AN EXPLORATION OF WORKING WITH GRADE 11 LIFE SCIENCES EDUCATORS ON THE USE OF VIRTUAL LAB TO MEDIATE LEARNING OF ENERGY TRANSFORMATIONS

BY

BRIAN SHAMBARE

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Supervisor: Dr Clement Simuja

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ABSTRACT

The Department of Basic Education (DBE) examiners' diagnostic reports for 2012-2019 indicate that National Senior Certificate (NSC) learners mostly perform poorly in examination questions based on scientific investigations. The low performance by learners in these questions has been attributed to the failure by teachers to effectively mediate the learning of scientific concepts due to lack of science laboratories or poorly resourced laboratories in most rural schools. As a result, most learners are finding that scientific concepts are decontextualized and hence abstract. Thus, this study explored making use of Virtual Lab to mediate learning of scientific investigations using the topic Energy transformations. The study was located within an interpretive paradigm and a qualitative case study approach was employed. The study was conducted in four different rural schools in the Joe Gqabi district and seven Grade 11 Life Sciences teachers participated. Data was generated using semi-structured questionnaires, semi-structured interviews, lesson observation, workshop discussions, and journal reflections. The study was informed by Vygotsky's (1978) Socio-Cultural Theory (SCT) as the theoretical framework, and Thompson and Mishra's (2006) Technological Pedagogical Content Knowledge (TPACK) as the analytical framework.

The results of this study showed that most educators have a positive predisposition towards the integration of Information and Communication Technologies (ICT) in their practice. The study found that using the Virtual Lab to teach Life Sciences has several benefits such as safe environment for conducting experiments; convenience and accessibility; positive teacher and learner attitudes and improvement on learner performance; elimination of physical limitations of a real lab; and availability top-class lab equipment and up-to-date reagents. The study also revealed some shortcomings that were associated with the use of the Virtual Lab. These are; lack of lab partner and peer-learning; and lack of direct supervision by a more knowledgeable facilitator. This study concluded that using the Virtual Lab enhances the quality of teaching scientific experiments in the selected under-resourced rural secondary schools. The study recommends the adoption of the Virtual Lab as a viable alternative to the conventional lab.

Key words: Virtual Laboratory, scientific investigation, Life Sciences, Energy transformations, Socio-cultural theory, TPACK, ICT, Technology.

DECLARATION

I declare that this is my own independant work. It is submitted for the degree of Master of Education in ICT in Education at Rhodes University, Makhanda. It has not been submitted before for any degree or examination at any other university. All the references that I have used have been indicated and acknowledged by means of complete references.

Brian Shambare

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February 2021

DEDICATION

‘In His days there were Giants. He was a Giant of a Man’

To my late Father Bruce Dewart Shambare

&

To my Son Bonginkosi Clever Shambare

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ICT: Information and Communication Technologies

VL: Virtual Lab

ECDOE: Eastern Cape Department of Education

DBE : Department of Basic Education

TPACK: Technological Pedagogical and Content Knowledge

PCK : Pedagogical Content Knowledge

CK : Content Knowledge

PK : Pedagogical Knowledge

TK : Technological Knowledge

PCK : Pedagogical Content Knowledge

TPK : Technological Pedagogical Knowledge

TCK: Technological Content Knowledge

CAPS: Curriculum, Assessment Policy Statement

NCS: National Curriculum Statement

UNDP: United Nation Development Programme

AU: African Union

CHAPTER ONE

INTRODUCTION

1.1 International context

Information and Communication Technology (ICT) has become a driving force in almost all aspects of human life and the field of education is not exception to it (Dodewar, 2020; Mahmud, Yogesh, Angela, Vinod, Sujeet & Nripendra, 2021). The United Nations Development Programme (UNDP) defined Information and Communication Technologies as an umbrella term that encompasses any software application or digital device such as television, radio, mobile phones, computer, notepad, network hardware or satellite system software that are used to produce, store, process, distribute and exchange information (UNDP, 2020). Ghosh and Bhattacharjee (2020), added that ICT also encompasses various services such as videoconferencing, tele-conferencing, email, audio conferencing, television lessons, radio broadcasts, interactive radio counselling, interactive voice response system (IVR) and related services.

Recently a study known as the Second Information Technology in Education Study (SITES) was sponsored by the International Association for the Evaluation of Educational Achievement (IEA). The study explored the use of ICT in classrooms across 26 countries in the world (Gosh & Bhattacharjee, 2020). The study found that the most common ICTs used in classrooms across the countries are data projectors and computers. These are used for lesson presentations, word processing and spreadsheets. In addition, Dodewar (2020); Jadhav and Takale (2020); Dnyaneshvar, Shrinivas and Nandkishor (2020); and Karakostantaki and Stavrianos (2021), identified e-books, internet, YouTube videos, teleconferencing, Modular Object-Oriented Dynamic Learning Environment (MOODLE), smart classrooms and social media as other ICT tools that are used for teaching and learning.

As a result of the recent shifts towards integration of ICT in teaching and learning, Jadhav and Takale (2020), argue that in today's modern age, the use of chalk and duster is no longer enough in the teaching and learning process. The researcher argues that teachers who appropriately integrate ICT in their teaching do not only enhance their technological and pedagogical content knowledge but also enable better learner performance, in particular science related subjects. One of the recent advances in integration of ICT in teaching and learning is the use of Virtual Lab. Lestari and Supahar (2020), define Virtual Lab as a form of interactive multimedia objects that simulate traditional laboratory experiments into a computer to provide a meaningful virtual experience for learners and present essential concepts, principles, and processes. This means that with Virtual Labs, the building and physical lab tools are transformed into computers and Virtual Lab software (Eljack, Alfayez & Suleman, 2020). Alneyadi (2019) and Veeckman and Temmerman (2021), indicated that Virtual Lab provides better opportunities for mediating scientific experiments as compared to the traditional laboratories.

Several international studies have been conducted on the use of Virtual Labs as an ICT teaching tool in science subjects. A review of these studies has highlighted several benefits which include safe environment for conducting experiments (George & Kolobe, 2014), affordability (Gambari, Obielodan & Kawu, 2017; Lestari, & Supahar, 2020), convenience and accessibility (Arista & Kuswanto, 2018; Castelló, Pellegrino, Argente, Gomez-Marquez, Gaudenz, Randall, Pereira, Alonso, Calvelo, Young, Acosta, Albarran, Gimenez, Sedraschi, Umpiérrez, Figares, Sagastizabal & Radmilovich, 2020), positive teacher and learner attitudes and improvement on learner performance (Bogusevschi, Muntean, & Muntean, 2020; Monita & Ikhsan, 2020; and Tobarra, Robles-Gómez, Pastor, Hernández, Duque & Cano, 2020), elimination of physical limitations of a real lab (Aliyu & Talib, 2019) and availability top-class lab equipment and up-to-date reagents (Rani, Mundilarto, Warsono & Dwandaru, 2019). Similarly, Gavronskaya, Larchenkova, Kurilova and Gorozhanina's (2021) study on Virtual Lab model for making online courses more inclusive for students with special educational needs, showed the effectiveness of the Virtual Lab in the development of scientific thinking.

