quantitative and qualitative findings, is not surprising, given the novelty of the technology. However, the teachers' acknowledgement of its potential benefits and their desire for support and training signifies an encouraging readiness to embrace VL if the necessary conditions are provided.

6.2.2.1.4 Factors Impacting the Use of VL in rural schools

The findings of this research resonate with earlier studies conducted in SA and other contexts on the factors that impact technology use in teaching (VL included). One factor that has consistently emerged in previous research in SA is the limited electricity supply (Muktiar & Sharma, 2019; Assey & Babyegeya, 2022), and this study reaffirms

its critical role in hindering the effective adoption of VL in teaching. The high mean score (M = 4.167, SD = 0.7705) obtained for limited electricity supply indicates that it significantly affects the teachers' capability to incorporate VL in teaching. Furthermore, the study validates previous studies on the essence of support when integrating technology into teaching. In reinforcing the established understanding that lack of support remains unaddressed in technology adoption in rural schools, the current research adds weight to the importance of addressing the support needs of teachers in implementing VL effectively.

Additionally, the study's identification of low skills/experience, lack of professional development, and poor maintenance of technology align with previous research findings in which these factors were sufficiently acknowledged as significant challenges for meaningful technology adoption (Koh & Chai, 2011; Carver, 2016; Ali & Ullah, 2020; Yazici & Nakıboğlu, 2023). VL is not an exception to these challenges, and the question is, when will these well-documented challenges be addressed to ensure successful technology integration in teaching? The present study supports previous studies on the factors impacting technology adoption by highlighting the challenges experienced by Life Sciences teachers in adopting VL in rural secondary schools. The following section discusses the results related to the last question.

6.2.3 RESEARCH QUESTION THREE

This section's results aimed to address the question:

- How can rural Life Sciences teachers' perceptions and experiences of the integration of Virtual Lab be understood and explained?

6.2.3.1 Explaining Teacher Perceptions and Experiences of Virtual Lab Integration.

In explaining the teachers' perceptions and experiences of VL for rural science teaching, this study used descriptive and inferential statistics by drawing on relationships between TAM and TPACK components. The brief answer to RQ3 is that teachers who have higher TPACK levels tend to hold more positive perceptions towards integrating VL, leading to enhanced experiences in implementing this technology. These results align with research conducted by Mishra and Koehler

(2006), which found that teachers with higher TPACK levels were more effective at adopting technologies in teaching. Additionally, the study by Archambault et al. (2010) supports these findings by revealing that teachers with higher TPACK levels reported positive views toward technology integration and were likelier to incorporate technology in their classrooms. Therefore, this research contributes to the existing literature by emphasising the influential role of TPACK in shaping teachers' perceptions and experiences of VL integration. Significantly, this pioneering study explores teachers' perceptions and experiences in integrating VL within the SA educational context, particularly the relatively unexplored rural and marginalised secondary schools' contexts. By recognising the critical role of perceptions in shaping practices, as established by previous research (Niess, 2011; Putri et al., 2022), it became evident that a comprehensive understanding of teachers' knowledge was necessary to foster acceptance and integration of VL effectively. The following sub-section delves into the influence of teacher knowledge on teachers' perceptions of VL.

6.2.3.1.1 Influence of Teacher Knowledge on Teacher Perceptions and Experiences on the Integration of Virtual Lab

A notable contribution of the present study lies in its amalgamation of TAM and TPACK frameworks to explain teacher perceptions and experiences regarding the integration of VL. TAM provided valuable insights into the factors affecting the adoption and use of VL by Life Sciences teachers in rural schools. Meanwhile, the TPACK framework offered a lens to comprehend the teachers' reported knowledge necessary to leverage technology in teaching. This amalgamation of TAM and TPACK represents a novel theoretical and methodological approach to examining technology integration, particularly within the context of rural science education. To the researchers' knowledge, no study has ventured into this intersection of TAM and TPACK when examining VL adoption in rural secondary schools in SA.

This study probed the teachers' self-reported TPACK levels across the six TPACK domains, categorised into two groups: non-technology domains (CK, PK, and PCK) and technology-related fields (TK, TPK, and TPACK). Notably, the non-technology domains exhibited higher mean scores (see Section 5.3.3.1), indicating a profound understanding of subject content and pedagogy among Life Sciences teachers. Conversely, the technology-related TPACK domains scored lower on the average

mean score (see Section 5.3.3.1). The present study validates previous research by Koehler and Mishra (2007), Cox and Graham (2009), and Gentles and Haynes-Brown (2021) that found practising teachers often exhibiting higher levels of PK, CK, and PCK compared to TK, TPK, and TPACK. This finding prompts the question of when teachers in rural schools will acquire and demonstrate superior proficiency in the technology-related TPACK fields. The higher mean scores for the non-related technology domains compared to the technology-related constructs imply that Life Sciences teachers better understand their subject content and the teaching approaches than their technological expertise. This finding was expected as it aligns with the country's teacher training system, where qualified teachers must hold a degree in their specific subject. Furthermore, continuous professional development programmes prioritise workshops that address content gaps and enhance pedagogical skills. As a result, teachers' proficiency in CK, PK, and PCK is further strengthened.

In addition, consistent with Violanti (2023), the present study found that TK was the most prominent domain among the three technology-related components. While Life Sciences teachers might have a more robust understanding of TK in isolation, this study found that merging it with CK and PK posed challenges, as demonstrated by the lower mean scores of TPK and TPACK (see Section 5.3.3.1). This finding aligns with past studies by Li (2007), Jang and Tsai (2013), Choi and Paik (2021), and Ong and Annamalai (2023). It confirms Koehler and Mishra's (2006) observation that teachers experience difficulties comprehending the dynamic interplay and the transactional relationships between CK, PK, and TK. Overall, it is crucial to acknowledge that technology constantly evolves, necessitating ongoing updates and adaptations. This dynamic nature of technology may contribute to the lag in developing technology-related knowledge domains compared to more stable domains such as PC and PK. Therefore, the rapid changes in technology and integration into teaching may explain the comparatively lower self-reported knowledge levels in the technology-related domains among the Life Sciences teachers in rural schools.