On the other hand, despite the several advantages of using the Virtual Lab as also reported by Eljack, Alfayez and Suleman (2020), researchers such as Nicholas and Ng (2012) cited in Murphy (2016), and Papadimitropoulos, Dalacosta and Pavlatou (2021), have warned that the Virtual Lab, like most ICT educational tools, is not and will not be a panacea in all situations. Papadimitropoulos et al. (2021), cited lack of ICT skills among most teachers and learners to operate in a virtual environment as a major challenge in adopting the Virtual Lab into classroom practice. Similarly, du Plessis and Webb (2012); Rabah (2015); Eshetu (2015); Young (2016); Elemam (2016) and Ngoungouo (2017) emphasized the fact that inadequate training and lack of technical skills remains a challenge in integrating ICT initiatives into teaching and learning. Other notable challenges of using the Virtual Lab as reported in previous studies include depriving learners of the experiences that involve concrete hands-on manipulation of physical materials which are essential for learning (Akkan, 2012; Gamor, 2021), lack of lab partner and peer-learning (Oloruntegbe & Alam, 2010; Papadimitropoulos, et al, 2021), lack of direct supervision by a more knowledgeable facilitator (Ateş & Eryılmaz, 2011), and teacher resistance to adoption of the Virtual Lab (Bhukuvhani, Kusure, Munodawafa, Sana & Gwizangwe, 2010; Hao, Zheng, Wang & Jiang, 2021).

1.2 Background

At regional level, the African Ministerial Forum of the African Union (AU) has stressed the urgency to accelerate integration of ICT in education to achieve Africa's agenda 2063 – *The Africa We Want* (African Union, 2020). Flagship project number 10 of the 15 projects of the Agenda 2063 seeks to transform Africa into an e-Society, and the integration of ICT in education has been identified as a starting point (African Union, 2020). This call is significant to the improvement of the standard and quality of education in African countries.

In South Africa, the integration of ICT in education has ascended the education agenda with the release of the White Paper on e-Education in 2004 (Thomson & Hodgkins-Williams, 2005). As set out in the White Paper 7 on e-Learning of 2004 (Surty, 2010), and in the National Development Plan (NDP) 2030 of 2012, the South African government has embraced the use of ICT in education. As a result, the Department of Basic Education (DBE) undertook various initiatives to equip schools with ICT and to empower teachers to integrate ICT skills in their teaching. In line with the goals of the e-Education policy, the Eastern Cape Department of Education (ECDoE) is in the process of rolling out laptops to all teachers in the province to ensure ICT integration in schools.

Even though the DBE and the ECDoE adopted several ICT educational policies and strategies, most teachers in South African schools are still challenged in integrating ICT to teach. Mooketsi and Chigona (2014) cited in Padayachee (2017), revealed that there is a disparity between government expectations and the practices of teachers. This observation is documented in the DBE's Action Plan to 2019 report, where the department concedes that "ICT-enhanced learning has not advanced in South Africa as predicted" (DBE, 2015, p. 14). The DBE estimates that a mere 26% of South African teachers are equipped with basic technology skills, with only 7% functioning at an intermediate level of competency (DBE, 2018). Mundy, Kupczynski and Kee (2012), further stated that even those teachers that grew up using technology and are having access to it, are not integrating technology in their practice.

Several reasons for failure by teachers to use ICT in teaching have been advanced. Unwin (2005); du Plessis and Webb (2012); Rabah (2015); Eshetu (2015); Young (2016); Elemam (2016); Ngoungouo (2017), stated that many teachers lack ICT skills necessary for effectively integrating ICTs into learning. As a result, ICT tools that have been made available by the government such as computers, laptops and tablets are often set aside and they remain objects of curiosity, fear, uncertainty, and mystery rather than enabling tools (Gamor, 2021). According to Ambusaidi, Musawi, Al-Balushi and Al-Balushi (2018) and Dodewar (2020), another reason for failure by teachers to use ICT in teaching is that in most cases where ICT initiatives in schools include training, the focus is often on computer literacy rather than how to use technology as a tool for teaching and learning.

Recently, Adu and Ojo (2018), conducted a study on the level of availability and utilization of ICT facilities by teachers, including science teachers, in high schools in Eastern Cape Province, South Africa as well as the factors influencing and challenging its effectiveness. They confirmed that there is a lack of ICT use in the Eastern Cape schools because of several factors. Firstly, they claim that there is poor availability of educational ICT tools. They also identified that teachers lack technological skills and knowledge for teaching. Further, they confirmed that technological resources in some of the schools are not being optimally utilized for teaching and learning purposes.

Whilst there are a plethora of studies considering the benefits and challenges associated with ICT integration in teaching and learning of science subjects, interventionist studies such as use of Virtual Lab as an alternative to traditional labs in South African secondary schools seemed to have escaped the focus of academic researchers. This study proposes to contribute knew knowledge in understanding how Virtual Lab can be used to mediate learning of science in resource-constrained schools. In the context of this study, resource-constrained schools refer to schools that do not have science laboratories.

1.3 Statement of the problem

The Department of Basic Education (2019) highlighted that Life Sciences is one of the most popular 'gateway' subjects in the Further Education and Training (FET) phase. However, despite its popularity, many learners continue to perform below average in Life Sciences. The DBE Examiners' Diagnostic report, (2019, p.139) states that "An area of poor performance remains the questions on scientific investigations, as evidenced once again in Papers 1 and 2 of 2019". The same observation was also reported in previous diagnostic reports of 2012 to 2018. The challenge faced by learners in scientific investigation questions could be attributed to lack of proper mediation of learning of experiments by teachers as observed by Gambari, Falode, Fagbemi and Idris (2012); Okono, Sati and Awuor (2015); and Hackman, Zhang and He (2021). Teppo, Soobard and Rannikmäe (2021), and Watters (2021), attributed poor performance of students in science to poor infrastructure and non-availability of standard science laboratories in most schools.