Furthermore, the present study's Pearson coefficient correlation analyses revealed positive correlations between TAM variables (PU, PEOU, BI) and all TPACK constructs (see Section 5.4). Notably, while positive relationships were observed

between PU and TPACK domains, the correlations were weak, indicating a moderate association at best. These findings suggest that higher TPACK levels among Life Sciences teachers contribute to a positive perception of VL's usefulness in teaching. Similar findings were revealed by Falade et al. (2020) and Yazici and Nakıboğlu (2023) that science teachers' technology self-efficacy can hugely impact their perceptions of teaching with educational technologies. Moreover, like in the present study, Davis (1989) and Ertmer (2005) observed that teachers having high self-efficacy often show a stronger inclination to use technologies, while those with minimal self-efficacy are usually more reluctant to use technologies and, thus, less likely to integrate technologies in their science classroom. Specifically, the present study found that TK exhibited the most substantial relationship with PU and PEOU compared to other technology-related TPACK components. This finding emphasises the pivotal role of TK as a foundational element for cultivating positive perceptions regarding VL's utility and ease of use in teaching. This finding aligns with the notion that increased familiarity and proficiency with a specific technology facilitate ease of use.

Additionally, the present research found positive correlations between BI and all TPACK constructs, with TK displaying the most significant relationship with BI (see Section 5.4). This result implies that higher levels of TK enhance Life Sciences teachers' intentions to utilise VL in their teaching. This finding runs parallel to research by Baturay, Gökçearslan, and Sahin (2017) and Njiku (2022**),** who found that PCK, rather than TK, exerts the greatest influence on teachers' intention to adopt the technology. One possible explanation for the contradiction could be that both TK and PCK play essential roles in teachers' intentions to integrate technology. However, their relative influences may vary depending on the specific context or educational setting. In some cases, such as in the present study, TK might have a more decisive impact, while PCK might be more significant in others. It is also possible that the influence of TK and PCK on teachers' intentions could interact with other factors about technology. More studies in various contexts are thus needed to further explore this observed phenomenon and to test the conjecture from the present study.

Most significantly, the present study identified a strong positive correlation ($r = 0.613$) between AU and TPACK (see Section 5.4). While some previous studies have reported positive correlations between TPACK and AU (Jang & Tsai, 2013; Zeichner,

2021; Ong & Annamalai, 2023), the present study offers new insights into rural school contexts. In sum, this study found that higher TPACK levels among Life Sciences teachers foster positive perceptions and experiences regarding the integration of VL in rural schools. This explanation was generated by combining the TAM and TPACK frameworks, illuminating the intricate dynamics of technology integration within rural science education. To the best of the researcher's knowledge, there is limited research exploring technology adoption using a combination of constructs from TAM and TPACK. Therefore, this study significantly contributes to technology integration research's theoretical and methodological landscape, providing a novel perspective on user acceptance and knowledge. As this was the first research to probe teachers' perceptions and experiences on integrating VL in rural schools in SA, it is envisaged that the investigation has set a theoretical and methodological foundation for future research on VL acceptance and adoption in similar contexts elsewhere. The following section sheds light on the new knowledge produced by this study.

6.3 CONTRIBUTION TO KNOWLEDGE

Building upon the discussion of findings, this section presents the new knowledge that this research has uncovered. The underlying contribution of this study to new knowledge is its departure from the common practice in prior research of solely blaming teachers for their lack of appetite for new technologies in science teaching. Instead, the present study examined the multifaceted aspects, perceptions, experiences, challenges, and opportunities that shape teachers' acceptance and adoption of VL for rural science teaching.

First, this study on teacher perceptions and experiences on integrating VL in rural schools in SA introduces several contributions that expand the existing knowledge frontiers and fill gaps identified in Chapter 2. The key contribution of the present study is that it has offered new insights into knowledge about VL integration not only in SA but also in the Global South context. As discussed in previous chapters, more research on VL integration has been conducted in the Global North, making research on VL less explored in the Global South and, to the researcher's knowledge, a new terrain altogether in SA. In the SA context, the few available research on virtual teaching-learning platforms placed more attention on the higher education level and none on the secondary schooling level. In the present research, the focus area was the

secondary schooling level. This focus area constituted a new research niche in science education in SA as it shifted the focus from higher education to the secondary schooling level concerning the integration of VL for rural science teaching.

More so, this study pioneers an investigation into the specific context of rural and poorly resourced schools - an under-researched territory in SA. While previous studies on technology integration have centred on urban or township settings, this study delves into the unique perspectives on the issues of acceptance and adoption of novel and innovative technologies by science teachers in rural schools. Specifically, the present research shed light on the perceptions and experiences of teachers in underserved rural contexts regarding the integration of VL. Therefore, this study contributes fresh insights crucial for understanding the issues that could shape the adoption of VL in rural schools. Moreover, this study fills a population gap by investigating the perceptions and experiences of Life Sciences teachers in rural schools, who have been underrepresented in previous research. Therefore, this research vehemently argues that it is vital to comprehend teachers' perceptions and experiences of technology. Without this understanding, there is a risk that VL may be abandoned or underutilised.

Second, this research does not claim that its combination of TAM and TPACK principles is new in science education research. Several researchers have done it elsewhere, mainly in the Global North (see Section 2.9). However, integrating the TAM and TPACK frameworks in this study represents a novel approach that expands the theoretical foundations of research on technology adoption in teaching in SA. The existing literature on technology integration in SA lacks theory triangulation to comprehensively understand the topic, especially the amalgamation of the TAM and TPACK framework. Current studies typically focus separately on UTAUT, TAM, or TPACK, limiting the depth of insight gained. Along the same line, Koehler and Mishra (2006) argue that in the complex and dynamic field of technology integration in teaching, it becomes evident that no singular framework can adequately encompass all the diverse questions that arise. In the present research, I aspired to offer a more comprehensive and nuanced exploration of teacher perceptions and experiences on integrating VL in rural schools by merging these two influential frameworks (TAM and TPACK). Combining the two frameworks enabled this research to explore the intricate

interplay between VL acceptance factors and the teacher knowledge required for successful integration. Incorporating multiple theories in research, James (1890) employs a potent fishing metaphor. He equates using several theories to casting multiple nets, enhancing the grasp of reality's intricacies. He articulately states: "Theories are nets cast to catch what we call reality. We must cast many nets, and pull them in many different ways, for each reveals something" (James, 1890:8). This underscores the value of diverse theoretical frameworks as applied in the present research to gain multifaceted insights. Since this study is the first in SA, such an analysis involving TAM and TPACK provides a theoretical contribution to previous research that employed other theoretical frameworks. In addition, this research offers a springboard for future researchers in similar contexts who may strive to investigate technology integration in teaching based on this study's theoretical lenses.