The National Senior Certificate (NCS) question papers are nationally set and internationally bench marked. This implies that learners from rural schools with no science laboratories are exposed to the same assessment instruments as their counterparts from schools that have well-resourced labs. The researcher, therefore, argues that learners from schools that do not have labs may be disadvantaged. As a Life Sciences National Senior Certificate (NSC) marker for the past ten years, the researcher has observed during marking sessions that learners mostly from rural schools perform poorly in questions that involve scientific experiments. In addition, having taught Life Sciences in a rural school with no laboratory for ten years from 2009 to 2019, the researcher personally experienced how challenging it is to enable learners to contextualise most scientific concepts without exposing them to hands-on practical experimentation. Currently, as a Subject Advisor for Life Sciences in a rural district, the researcher finds it difficult to enforce that teachers should administer practical experimental tasks as required by Curriculum and Assessment Policy Statement (CAPS). The response that the researcher gets from the teachers is that they do not have science laboratories to conduct experiments at their schools and therefore cannot expose learners to hands-on experiments. In such cases, Falode and Onasanya (2015), and Hao et al. (2021), suggested that the Virtual Lab could be an effective alternative to the traditional labs and may improve learners' performance in science.

However, when the researcher searched for literature, no studies could be found on use of Virtual Labs in resource constrained secondary schools in South Africa, therefore, a knowledge gap exists on affordances and hinderances when mediating learning of scientific investigations using Virtual Labs. Most of the studies in the context of ICT in education have focussed on benefits and challenges of using ICTs for teaching and learning as well as teachers' perceptions and attitudes on ICT integration in the classrooms. It is against this background that in this interventionist study, researcher seeks to explore working *with* teachers how to mediate learning of scientific investigations using Virtual Lab.

1.4 Purpose and significance of the study

The keen interest in the study was triggered by the researcher's personal experience as a Life Sciences Subject advisor who works with teachers in rural schools. A teacher for example, asked a question during a subject meeting, if there is any other way that can be used to teach experiments in schools that do not have laboratories. With the increase in the global change towards integration of ICTs in mediation of learning, this study might provide the teachers (including the researcher) who will be involved in the study with pedagogical and technological knowledge on use of Virtual Lab as an ICT tool in education.

Working collaboratively towards shared goals in a professional learning space might equip the participants in supporting one another *within*, *across* and *beyond* schools as suggested by Ngcoza and Southwood (2019). The study might contribute towards filling the knowledge gap that exists on affordances and hindrances of using Virtual Lab to teach scientific investigations in South

African Life sciences classrooms. Although this study will focus on equipping teachers to *teach* using Virtual Lab, in the end, the study seeks to ensure that *learning* does indeed takes place in the classrooms. The knowledge gained from this study on use of Virtual Lab in Life Sciences may also be transferred to other related science subjects that require teaching using scientific experiments such as Physical Sciences, Technical Sciences and Agricultural Sciences, to mention a few. In addition, the school closures in response to the current covid-19 pandemic have affected approximately 1.723 billion learners worldwide (UNESCO, 2020) and 13 million learners in South Africa as of 21 April 2020 (Lindzon, 2020). According to Karp and McGowan (2020), these closures have shed more light on the importance of ICT-enhanced teaching post covid-19 pandemic. Therefore, results from this study might inform South African education policy makers on the use of Virtual Lab as an ICT tool for teaching scientific investigations. Moreover, the findings from the study might be used as a basis for future research.

1.5 Research goal

This main goal of this study is to explore working *with* Grade 11 Life Sciences teachers on make use of Virtual Lab to mediate learning of Energy transformations in rural resource-constrained secondary schools in Eastern Cape Province.

To achieve this goal, the following research questions will be addressed:

1.6 Research questions

i. What are the perceptions and attitudes of Grade 11 Life Sciences teachers on use of ICT for teaching and learning?

ii. What are the pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments using the topic *Energy transformations*?

iii. What are the enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments using the topic *Energy transformations*?

iv. How can Virtual Lab be used by Grade 11 teachers to mediate learning of scientific experiments using the topic *Energy transformations*?

1.7 Overview of the thesis

This thesis comprises seven chapters.

Chapter One introduces the main concepts of the research with reference to its background, objectives, and significance. Specifically, Chapter One focuses on placing the topic under investigation into its international and local contexts. Furthermore, it covers the research questions and the content of the subsequent chapters in the thesis.

Chapter Two presents the latest and most relevant literature related to the study. The research questions in chapter one directed the literature review process. Literature reviewed was drawn from authoritative electronic databases such as Google Scholar, Science Direct and Web of Science. Scarcity of literature on Virtual Lab in South African context led to the review of literature mostly from the international context. Literature reviewed focused on Virtual Lab in Science teaching in secondary schools, and science practical experiments.

Chapter Three presents Vygotsky's socio-cultural theory and TPACK theory, as theoretical framework, and analytical framework, respectively. In addition, it also explains the rationale of choosing these theories and their applications in this study. Furthermore, this chapter reviews RAT and SAMR model as potential frameworks that could have been chosen and highlights reasons why these models where not used in this sudy. Lastly, the researcher concludes this chapter by acknowledging the limitations of the TPACK that was used as the analytical framework.

Chapter Four provides an account of the research design used, locating it within the interpretive qualitative research paradigm using a case study approach. The decision to use the qualitative design through a case study approach is discussed and justified. The sample size and sampling criteria are also explained and justified in this chapter. In addition, the strengths of the data generation methods used are explained and shortcomings are also acknowledged. Data generation methods used are semi-structured questionnaires, journal reflections, field notes, observations, and semi-structured interviews. This chapter clearly shows how the study is consistent and coherent, for example, how the methodology is appropriate to the research question, as well as how the design and execution of the methodology is adequate in relation to the research questions and data analysis. In addition, the chapter discusses the thematic data analysis process, and triangulation, and research evaluation which focused on trustworthiness, credibility, transferability, and confirmability. The chapter concludes by addressing ethical considerations of this study.

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

Chapter Six presents a discussion of the findings of the study. The findings are contrasted with prior literature that was reviewed in Chapter Two. Previous findings that are consistent with the findings of this study are cited and those previous findings that the findings of this study contradicted are also acknowledged. The discussion of the results shows insight and originality by suggesting implications and making recommendations that are applicable and useful. The research questions are comprehensively answered in this chapter, and the conclusions that this study comes to are justifiable in terms of methodology and the applicable results presented and discussed in this chapter.