Third, it is worth noting that the present study is not the first to explore teachers' perceptions of VL in teaching. Previous scholars have already conducted similar investigations in different locations or contexts. For example, Yazici and Nakıboğlu's (2023) recent publication in Turkey examined chemistry teachers' perceptions and factors affecting VL use. However, the current research distinguishes itself from Yazici and Nakıboğlu's (2023) study by employing a mixed-methods approach, in contrast to their exclusive reliance on a qualitative methodology. Therefore, the present study's utilisation of a mixed-methods research design represents a significant methodological contribution and innovation, especially as this is the first study to investigate the adoption of VL in rural schools in SA. The study combined quantitative and qualitative data to capture a holistic and multifaceted view of teacher perceptions and experiences on integrating VL in rural schools. This integration of various data sources provides a richer and more nuanced understanding of the intricate dynamics surrounding VL use in rural schools. Such a methodological approach increases the reliability and validity of the research findings.

Fourth, this pioneering investigation on perceptions and experiences of teachers on integrating VL for rural science teaching offers practical insights that can drive the adoption of the technology in rural schools. This research identified the challenges and opportunities the teachers face in rural contexts and provided evidence-based and actionable recommendations. These recommendations can inform the

development of tailored support initiatives, teacher training programs, and policy interventions. These evidence-based recommendations contribute to knowledge that can enhance the potential to ensure that VL integration takes off in rural SA schools. The next section acknowledges the present study's limitations.

6.4 LIMITATIONS OF THE STUDY

It is essential to recognise that each research study possesses its own set of strengths and limitations, and the current study is not exempt from this reality. For example, the present research encountered limitations regarding the constrained data collection timeframe. Both quantitative and qualitative data were collected during a demanding period for the teachers. During the data collection period, teachers faced time pressures as they needed to cover the curriculum for the first term and prepare learners for formal tests. Consequently, it is plausible that the time constraints may have impacted the thoroughness of their responses to the questionnaires and interviews. Nonetheless, I employed multiple data collection methods, i.e., questionnaires and semi-structured interviews. Although each method inherently carries its limitations and potential errors, the combination of these approaches, through triangulation, bolstered confidence in the study's findings.

Furthermore, this study could have been vulnerable to biases and subjectivity due to its reliance on self-reported perceptions and experiences of the participating teachers. Participants' responses might have been influenced by their personal opinions, beliefs, or previous encounters, introducing potential biases into the collected data. This potential bias was accentuated by the study examining the perceptions and experiences of teachers who report to me as their supervisor, potentially influencing their responses. This study utilised multiple data sources to mitigate these biases and cross-referenced the findings.

Moreover, it is crucial to acknowledge that the study may have had a relatively small sample size, limiting the generalisability of the findings to a broader population of Life Sciences teachers in rural areas. The qualitative component of the study involved participants from a single district where similar contextual factors existed. A more extensive and diverse sample would be beneficial to improve the representativeness of the investigation and attain a more comprehensive understanding of teachers'

perceptions and experiences across various rural contexts. This recommendation stems from the view that the present study's focus on a specific rural area restricts the applicability of its findings to other rural areas. It is essential to recognise that different rural areas can possess distinct characteristics, resources, and challenges that can influence the integration of VL. Therefore, the findings should be interpreted within the specific geographic context under investigation. The subsequent section provides recommendations arising from this research.

6.5 RECOMMENDATIONS

6.5.1 Recommendations for Practice

6.5.1.1 Enhancing Professional Teacher Development

The present research findings revealed that most teachers lack the requisite knowledge to teach with VL, implying that integrating VL into teaching could become challenging without adequate continuous professional development. More so, this research showed that TPACK is crucial in determining the intention of rural Life Sciences teachers to adopt VL into their teaching. Therefore, it is now necessary for professional development to shift its focus away from solely teaching teachers to use technological tools towards guiding them on effectively integrating technology into their content and pedagogy.

Moreover, this research suggests that teachers should be offered professional development training within their own classroom and school settings, where they already feel comfortable. This way, teachers can immediately put their newly acquired knowledge and skills into practice in their teaching. Furthermore, the present study's findings demonstrate that teachers perceive inadequate peer or colleague support when integrating VL into their classrooms. Therefore, it is recommended that teachers be clustered based on their department or subject area during professional development sessions. This collaborative arrangement would enable them to collectively explore new technologies like VL in their actual classrooms alongside their colleagues. Such a collaborative approach would foster a sense of peer support, ultimately boosting teachers' readiness and confidence in using VL within their teaching environments.

In addition, it is essential to identify a skilled ICT teacher who can act as a catalyst for change to drive technology initiatives within a school. This chosen ICT expert will be pivotal in supporting teachers who may hesitate to incorporate new technologies into their teaching due to limited technological proficiency. The designated ICT “champion” will help teachers by engaging in one-on-one sessions to understand their apprehensions about technology use in teaching and learning. For meaningful VL integration, the ICT “champion” role will enlighten hesitant teachers about the tool’s potential benefits. This can be achieved through the following steps: (a) introducing teachers to commonly used VL applications in Life Sciences, (b) demonstrating how these applications can be applicable to their subjects, thereby enhancing teaching experiences, and (c) illustrating how the integration of VL aligns with their teaching goals and aspirations. Such activities can alleviate teachers’ reservations and facilitate their smooth integration of VL in the classroom.

6.5.1.2 Infrastructure and resource allocation

At the beginning of this study, I highlighted that the rural school context is fraught with many difficulties related to the lack of proper science facilities and infrastructure. This study has revealed two critical contextual factors that significantly impact the successful adoption of VL: persistent power cuts and limited internet access. While addressing power cuts may present a challenge for rural schools, particularly regarding affordability for generators, the relevant managers should prioritise ensuring that the school infrastructure allows for reliable wireless and wired connectivity throughout the entire school area.

Furthermore, every teacher needs access to internet-enabled devices and suitable VL software. Equipping teachers with the necessary tools will enable them to grasp the potential benefits of educational technologies like VL. Additionally, provisions should be made to address maintenance of infrastructure concerns, including upgrades to wired and wireless access and replacing old digital devices. These measures are vital to meet teachers’ evolving needs and ensure the speed required for utilizing VL in rural schools. Furthermore, advocacy efforts should be made to secure increased funding and resource allocation specifically targeted at technology integration in rural schools. The following section points to areas of further research.

6.6 FURTHER RESEARCH

The present study's findings have stimulated thoughts for further investigation. As VL integration for rural science teaching represents a new research area, several thoughts on potential avenues for future investigation have emerged. These thoughts point to unexplored avenues or unanswered questions that have arisen from the current study. Therefore, this section encourages further exploration and invites subsequent researchers to probe deeper into the following areas:

First, the present study's focus was on Life Sciences teachers in rural secondary schools, and there is a necessity to conduct cross-disciplinary research that explores the integration of VL in other science disciplines beyond Life Sciences, such as Physical Sciences, Agricultural Sciences or Engineering Graphics and Design in rural school contexts. Such a study could investigate the similarities and differences in teacher perceptions and experiences across the various science subjects to gain insights into the broader science field.

Second, the present research utilised a mixed-method approach. There is a need to conduct in-depth qualitative studies to gain deeper insights into the underlying factors influencing teacher perceptions and experiences of VL integration in rural schools. Given that this study has explicitly revealed the usage of VL by some teachers in teaching, further investigation is required to explore their beliefs, motivations, and attitudes towards VL integration and its impact on teaching and learning. Additionally, by conducting in-depth interviews with teachers, valuable insights can be gained regarding their pedagogical viewpoints on technology integration, their assessment of learners' engagement with VL, and their confidence levels when utilising specific technological tools. Through these interviews, researchers can explore teachers' experiences and capture their rich insights on how VL has influenced teaching and learning practices.

Third, since the current research only zoomed on the teachers' perceptions and experiences of integrating VL in teaching, further research could concentrate on delving into learner perceptions and experiences regarding the integration of VL. The study could investigate how incorporating VL affects learner engagement, motivation, and overall learning experiences within rural schools. The goal will be to gain insights

into how learners perceive and interact with this technology and how it impacts their understanding of life sciences concepts using technology acceptance theories such as TAM and learning theories such as Socio-cultural theory or constructivism. This further research could provide opportunities to understand the impact and potential benefits of integrating VL into learners' educational experiences. Understanding learners' educational experiences should be the holy grail in any technology teaching-learning initiative.

Fourth, the current research findings highlight inadequate support from colleagues regarding the integration of VL. Therefore, further investigation into support structures within schools is necessary. Examining the support mechanisms and structures that can be implemented to facilitate the successful integration of VL in rural schools is essential. This investigation would explore the roles of school leaders, district-level support, and community partnerships in providing the required support and resources for effective technology adoption. Additionally, it is crucial to explore professional learning networks and collaboration opportunities that can enhance the integration of VL in rural settings. Examining these aspects could offer a more profound understanding of the support systems required to successfully implement VL in rural schools.

Fifth, as I demonstrated in Chapter 2, VL integration in teaching is a new research area in education. Therefore, the present study served to break ground and lay the first brick for research on VL adoption in rural schools in SA. The present research effort is in anticipation of the widespread adoption of VL in the near future. Therefore, with the expected roll-out and adoption of VL in rural schools and similar contexts, this research recommends longitudinal, scalability, and sustainability studies to investigate the long-term impacts of VL integration on teaching, learner engagement, and tracking learner performance over time. As technology adoption and teaching practices can evolve, conducting longitudinal studies that span an extended period would provide valuable insights into the long-term impacts and challenges associated with VL integration in rural classrooms. Such studies could hone on factors such as cost-effectiveness and feasibility of VL integration in resource-poor rural schooling contexts.

Sixth, the present research findings have shown that combining two theories, i.e., TAM and TPACK, can offer a holistic understanding of technology adoption by considering issues of technology acceptance and teacher knowledge. The present study shows how teacher knowledge (TPACK) influences the teachers' intention to adopt VL in their teaching using the TAM and TPACK framework. Further studies could explore the integration of VL from different theoretical perspectives to gain insights from multiple angles. Similarly, since this research revealed a deficiency of support from school leaders, additional research could examine the acceptance of VL integration and the support provided by school leaders, utilising leadership theories such as the Principal Instructional Management Rating Scale (PIMRS). This model is built upon three perspectives of the principal's instructional leadership function: defining the school's mission, overseeing the instructional programme, and fostering a favourable learning environment. The following section folds the research.

6.7 CONCLUSIONS

The concluding section ties together all the elements presented in this thesis, providing a cohesive and concise account of the investigation's main findings and contributions while underscoring the research's significance within the broader context of the field. The study was grounded in two theoretical frameworks., i.e., the TAM and TPACK framework, which also influenced the type of survey questions used in this research. Using both the TAM and TPACK frameworks, I gained an in-depth comprehension of the issues influencing the adoption of VL in rural schools. The TAM provided insights into the teachers' perceptions towards the technology, while the TPACK framework focused on the teachers' knowledge and pedagogical practices related to VL integration in teaching. These lenses enriched the study's analysis and interpretation of the study results. From this enrichment, the present study asserts that combining TAM and TPACK frameworks for data collection and analysis can aid in obtaining a comprehensive understanding of teachers' perceptions and experiences on integrating novel technologies such as VL.

In this investigation, I used a mixed methods approach to investigate Life Sciences teachers' perceptions and experiences on integrating VL into rural teaching. I performed statistical analysis following the survey of 186 Life Sciences teachers from

rural schools in the EC province of SA. Additionally, I thematically analysed the semi-structured interview data collected from four teachers from different rural secondary schools in the Joe Gqabi District. The survey captured the teachers' perceptions and experiences regarding using VL, while the interviews provided more profound insights into their perceptions and experiences with this technology. The combined results indicated that the Life Sciences teachers in rural secondary schools held positive perceptions of the integration of VL for teaching.