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

1.8 Conclusion

This chapter presented a compelling argument for the need to explore working *with* Grade 11 Life Sciences teachers on make use of Virtual Lab to mediate learning of Energy transformations in rural resource-constrained secondary schools in the Eastern Cape Province. In addition, the chapter provided the background on the research problem, the objective of the study and the research questions, and the significance of the study. The chapter concludes by providing an overview of the subsequent chapters. The next chapter will focus on a literature review that is related to the main debates, trends, and gaps on the research topic.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The previous chapter introduced the main concepts of the study with reference to its background, objectives, and significance. This chapter presents the literature review. Literature refers to a collection of published information such as books, scholarly articles and other sources that are related to the main debates, trends and gaps on a particular area of research or topic (Giannakos, Mikalef & Pappas, 2021). On the other hand, literature review refers to a systematic and comprehensive analysis of literature relevant to the research area and that analysis should direct the research questions and objectives of a study (Bert & David, 2016). The search for the relevant literature was conducted using aunthentic and authoritative electronic sources such as Google Scholar, Science Direct and Web of Science. The purpose of literature review in this study was to; provide a foundation of knowledge on the research topic (Jalali & Wohlin, 2012); identify areas of prior scholarship to prevent duplication (Lal & Paul, 2019); give credit to other researchers (Snyder, 2019); identify gaps and conflicts in previous studies (Haddaway, Woodcock, Macura & Collins, 2015) and; place this research within the context of existing literature and thus making a case for why this study is necessary (Xiao & Watson, 2019). This chapter draws on the latest and most relevant prior literature related to the use of Virtual Lab as an ICT tool for teaching and learning. The chapter has nine sections and begins with: (a) a general overview of literature concerning the use of ICT in Education , (b) followed by the role of ICT in Teaching and Learning, (c) teachers' and learners' perceptions and attitudes towards the use of ICT in Teaching and Learning, (d) challenges associated with ICT in Teaching and Learning, (e) a brief explanation of what Virtual Lab is, (f) benefits of using Virtual Lab in Teaching science subject, (g) challenges associated with using Virtual Lab in Teaching science subject, (h) a review of literature on the importance of conducting Laboratory experiments in teaching science, and (i) a conclusion.

2.2 Use of ICT in Education

Information and Communication Technology (ICT) has become a driving force in almost all aspects of human life and the field of education is not exception to it (Dodewar, 2020; Mahmud, Yogesh, Angela, Vinod, Sujeet & Nripendra, 2021). According to the United Nations Educational, Scientific and Cultural Organisation (UNESCO), (2020), the African Ministerial Forum has stressed the urgency to accelerate the integration of ICT in education in order to achieve Africa’s agenda 2063. Flagship project number 10 of the 15 projects of the African Union seeks to transform Africa into an e-Society and integration of ICT in education has been identified as the starting point (African Union, 2020). Babu and Maruti (2020), defined ICT as an umbrella term that encompasses any application or device such as television, radio, mobile phones, computer, notepad, network hardware or satellite system software. Ghosh and Bhattacharjee (2020), added that ICT also encompasses various services such as video-conferencing, tele-conferencing, email, audio conferencing, television lessons, radio broadcasts, interactive radio counselling, interactive voice response system (IVR) and related services. In this study, the researcher applies both definitions of ICT as defined above.

Currently, there are several studies on ICT use in education that are reviewed below. SITES (the second information technology in educational study), sponsored by the International Association for the Evaluation of Educational Achievement (IEA), is an exemplary study which identifies and describes the educational use of ICT across 26 countries in the world (Ghosh, 2020). The study explores the use of ICT in education and has reported that ICT helps to improve the quality of educational outcomes (Bhattacharjee, 2020).

Over the last decade, several international studies have documented the use of ICT in education around the globe. These include studies conducted by Ertmer and Ottenbreit-Leftwich, (2010); Suduc, Bîzoi, Gorghiu and Gorghiu, (2011); Ertmer, Otternbreit-Leftwich, Sadik, Senderur and Senderur, (2012); Sánchez, Marcos, González and Lin, (2012); Enrique-Hinostroza, Labbé, Brun and Matamala, (2011); Adu (2016); Mooketsi and Chigona (2014) cited in Padayachee (2017); Ambusaidi, Musawi, Al-Balushi and Al-Balushi, (2018); Dodewar, (2020); Jadhav and Takale, (2020); Dnyaneshvar, Shrinivas and Nandkishor, (2020); Giannakos, Mikalef, and Pappas, (2021); Gamor, (2021); and Mutwiri, Kafwa, and Kyalo, (2021).

These researchers have documented different uses of ICT in education. Suduc *et al.* (2011), documented two main categories of ICT use by teachers that is; (i) supportive ICT use, and (ii) classroom ICT use. According to Ertmer *et al* (2012) and Elemam (2016), supportive ICT use refers to the use of ICT for administrative purposes. This includes the use of ICT for student administration, worksheets preparation, evaluation development activities, tracking learners' learning progress, writing correspondence and reports, and assigning learners to classes (Adu & Ojo, 2018).

The second category, classroom ICT use, aims to support and enhance the actual teaching and learning process. This includes the use of computers for demonstration purposes, drill and practice activities, modelling, representation of complex knowledge elements, discussions, collaboration, project work, etc. (Dnyaneshvar *et al.,* 2020). In addition, apart from ICT use for administration and classroom teaching, ICT is also being used as a source of teaching and learning material. Jadhav and Takale (2020), reported that ICT provides access to teaching and learning resources whereby teachers and learners can browse through e-books, e-journals, sample examination papers and can also have an easy access to resource persons, mentors, experts, researchers, professionals and peers all over the world.

In sum, whilst most of the studies reviewed above by the researcher indicated that the use of ICT in education has indeed improved the quality of educational outcomes, there are several researchers who have reported some challenges that are associated with the use of ICT particularly in teaching and learning. Therefore, the next sections discuss the role of ICT, and its challenges, in teaching and learning. The challenges of ICT in teaching and learning are discussed in detail in Section 2.2.3.

2.3 Role of ICT in Teaching and learning

In today's modern age, the use of chalk and duster is no longer enough in the teaching process (Jadhav & Takale, 2020). Several studies conducted on the role of ICT in teaching have reported several benefits (Eze, Adu & Ruramayi, 2013; Meng & Wang, 2018; Graham, Stols & Kapp, 2020). The role of ICT in teaching has been identified as; allowing teachers to engage and motivate learners to a greater degree (Stockwell, 2016); the internet increases access to authentic information (Bhattacharjee, 2020); simulations enable teachers to show experiments that would not otherwise be possible to visualize or perform (Dnyaneshvar *et al.,* 2020); data logging and digital video recording allow access to new sources of data in a wider range of experimental settings (Safitri, Fahrudin & Jumadi, 2020) and ICT provides quicker and more accurate data collection thereby saving lesson time and providing better quality results (Ambusaidi *et al.,* 2018). As a result of these benefits, Ghosh (2020), reported that more educators are showing an increasing tendency to use ICT in their practice. For example, as a Subject Advisor, the researcher personally noted during school visits as part of his duties that most educators now use laptops and data projectors during lesson delivery as part of the tendency to integrate ICT in their teaching practice. In addition, most educators are now surfing the internet for teaching and learning material such as textbooks and question papers and are able to share these material amongst themselves via the internet.