Moreover, the present research also identified a limitation teachers face regarding their knowledge of teaching with technology, specifically VL. The study revealed variations in the level of TPACK among the teachers, i.e., some TPACK components were more pronounced in some teachers than others, suggesting that teachers possessed varying degrees of knowledge related to technology integration. Overall, the study found that teachers with higher levels of TPACK demonstrated stronger intentions to adopt VL in their teaching. This underlines the significance of enhancing teachers' TPACK to promote the effective integration of VL technology in rural science teaching contexts.

As a Subject Advisor (Senior Education Specialist) tasked with supporting and advising Life Sciences teachers in rural schools, this study has offered me valuable insights into (re)evaluating my practice while advocating for technology integration, especially VL, in their teaching. I am now more conscious of the challenges and contextual factors that may affect teachers' adoption of VL. This awareness allows me to provide more targeted guidance and support, tailoring my advice to address specific challenges such as lack of training or professional development opportunities for teachers in technology integration and potential resistance to change or apprehension towards new technologies among teachers. Additionally, the study has enhanced my understanding of the importance of teachers' TPACK and how it relates to effectively utilising VL in the classroom. Armed with these insights, I am now better prepared to facilitate technology workshops that emphasise integrating technology into pedagogy as part of my job. In contrast to previous workshops that I used to conduct that solely emphasised how to use technology tools without considering any pedagogical intent, I am now aware that I should mediate workshops that highlight the importance of aligning technology with effective teaching practices. This shift will allow me to support

and empower Life Sciences teachers in effectively incorporating new technologies, such as VL, into their pedagogy and promote meaningful learning experiences for the learners.

In summary, this research confirms previous studies on teachers' perceptions of technology integration in a global context. However, the significance of this research lies in its focus on SA, as no previous studies of this nature were found in the literature reviewed. By examining teachers' perspectives in rural secondary schools in the Global South, particularly in SA, this study has contributed a unique dimension to the broader understanding of VL integration in teaching. Moreover, this research has opened numerous avenues for further research that can deepen the knowledge of teachers' perceptions and experiences on integrating VL into Life Sciences teaching. These potential research lines can then be extended to the overarching domain of science teaching. Looking ahead, the adoption of VL for rural science teaching and learning is promising. Despite potential challenges, such as limited access to electricity and internet connectivity in rural schools, this study reveals that teachers are enthusiastic about incorporating VL into their teaching. This bodes well for the future adoption of this technology. It would be exciting to follow up on the teachers' adoption of VL to examine the nature of the support teachers receive while considering the challenges and opportunities that arise in the process of widespread VL adoption into rural science teaching.

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APPENDICES

APPENDIX A: PLAGIARISM REPORT

Submission date: 06-Nov-2023 12:05PM (UTC+0200)
Submission ID: 2140884157
File name: B._SHAMBARE_THESIS_FINAL_DRAFT.docx (5.11M)
Word count: 75083
Character count: 440744

B. SHAMBARE THESIS FINAL DRAFT

ORIGINALITY REPORT

8%	7%	3%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	researchspace.ukzn.ac.za Internet Source	1%
2	core.ac.uk Internet Source	1%
3	scholar.ufs.ac.za Internet Source	<1%
4	vital.seals.ac.za:8080 Internet Source	<1%
5	uir.unisa.ac.za Internet Source	<1%

Exclude quotes	On	Exclude matches	< 10 words
Exclude bibliography	On		

APPENDIX B: LANGUAGE EDITING

590 Miami Road
Hibberdene
KZN
4220
Cell: 0842648401
brian.naidoo25@gmail

PROFESSIONAL LANGUAGE EDITING SERVICES

STRIVING FOR EXCELLENCE

Brian Naidoo (BA Hons English; BA Hons TESOL; BEd Hons.
BA- English major; Univ. Dip. in Ed.[English special];UCT Cert.in
Legal and Business Writing; UCT Cert. in Copy-Editing; PG Research Prog. UFS. Assessor's Cert. UFS. Unisa
Counselling Certificate., Evaluator of Schools for Umalusi.

SPECIALISING IN THE LANGUAGE EDITING OF THESES, DISSERTATIONS, JOURNAL ARTICLES, PROPOSALS, POLICIES AND PUBLICATIONS.

CERTIFICATE FOR LANGUAGE EDITING A THESIS (PhD)

PERCEPTIONS AND EXPERIENCES OF LIFE SCIENCES TEACHERS ON THE INTEGRATION OF A VIRTUAL LABORATORY FOR RURAL TEACHING

BRIAN SHAMBARE

UNIVERSITY OF THE FREE STATE

TO WHOM IT MAY CONCERN

This certificate confirms that the above-mentioned student submitted his draft Doctoral thesis to me for language-editing, which included correcting in-text citations and the list of references. This was duly edited and returned to the student for revisions as per suggestions from me. I make no claim as to the accuracy of the research content. The text, as edited by me, is grammatically correct. After completion of the language editing, the student has the option to accept or reject suggestions/changes prior to re-submission to the supervisor.

B. Naidoo **ID: 5606255134081** **DATE: 06/11/2023**

Professional EDITORS Guild

Brian Naidoo
Associate Member

Membership number: NAI001
Membership year: March 2022 to February 2023

084 264 8401
brian.naidoo25@gmail.com

www.editors.org.za

THANK YOU FOR YOUR SUPPORT

APPENDIX C: RESEARCH QUESTIONNAIRE

SECTION A: BIOGRAPHICAL AND BACKGROUND INFORMATION
(Please check √ only one option for each statement below.)

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. I identify my ethnicity as

Black		Coloured	
Indian		Other	
White		Prefer not to answer.	

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

10	
11	
12	

5. What is your current teaching experience?

0-4		16-20	
5-10		21-25	
11-15		26 or more years	

6. What is the highest level of education you have completed?

Bachelor's Degree		Doctoral Degree (PhD, EdD)	
Post-Graduate Certificate		Other	
Master's Degree			

7. Which of the following best describes your school's designation by your state department of education?

Public		Other	
Private		I don't know	

SECTION B: PERCEIVED USEFULNESS AND PERCEIVED EASE OF USE OF THE VIRTUAL LABORATORY

Please rate the extent to which you agree with each statement below.

(Please check √ the most appropriate option for each statement below.)

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree					
B1. PERCEIVED USEFULNESS of the Virtual Laboratory to teach science experiments.					
8. Using the Virtual Laboratory enables me to teach lab practicals more quickly.	1	2	3	4	5
9. Using the Virtual Laboratory enhances the quality of my Life Sciences teaching.	1	2	3	4	5
10. Using the Virtual Laboratory makes it easier to do my work.	1	2	3	4	5
11. I find the Virtual Laboratory useful in my work as a Life Sciences teacher.	1	2	3	4	5
B2. PERCEIVED EASES OF USE of Virtual Laboratory to teach science experiments.					
12. Learning to teach with the Virtual Laboratory is easy for me.	1	2	3	4	5
13. I find it easy to teach Life Sciences experiments with the Virtual Laboratory.	1	2	3	4	5
14. I find it easy for me to become skilful in teaching with the Virtual Laboratory.	1	2	3	4	5
15. I find the Virtual Laboratory easy to use.	1	2	3	4	5

SECTION C: SOCIAL INFLUENCE AND FACILITATING CONDITIONS OF THE VIRTUAL LABORATORY USAGE

Please rate the extent to which you agree with each statement below.

(Please check √ only one option for each statement below.)

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree					
C1. SOCIAL INFLUENCE of Virtual Laboratory to teach science experiments.					
16. My peers think that I should teach with the Virtual Laboratory.	1	2	3	4	5
17. My family and friends think that I should teach with the Virtual Laboratory.	1	2	3	4	5
18. My learners think that I should teach with the Virtual Laboratory.	1	2	3	4	5
19. My School Management Team think that I should teach with the Virtual Laboratory.	1	2	3	4	5
20. My school community generally supports teaching with the Virtual Laboratory.	1	2	3	4	5
C2. FACILITATING CONDITIONS within your school about teaching with the Virtual Laboratory.					
21. The necessary resources (e.g., computer hardware and software) are available for me.	1	2	3	4	5
22. I can access the Internet very quickly within my school.	1	2	3	4	5
23. Guidance is available to me to effectively teach with the Virtual Laboratory.	1	2	3	4	5
24. A specific person (or group) is available for assistance to teach with the Virtual Laboratory.	1	2	3	4	5

SECTION D: BEHAVIOUR INTENTION TO USE THE VIRTUAL LABORATORY IN THE FUTURE

Please rate the extent to which you agree with each statement below.

(Please check √ only one answer)

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree					
D1. BEHAVIOUR INTENTION to teach with the Virtual Laboratory in the future.					
25. I intend to use the Virtual Laboratory more when teaching Life Sciences through experiments.	1	2	3	4	5

26. I would like to use the Virtual Laboratory in all my experiments.	1	2	3	4	5
27. I would recommend using the Virtual Laboratory to others.	1	2	3	4	5
28. I intend to use the Virtual Laboratory more to enhance my Life sciences teaching.	1	2	3	4	5
D2. ACTUAL USAGE in teaching and teaching-related tasks.					
29. I use the Virtual Laboratory when teaching Life Sciences experiments.	1	2	3	4	5
30. I use the Virtual Laboratory when preparing my lessons.	1	2	3	4	5
31. I use the Virtual Laboratory to enhance my Life Sciences teaching.	1	2	3	4	5
32. I use Email for student contact and to give my advice	1	2	3	4	5
33. I tend to use the Virtual Laboratory for as long as necessary.	1	2	3	4	5

SECTION E: TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE TO USE THE VIRTUAL LABORATORY TO TEACH

Please rate the extent to which you agree with each statement below.
(Please check √ only one answer.)

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree					
E1. TECHNOLOGY KNOWLEDGE (TK)					
34. I can learn to use educational technologies easily.	1	2	3	4	5
35. I keep up with important emerging technologies.	1	2	3	4	5
36. I frequently play around with technology.	1	2	3	4	5
37. I know about a lot of different technologies.	1	2	3	4	5
38. I can teach with the use of different technologies.	1	2	3	4	5
39. I know which technologies would work best for my Life Sciences teaching.					
E2. CONTENT KNOWLEDGE (CK)	1	2	3	4	5
40. I possess sufficient Life Sciences knowledge to teach the subject.	1	2	3	4	5
41. I can use a scientific way of thinking.	1	2	3	4	5
42. I have various ways and strategies for developing my understanding of Life sciences.					
43. I am familiar with the Life Sciences content that is prescribed by CAPS.	1	2	3	4	5
44. I understand and can explain the concept of the scientific method.	1	2	3	4	5
45. I have sufficient knowledge to answer most learners' Life Sciences questions.	1	2	3	4	5
E3. PEDAGOGICAL KNOWLEDGE (PK)					
46. I know how to assess learners' performance in Life Sciences, including knowledge of different cognitive levels, degrees of question difficulty and the concept of a 'reasonable learner'.	1	2	3	4	5
47. I can adapt my teaching depending on what learners understand or do not understand.	1	2	3	4	5
48. I can adapt my teaching style to different learners.	1	2	3	4	5
49. I know how to assess learning in multiple ways.	1	2	3	4	5
50. I can use a variety of teaching strategies in my Life sciences class.	1	2	3	4	5
51. I am familiar with common learners' understandings and misconceptions of Life sciences	1	2	3	4	5
52. I know how to organise and maintain class management and control.	1	2	3	4	5
53. I am familiar with the prescribed Life sciences textbooks and other learning resources used in most South African classrooms.	1	2	3	4	5
E4. PEDAGOGICAL CONTENT KNOWLEDGE (PCK)					
54. I know how to teach specific Life Sciences concepts/topics using specific VL experiments.	1	2	3	4	5
55. I know which Life sciences concepts/topics to teach using simulations.	1	2	3	4	5

56. I know how to teach Life Sciences using audio and videos, e.g., from YouTube.	1	2	3	4	5
57. I know how to teach Life Sciences using VLs on mobile devices such as cell phones, Tablets and iPads.	1	2	3	4	5
58. I know how to teach Life Sciences using digital boards, e.g., Smartboard and data projector.	1	2	3	4	5
E.5 TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE (TPK)					
59. I can choose technologies that enhance my teaching strategies for a lesson.	1	2	3	4	5
60. I can choose technologies that enhance learners' understanding of a lesson.	1	2	3	4	5
61. I always think critically about how to use the VL in my Life Sciences class.	1	2	3	4	5
E6. TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK)					
62. I can adapt and use particular experiments in the VL to meet my different learners' learning capabilities.	1	2	3	4	5
63. I can teach Life Sciences concepts/topics that appropriately combine the content with technology skills using science experiments in the VL.	1	2	3	4	5
64. I can teach Life Sciences concepts/topics that appropriately combine the content with different teaching strategies using science experiments in the VL.	1	2	3	4	5

SECTION F: FACTORS IMPACTING THE USE OF THE VIRTUAL LABORATORY FOR RURAL TEACHING

Please rate the extent to which you agree with each statement below.
(Please check √ only one answer.)