On the other hand, when examining the use of ICT in learning, studies conducted by Duff (2015), Holmes and Gardner (2016), Ulbricht (2016) and Babu and Maruti (2020) on use of ICT in the classroom have reported that the use of technology motivates learners to learn and therefore result in a better quality of learning. Stockwell (2016), found that by using ICT, teachers could make their lessons more attractive and livelier by using multi-media, and this led to learners being able to understand easily. In addition, other scholars have indicated that ICT presents an entirely new learning environment for learners. Ghosh (2020) pointed out that learners learn more in less time and enjoy classes more when ICT-based learning environment is provided. Moreover, ICT provides an opportunity to access an abundance of information using multiple information resources and viewing information from multiple perspectives, thus fostering the authenticity of information (Dodewar, 2020). In the developing world, ICTs are used largely to increase access to and improve the relevance and quality of learning. ICTs have demonstrated potential to increase the options, access, participation, and achievement for all learners. ICT enables learners to learn anywhere and at any time (Sharma, 2016). According to Ghosh (2020), the unprecedented speed and general availability of diverse and relevant information due to ICT extends learning opportunities to the marginalised and vulnerable groups among the other disadvantaged.

2.4 Teachers' and learners' perceptions and attitudes towards the use of ICT in Teaching and learning

For successful integration of ICT in teaching and learning processes, it has been suggested that change must begin with teachers (Castelló, Pellegrino, Argente, Gomez-Marquez, Gaudenz, Randall, Pereira, Alonso, Calvelo, Young, Acosta, Albarran, Gimenez, Sedraschi, Umpiérrez, Figares, de Sagastizabal & Radmilovich, 2020). This is because teachers are one of the key species in the learning ecosystem, and therefore, the perceptions and attitudes of ICT use by teachers are critical in integrating technologies into the teaching processes (Murphy, 2016). Concurringly, Oliveira, Behnagh, Ni, Mohsinah, Burgess and Guo (2019), pointed out that teachers' educational beliefs are strong indicators of their planning, instructional decisions and classroom practices and teachers are the most influential factors if educational changes are to be fruitful.

Ngoungouo (2017), investigated the perceptions of educators on the use of ICTs in primary and secondary schools in Cameroon. He found that educators have varied perceptions of what ICT tools are and that these perceptions had an impact on how educators would use ICT tools for teaching. Similar findings were also reported by Gambari, Obielodan and Kawu (2017) in their study conducted in Nigeria. In addition, Oliveira, Behnagh, Ni, Mohsinah, Burgess and Guo (2019), explained that if a teacher has a narrow view of what educational technology is and how it might be used in the classroom, the teacher will perceive technology as a constraint in teaching and learning. Monita and Ikhsan (2020), added that if a teacher has a broader view of what educational technology is and how it might be used in the classroom, then the teacher will perceive technology as empowerment. Thus, it is important to move educators' perceptions from a narrow to a wider view so that educators should see the use of technology as empowerment and not a constraint. A study conducted in Indonesia by Azizah, Karyanto and Rinanto (2019) on challenges and opportunities of using Virtual Laboratory in teaching biodiversity and classification also found that educators who perceived technology to be useful in their teaching were regular and confident users of technology. Thus, the educators' perceptions toward technology result in better attitudes towards technology use.

Most of the studies conducted on learners' perceptions on ICT use for learning are on Internet-enabled learning environments (Barjis, Sharda, Lee, Gupta, Bouzdine-Chameeva & Verbraeck, 2012; Muhamada, Zaman & Ahmad, 2012; Arista & Kuswanto, 2018). These studies found that learners think that the use of ICT tools increased their self-confidence on how to use the tools for their schoolwork. When they are confident, it shows that they see the value of ICT tools in their learning.

2.5 Challenges associated with the integration of ICT in Teaching and Learning

ICT integration in teaching and learning has remained inadequate in many countries despite all the investments in infrastructure and professional development of teachers (Zaka, 2013; Padayachee, 2016). In South Africa, the Department of Basic Education (DBE), turned to the use of technology to help improve teaching and learning and to redress past inequalities in schools (Graham, Stols, and Kapp, 2020). However, Karsenti, Collin and Harper-Merrett (2011), point out that this intervention has made little progress over the years. Mooketsi and Chigona (2014) cited in Padayachee (2017), revealed that there is a disparity between government expectations and the practices of teachers. This observation is documented in the DBE's Action Plan to 2019 report, where the department concedes that "ICT-enhanced learning had not advanced in South Africa as predicted" (DBE, 2015, p. 14).

Recent literature suggests that in South Africa, only a small number of teachers are effectively integrating technology in the classroom (Nkula & Krauss, 2014; Padayachee, 2016). The DBE estimated that a mere 26% of South African teachers are equipped with basic technology skills, with only 7% functioning at an intermediate level of competency (DBE, 2016). Mundy, Kupczynski and Kee (2012), further stated that even those teachers that grew up using technology and are having access to it, are not integrating technology in their practice.

Ertmer (1999), provides a model that describes two types of challenges that hamper teacher ICT integration in the classroom. These are first-order barriers (i.e. extrinsic to the teacher) and second-order barriers (i.e. intrinsic to the teacher).

The first-order barriers are well documented as; inadequate training and lack of technical skills (du Plessis & Webb, 2012; Rabah, 2015; Eshetu 2015; Young, 2016; Elemam 2016; Ngoungouo 2017), theft of ICT infrastructure (Ford, Botha & Meraka 2015; Ngqakamba 2019) and heavy workload and lack of time (Mulwa & Kyalo 2013; Ghavifekr, Kunjappan, Ramasamy & Anthony 2016). The most cited extrinsic barrier to ICT integration by teachers is lack of access to appropriate resources such as computers, software, hardware, and internet access (Steyn & Van Greunen, 2014; Albugami & Ahmed, 2015; Francis, Ngugi & Kinzi 2017; Özdemir, 2017). However, Ertmer and Ottenbreit-Leftwich (2012, 2013), argued that access to ICT resources is no longer a significant barrier to its integration in the classroom. Msila (2015), is of the view that the successful implementation of ICTs in schools is not about providing hardware and software, but motivating teachers. Furthermore, successful implementation of technology in schools is also not about acquiring ICT skills but assisting teachers in their daily engagement with learners. Thus, the availability of ICTs at schools does not necessarily imply that teachers will adopt the technologies in the teaching and learning process.

The second-order barriers are intrinsic to teachers and include attitudes toward new technologies (Yusuf and Balogun, 2011; Mustafina, 2016), beliefs about teaching and learning (Chikasa, Ntuli and Sunderjee, 2014), resistance in teachers towards new ICTs (Raman and Yamat, 2014), technophobia or fear of technology (Chigona 2011; Ndlovu, 2016). It can, therefore, be noted that schools with teachers who know the benefits of technology are more likely to be ready to integrate ICT in the classroom. Those teachers who do not value and understand the benefits of ICT will, on the other hand, have difficulties in integrating technologies in teaching and learning. In sum, with regards to the role of ICT in education, the researcher noted that whilst there are challenges that are associated with ICT integration, the benefits of ICT in education outweigh the challenges and therefore worth exporing.

2.6 What is a Virtual Lab?

Virtual Lab (VL) is a simulated version of the traditional laboratory that refer to a learner-centered approach in which the learner is provided with instruments that are virtual representations of real objects used in conventional laboratories (Lestari & Supahar, 2020). Bogusevschi, Muntean and Muntean (2020), defined VL as a highly interactive computer-based multimedia environment that brings learners into a virtual world that allows them to create and to conduct simulated experiments, and to visualize in a 3D environment the effects of the experiment.

A Virtual Lab contains a set of all apparatus such as microscopes, centrifuges, whole organisms, or individual cells, each with specific pre-programmed behaviours (Aliyu & Talib, 2019). The learner can interact with the virtual objects in order to attain a set of given goals, i.e., the study of cell features, separation of cellular components, measurement of enzyme activities, quantification of cell division, etc. (Pedaste, Mitt & Jürivete, 2020). The use of creative renderings of objects and their behaviours allows the learner to freely experiment in the virtual world. According to Aliyu and Talib (2019), learners can use graphics editor available in the framework to prepare lab reports after the exercises. Billah and Widyarmoko (2018), pointed out that any stage of the lab can be captured and copied in the report document at the level of structured graphics, rather than screen bitmaps, and that the documents are stored in XML and can be reviewed and edited manually if necessary.

Fig. 1 and Fig. 2 below shows that Virtual Labs are state-of-the-art virtual teaching and learning environments that contain a set of modern apparatus such as microscopes, laptops, test-tubes, beakers, centrifuges etc., as indicated by Aliyu and Talib (2019). This means that by using Virtual Labs, learners will experience the use of top of the range instruments and lab environments that they could possibly not be able to experience in resource-constrained rural schools.

Figure 1: Inner view of PraxiLab Virtual Laboratory (http://praxilab.com)

Fig. 1 above shows that in a Virtual Lab, the required chemicals and reagents are readily available. Unlike traditional labs, where equipment wears out, become outdated and chemicals and reagents expire, Mathew (2016), points out that in Virtual Labs, chemicals do not expire and equipment do not wear out. This has the advantage of eliminating experimental error that may arise due to use of deteriorating equipment and reagents.

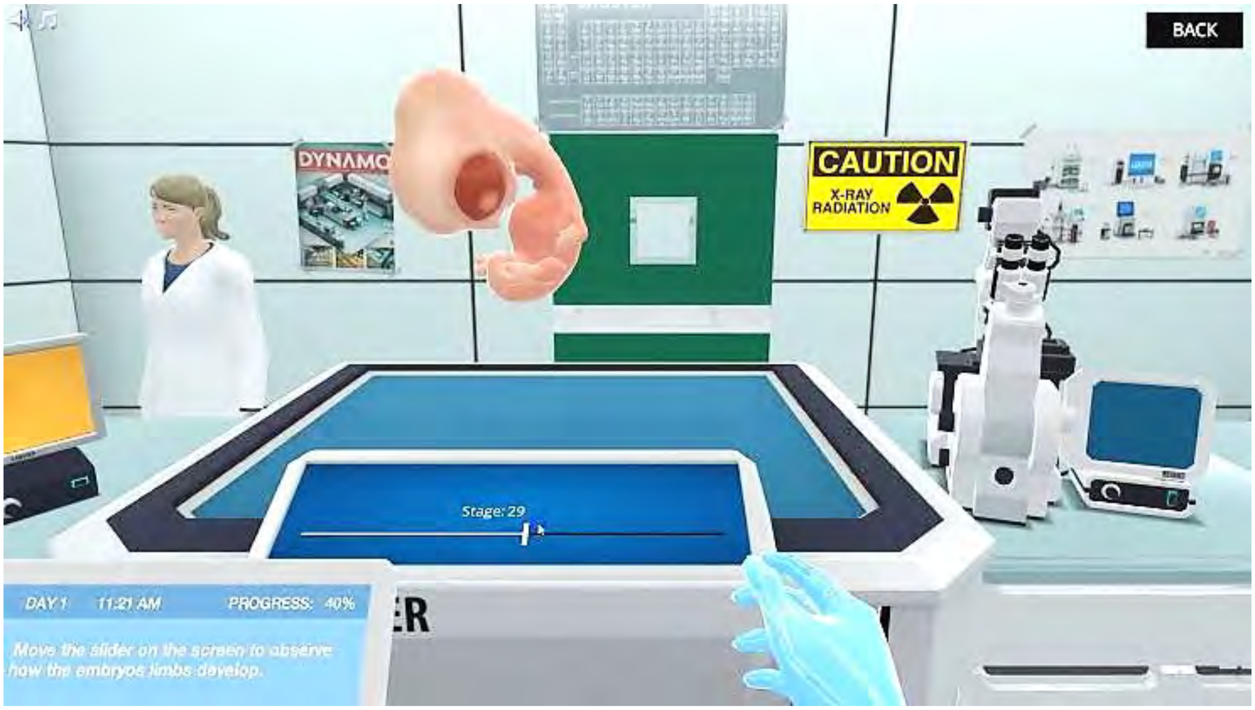

Figure 2: Inner view of Labster Virtual Laboratory (http://labster.com)

Fig. 2. demonstrates that by using Virtual Lab, learners may be able to observe 3D life processes that would otherwise be impossible to visualise in real life. In the example above, by moving the slider on the screen, learners may be able to visualise in detail the stages of embryonic development from conception up to the full term of the gestation period. This was confirmed by Wu, Lee, Chang, and Liang (2013), who indicated that Virtual Lab could be efficient for interacting with 3D objects including at atomic, cellular and molecular level, an interaction that would be impossible in a traditional laboratory.