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree					
F1. Have the following factors influenced your use of VLs in your Life sciences classroom?					
65. Lack of skills/experience	1	2	3	4	5
66. Confidence	1	2	3	4	5
67. Insufficient pedagogy and content	1	2	3	4	5
68. Lack of professional development/Insufficient training	1	2	3	4	5
69. Lack of support	1	2	3	4	5
70. Insufficient access or maintenance to technology	1	2	3	4	5
71. Restrictions in educational environment or curriculum	1	2	3	4	5
72. Insufficient time	1	2	3	4	5
73. Lack of a school-based technician	1	2	3	4	5
74. Limited supply of electricity	1	2	3	4	5
75. Limited access to high-speed internet	1	2	3	4	5
76. Not a priority	1	2	3	4	5
77. Other	1	2	3	4	5

APPENDIX D: SEMI-STRUCTURED INTERVIEW PROTOCOL

1. How do you perceive educational technologies?
2. What are your views and understanding of the integration of VL for rural teaching?
3. Based on your experience using the VL, what do you understand as the advantages and disadvantages of using the VL for rural teaching?
    - Probe:
        - Probe for perceived usefulness
        - Probe for learners' learning
        - Probe for teachers' teaching (planning, teaching, assessing, etc.)
4. Has the utilisation of Virtual Learning (VL) made your teaching more manageable?
    a. Follow-up:
        i. Inquire about the ease of use.
        ii. Ask about your level of interest.
5. Did the training you received on VL prior to your interaction with students adequately prepare you?
    a. Follow-up:
        i. Probe for TK, TPK, and TTPACK.
6. Based on your experience teaching with VL, what factors do you believe:
    a. Can encourage educators to incorporate VL into their teaching?
    b. Can hinder teachers from integrating VL into their teaching?
7. Do you believe VL should be employed for rural Life Sciences education? Please provide reasons for your response.
8. From your perspective, what measures should be taken to effectively implement VL for rural teaching?
9. Is there anything you think would be valuable for me to be aware of that I haven not inquired about?

APPENDIX E: TEACHER LETTER. INVITATION TO RESPOND TO THE QUESTIONNAIRE

DEAR SIR/MADAM,

I am a Doctoral student in the Department of Natural Sciences, Mathematics, and Technology Education at the University of the Free State, where Professor T. Jita supervises me. I wish to invite you to participate in my study titled: *"Perceptions and Experiences of Life Sciences Educators Regarding the Implementation of a Virtual Laboratory for Rural Teaching."* The research's primary objective is to gain insights into the perceptions and experiences of Life Sciences teachers concerning the use of a Virtual Laboratory.

Your participation in this research would be highly valued because of your unique position to elucidate your personal viewpoints and experiences with the Virtual Laboratory in the context of rural teaching. This study will entail completing a questionnaire, and there may also be an opportunity for you to engage in an interview to discuss your perceptions and experiences with the Virtual Laboratory in the context of teaching Life Sciences. Please be assured that any details you provide, including your identity, will be treated with utmost confidentiality and will not be linked to any specific person or organization. All answers will be securely kept, and the findings of this research will be exclusively employed for academic purposes. Your cooperation and contribution to this study are greatly appreciated, and I appreciate your time and involvement.

This research has been approved by UFS's General/Human Research Ethics Committee and the Eastern Cape Department of Education. Please contact me at 0735414193 or brianshambare@gmail.com or my supervisor, Prof T. Jita, at JitaT@ufs.ac.za or 051 401 7441 for inquiries regarding this research.

Warmest regards,
……
Brian Shambare

CONSENT: I ACKNOWLEDGE THAT

- I will be participating as a respondent in the research on the aforementioned topic.
- My identity in this study will be safeguarded in line with the ethical guidelines established by the UFS.
- I may withdraw from this research at any time without any penalties.
- The information I provide will exclusively be used for the research project.
- After carefully considering the aforementioned details, I willingly offer my participation in the research process and affirm that my involvement is entirely voluntary, and I have not been subjected to any form of coercion.

DECLARATION

I_____ (INITIAL and SURNAME OF PARTICIPANT) I affirm that I have comprehended this letter and the research scope. My consent for participation in the research is freely given.

Signature of the Respondent:_____Date: _____
Signature of the Researcher: _____Date: _____

APPENDIX F: TEACHER LETTER. INVITATION FOR PARTICIPATION IN THE INTERVIEW

DEAR LIFE SCIENCES TEACHER

I am a Doctoral candidate under Prof. T. Jita's supervision at the UF's Faculty of Education. My research is titled *"Perceptions and Experiences of Life Sciences Teachers on the Integration of a Virtual Laboratory for Rural Teaching."* This research aims to understand how Life Sciences teachers view and engage with Virtual Laboratories in rural teaching.

I would greatly appreciate your participation in this voluntary study if you are a secondary school Life Sciences teacher. The interview lasts approximately 30 minutes at a convenient time and place. Your responses will remain confidential; you can choose a pseudonym for privacy. Additionally, you will have the opportunity to review the interview transcript and assist with data analysis, which will also take around 30 minutes. Your participation is invaluable, and to thank you, I will send you a thank-you letter and offer you a copy of the final thesis. This research has the approval of the UFS General/Human Research Ethics Committee and the Eastern Cape Department of Education.