2.6.1 Benefits of using Virtual Lab in teaching Science

The review of the previous research yielded numerous benefits of using Virtual Lab to mediate learning of science practical experiments in secondary school educational settings. These benefits are drawn from the perspectives of both teachers and learners and are discussed below.

i. Convenience and Accessibility

A more recent technological advancement of VL is that it could be operated in mobile devices such as smartphones and tablets and used in and out of school time. This means that unlike the real laboratory where teachers and learners have to be physically present in the lab at specified times, with the VL, teachers and learners can carry out their experiments at their convenient time and place and do not need to be in a lab building. This is supported by Arista and Kuswanto (2018), who investigated the potential of VL application to improve learning independence and conceptual understanding. Results of their study indicated that VL could be used both in and outside the school and could improve learners' learning independence. In addition, Aliyu and Talib (2019), studied VL as a solution to challenges of conducting chemistry practicals in secondary schools in Nigeria. They also found that with VL, teachers and learners do not need to be in a lab to conduct experiments. On the accessibility of the VL, Castelló, Pellegrino, Argente, Gomez-Marquez, Gaudenz, Randall, Pereira, Alonso, Calvelo, Young, Acosta, Albarran, Gimenez, Sedraschi, Umpiérrez, Figares, Sagastizabal and Radmilovich, (2020) in their study conducted in Uruguay, *'Real and Virtual Biological Science Living Laboratory for Science Teaching',* confirmed the findings of Martin and Parker (2014), that VL has the ability to be accessed simultaneously from different locations in an unlimited way. This means that many learners can perform their experiments simultaneously without having to be in the same physical space. This also means that even learners from those schools that do not have real laboratories can still be able to conduct science practicals. This is significantly more important in maintaining social distancing by avoiding being in the same physical building in the context of the COVID-19 pandemic.

ii. Safe environment for conducting experiments

Conducting experiments in real science laboratories can expose learners to danger, especially when fire, chemical reagents or animal specimens are involved. Some of the dangers that might occur include burns, electrical shocks, gas leakages, adverse chemical reactions, and infections (Muhamada, Zaman, & Ahmad, 2012; Aliyu & Talib2019). One of the most highlighted benefits of VL from previous research is the elimination of the dangers that are associated with real laboratories. For example, George and Kolobe (2014), in their study on the exploration of the potential of using Virtual Lab for chemistry teaching at secondary school level in Lesotho, reported that VL enables learners to conduct experiments that could otherwise be too dangerous to perform in a real lab. They also reported that VL allows learners to visualise places that could be dangerous or impossible to visit, such as the deep ocean floor and high mountains. Concurringly, Castelló, Pellegrino, Argente, Gomez-Marquez, Gaudenz, Randall, Pereira, Alonso, Calvelo, Young, Acosta, Albarran, Gimenez, Sedraschi, Umpiérrez, Figares, de Sagastizabal and Radmilovich (2020) in their study titled: *'Real and virtual biological science living laboratory for science teaching'*, reported that a striking feature of the Virtual Lab is that teachers and students can have the opportunity to freely conduct experiments in a virtual and safe environment. This study suggests that the VL is not only safe against the physical dangers reported in the previous research but could also be safe in avoiding COVID-19 transmissions.

iii. Affordability of running the lab

Conducting lab experiments in real labs can be very costly, especially for under-resourced rural schools. The cost arises from procurement of up-to-date lab equipment, maintenance of the equipment and replenishment of lab consumables (Ogunleye, 2010; Oliveira, Behnagh, Ni, Mohsinah, Burgess, & Guo, 2019). VL experiments may be a great alternative to the physical lab in terms of lowering lab costs, while still creating good laboratory experiences (Diwakar, Radhamani, Sujatha, Sasidharakurup, Shekhar, Achuthan, Nedungadi & Raman, 2014; Gambari, Obielodan & Kawu, 2017; Lestari, & Supahar, 2020). Since Virtual Lab experiments are conducted within a virtual environment that uses simulations, this means that once developed, the simulations can function at no extra operational cost as many times as required. This is because in VL applications, lab equipment does not wear out, and chemical reagents do not expire. This feature of the VL allows learners from resource-constrained schools to be able to perform standard experiments which they would otherwise be unable to perform due to the cost associated with the real lab.

iv. Teacher and learner attitudes towards VL including effect on learner performance

A number of studies (Akkan, 2012; Tatli, Z. & Ayas, 2012; Herga, Grmek & Dinevski, 2014; George & Kolobe, 2014; Musawi, Ambusadi, Al-Balushi, S. & Al-Balushi, 2015; Bogusevschi, Muntean & Muntean, 2020; Monita & Ikhsan, 2020 and; Tobarra, Robles-Gómez, Pastor, Hernández, Duque & Cano, 2020) have focused on teacher and learner attitudes towards the use of VL including learner performance due to the use of VL. Most of these studies have reported positive teacher and learner attitudes. For example, George and Kolobe (2014) explored the potential of using a Virtual Laboratory for chemistry teaching at secondary school level in Lesotho. They found that this technology is generally accepted (96 % of 166 teachers) with only a minority indicating that it can never replace traditional laboratory. In addition, Achuthan, Sivan and Raman (2014) in their study conducted in India on teacher receptivity in the creative use of Virtual Laboratories found that teachers predominantly felt that teaching concepts using VL would shorten the time to teach that specific concept by over 65% and that VL would help more than 80% of learners understand them better as compared to using the real lab. However, they also found that second-order barriers, such as teacher beliefs and attitudes can affect the adoption of VL. Bogusevschi, Muntean and Muntean (2020) in their study *'Teaching and Learning Physics using 3D Virtual Learning Environment: A Case Study of Combined Virtual Reality and Virtual Laboratory in Secondary School'* in Dublin, Ireland, 27 children of age 12-13 years old took part in the study as part of the experimental group. Over 74% of these learners found VL to be a good learning experience and would love to take part in this learning platform more often. Lestari and Supahar (2020) studied students and teachers' necessity toward virtual laboratory as an instructional media of 21st-century science learning. The results of their study show that 94,3% of students need VL. The teachers state that it is necessary to use VL to overcome the constraints of science practicum in schools.

v. Elimination of physical limitations of a real lab

Some of the limitations that are attributed to real laboratory from previous research include that; planning and application are time-consuming, monitoring learners' work during lab activities can be difficult in over-crowded environments, and most commonly lack of standard lab equipment in most rural schools (Gambari, Fagbemi, Falode & Idris, 2013; Falode, 2014; Kawu, 2015). These limitations can negatively impact on the learners to perform even simple laboratory activities. The experiments on animal cloning and tissue culture, as examples are never done in rural schools because they are costly and take a long time. With the use of VL, these limitations can be eliminated as all the required apparatus are readily available and do not need any preparation or calibration, thereby saving time (Aliyu & Talib, 2019; Iglesias-Pradas, Hernández-García, Chaparro-Peláez, José, 2021). In addition, learners can observe simulated versions of scientific and natural phenomena such as cell division, water cycle or human embryonic development which they cannot observe directly in the real lab because these processes are too comprehensive, too complicated and too slow or too fast. In addition, VL could be efficient for interacting with 3D objects. This means that learners could view the objects from different sides and go inside them. This could be very helpful in better understanding complex and tiny objects in science such as cellular, atomic, or molecular structures.