For more information about this study, please contact me at brianshambare@gmail.com, 0735414193 or my supervisor, Prof. T. Jita, at JitaT@ufs.ac.za or 0514017441.

Warmest regards,
……
Brian Shambare

CONSENT: I UNDERSTAND THAT

- I am a participant in the research project mentioned above.
- I am available for an interview and will have time to do it.
- I can withdraw from the study without facing any harmful or detrimental penalties.
- My information will be used for research purposes only.
- I understand that the information I provide will be treated in the strictest confidence and that the research findings will be used in the research report.
- In this study, my identity will be safeguarded in accordance with the ethical guidelines outlined by the UFS.
- Having duly considered the above information, I willingly offer my participation in the study and affirm that I was not coerced to participate.

DECLARATION

I_____ (INITIAL and SURNAME OF PARTICIPANT) I confirm my understanding of this letter and the scope of the study. I agree to participate in the research.

Signature of the Participant: _____Date: _____
Signature of the Researcher: _____Date: _____

APPENDIX G: LETTER TO PRINCIPAL

DEAR PRINCIPAL

REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I am Brian Shambare, a Doctoral student at the UFS. As part of my doctoral programme, I am carrying out research and would like to request your permission to work with a Life Sciences teacher in your school. The research is titled: *"Perceptions and Experiences of Life Sciences Teachers on the Integration of a Virtual Laboratory for Rural Teaching."*

This study aims to understand Life Sciences teachers' perceptions and experiences concerning integrating a Virtual Laboratory in rural teaching. This research could contribute to the successful integration of Virtual Laboratories in rural schools. The study will involve two interview sessions with the teacher, each lasting no more than 30 minutes. I assure you that the research will strictly adhere to ethical guidelines, ensuring the confidentiality of participant identities and their views. The UFS General/Human Research Ethics Committee and the Eastern Cape Department of Education have approved this research.

For enquiries concerning this research, please contact me at brianshambare@gmail.com or 0735414193 or my supervisor, Prof. T. Jita, at 0514017441 or JitaT@ufs.ac.za. Your cooperation is greatly appreciated.

SCHOOL PRINCIPAL'S CONSENT FORM

- I clearly understand the objectives and intentions of the study conducted by Brian Shambare.
- I acknowledge that the Life Sciences teacher's involvement in this research is voluntary, and any concerns will be addressed to their satisfaction.
- I know that the Life Sciences teacher can withdraw from the research at any time without repercussions.
- I understand that the information I provide will be treated in the strictest confidence and that the research findings will be used in the research report.
- I am aware that the interviews will be recorded, and the participant can ask for the recording to be paused or cease temporarily or permanently at any time. Furthermore, participants will receive the interview transcript copy for correctness verification.
- Given the above understanding, I hereby grant permission for the research study to be conducted with the teacher in this school.

SCHOOL PRINCIPAL DECLARATION

I_____ (INITIAL AND SURNAME OF PRINCIPAL) I at this moment affirm my consent and grant permission for the research to be conducted with the requested teacher.

Principal' Signature_____ Date_____

SCHOOL STAMP

APPENDIX H: APPROVAL LETTER. EASTERN CAPE DEPARTMENT OF EDUCATION

Province of the
EASTERN CAPE
EDUCATION

CORPORATE PLANNING, MONITORING, POLICY AND RESEARCH COORDINATION
Steve Vukile Tshwete Complex, Zone 6 Zwelitsha, 5608, Private Bag X0032, Bhisho, 5605 REPUBLIC OF SOUTH AFRICA
Enquiries: **Ms. F. Pakade Tel: 040 608 7170/4001 . Fax :040 608 4372. Email:** fundiswa.pakade@ecdoe.gov.za
Website: www.ecdoe.gov.za **Date: 02 November 2022**

Mr Brian Shambare

P. O Box 92718

Mount Frere

5090

Dear Mr. B Shambare

PERMISSION TO UNDERTAKE A DOCTORATE RESEARCH : PERCEPTIONS AND EXPERIENCES OF LIFE SCIENCES TEACHERS ON THE INTEGRATION OF A VIRTUAL LABORATORY FOR RURAL TEACHING

1. Your application to conduct the above - mentioned research involving one hundred (100) participants and four (4) selected secondary schools in the Joe Gqabi District under the jurisdiction of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:

   a. there will be no financial implications for the Department;

   b. institutions and respondents must not be identifiable in any way from the results of the investigation;

   c. you seek parent's consent for minors;

   d. it is not going to interrupt educators' time and task;

   e. the research may not be conducted during official contact time;

   f. the research may not be conducted during official contact time, provided that an arrangement to do research at the school including getting inside a classroom has been arranged and agreed upon in writing with the Principal and the affected teacher/s;

   g. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;

   h. you will make all the arrangements concerning your research;

i. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Corporate Strategy Management;

j. you present the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 – 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis;

k. you present the findings to the Research Committee and/or Senior Management of the Department when and/or where necessary;

l. you are requested to provide the above to the Chief Director: Corporate Strategy Management upon completion of your research;

m. you comply with all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you;

n. you comply with your ethical undertaking (commitment form);

o. You submit on a six-monthly basis, from the date of permission of the research, concise reports to the Chief Director: Corporate Strategy Management.

2. The Department reserves a right to withdraw the permission should there be non - compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE and/or legal requirements to do so.

3. The Department will publish the completed Research on its website.

4. The Department wishes you well in your undertaking. You can contact Mrs. Fundiswa Pakade on the numbers indicated in the letterhead or email fundiswa.pakade@ecdoe.gov.za should you need any assistance.

T. MASOEU
CHIEF DIRECTOR: CORPORATE STRATEGY MANAGEMENT

FOR SUPERINTENDENT-GENERAL: EDUCATION

APPENDIX I: ETHICS STATEMENT

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

09-Nov-2022

Dear Mr Brain Shambare

Application Approved

Research Project Title:
PERCEPTIONS AND EXPERIENCES OF LIFE SCIENCES TEACHERS ON THE INTEGRATION OF A VIRTUAL LABORATORY FOR RURAL TEACHING

Ethical Clearance number:
UFS-HSD2022/1276/22

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

Adri Du Plessis
Digitally signed by Adri Du Plessis
Date: 2022.11.10 10:21:00 +02'00'

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