vi. Top-class lab equipment and up-to-date reagents

In science experiments, modern instruments and up-to-date chemical reagents are recommended as they are more likely to give reliable results with minimum chances of error and reporting incorrect result (Herga, Grmek & Dinevski, 2014). The modern instruments are very expensive that most rural schools cannot afford them and as a result, many of the schools have out-dated lab equipment and expired chemical reagents, which have greater chances of yielding inaccurate experimental results. According to Roth, Appel, Schwingel and Rumpler (2019) in their study on learning in virtual physics laboratories assisted by a pedagogical agent, virtual experimentations have the benefit of minimization of error due to the use of top-notch equipment. This was confirmed in Indonesia by Rani, Mundilarto, Warsono and Dwandaru (2019), in their study *'Physics virtual laboratory: an innovative media in 21st century learning',* in which they found out that the Virtual Lab has, among other benefits such as creating active learning and can be used many times, the Virtual Lab also replaces the expensive real equipment with up-to-date simulated versions of the equipment.

2.6.2 Constraints of using Virtual Lab in teaching and learning practical experiments

Apart from the popularity and potential benefits that the VL might contribute to laboratory experimentation, there are findings that disapprove the use of VL on the grounds of cost, depriving learners of experiences that involve concrete hands-on manipulation of physical materials which are essential for learning, and lack of direct supervision. These are discussed below.

i. Cost

Contrary to Diwakar, Radhamani, Sujatha, Sasidharakurup, Shekhar, Achuthan, Nedungadi, and Raman, (2014); Gambari, Obielodan and Kawu, (2017) and Lestari and Supahar, (2020) who noted that VL is a more affordable environment to perform experiments than a physical lab, Tatli and Ayas (2012), revealed that VL is not as affordable. They argued that development of VL and constant maintenance (i.e., debugging), the price of devices, instruments, servers, and expertise needed to develop the software and its updates could potentially be a major cost factor and this cost should be considered when deciding whether VL is affordable. On the part of learners in rural schools, most of them could be disadvantaged as they cannot afford mobile devices such as smartphones and this might affect the accessibility of VL to the learners. To remedy this, the Eastern Cape department of Education (ECDoE), for example, has entered a partnership with mobile network operators to provide 72 000 sim cards and 55 000 Samsung 8″ tablets to learners to allow learners. This partnership has a great potential to enable the disadvantaged learners to access the VL.

ii. Lack of 'Hands-On' Approach

Akkan (2012) in his study '*VIRTUAL OR PHYSICAL: In-service and Pre-Service Teacher's Beliefs and Preferences on Manipulatives'* conducted in Turkey reported that a major constraint of using VL as compared to the real lab is the lack of a 'hands-on' approach for learners. The researcher pointed out that in a biology lab, for example, much is learnt from hands-on experience which the VL cannot offer such as slide preparation (i.e., slicing, staining, and creating a microscope slide of a sample). Holding a similar view are Ateş and Eryılmaz (2011), who indicated that learners learn better when they measure, touch, feel, make charts, manipulate, draw, record data, interpret data and make their own conclusions. The researcher, however, asked the question: Is there experiential evidence to show that learners are at a disadvantage when they do not experience a hands-on lab? This question was answered by Oloruntegbe and Alam (2010) in their study conducted in Malaysia *'Evaluation of 3D environments and virtual realities in science teaching and learning: The need to go beyond perception referents'* discovered that there was no statistical difference between mean score marks of post-tests of two groups of learners exposed to virtual and 'hands-on' experimentation. The lack of 'hands-on' experiences, therefore, may not be a constraint after all. In the context of the global COVID-19 pandemic, this study suggests that the lack of 'hands-on' in VL could indeed be a benefit in stemming the spread of the corona virus by not handling lab equipment that might be contaminated.

iii. Teacher resistance

Although an overwhelming majority of studies reviewed by the reseacher showed high acceptance of VL among teachers (Akkan, 2012; Tatli & Ayas, 2012; Herga, Grmek & Dinevski, 2014; George & Kolobe, 2014; Musawi, Ambusadi, Al-Balushi & Al-Balushi, 2015; Bogusevschi, Muntean & Muntean, 2020; Monita & Ikhsan, 2020; and Tobarra, Robles-Gómez, Pastor, Hernández, Duque & Cano, 2020), Nicholas and Ng (2012) cited in Murphy (2016), observed that teacher resistance to the use of VL is the most important factor when incorporating this technology in their practice. In a study conducted in Zimbabwe by Bhukuvhani, Kusure, Munodawafa, Sana and Gwizangwe (2010) on teachers' use of improvised and virtual laboratory experimentation in science teaching, a large number of teachers (63.6%) indicated that they did not use virtual experimentation in their teaching. The most cited reasons for teacher resistance included; inadequate training and lack of technical skills (du Plessis & Webb, 2012; Rabah, 2015; Eshetu 2015; Young, 2016; Elemam 2016; Ngoungouo 2017) and heavy workload and lack of time (Mulwa & Kyalo 2013; Ghavifekr, Kunjappan, Ramasamy & Anthony 2016). In addition, Hartman, and Jackson (2019), found out that another reason why teachers resisted change from traditional teaching to teaching in a virtual environment was due to not consulting them in the migration to virtual teaching and learning environment. Similar findings were reported by Monita and Ikhsan (2020) in a high school in Indonesia where after four years of attempting to get teachers involved in teaching in a virtual environment, the teachers continued to show resistance, mainly because the teachers had never been involved in the decision-making and planning process to move towards virtual teaching environments. In another study conducted in Spain by Tobarra, Robles-Gómez, Pastor, Hernández, Duque and Cano (2020), these researchers found out that while there was evidence of learning improvement and performance enhancement due to the use of VL, over 85% of the data centred around issues of interest, enjoyment, and fun. The researchers, therefore, concluded that there was no empirical evidence yet to support the pedagogical effectiveness of this modern technology, thereby contributing to the resistance of the VL by some teachers. The researchers, however, appreciate the newness of this innovation and are of the view that extensive research is required to make the valid evaluation possible. With regards to the teacher resistance, this study predicts a shift towards teacher acceptance of the VL due to the experiences of the COVID-19 pandemic, where technology is becoming more inevitable in all aspects of human life, including education.

2.7 Importance of conducting Laboratory activities in Teaching and Learning of Science

Laboratory activities have important role in science learning, including Life Sciences (Sutarno, Setiawan & Suhandi, 2019). Laboratory activity in science teaching and learning is often referred to as a scientific experiment. Conducting scientific experiments in science learning is a cornerstone in developing learners' science problem solving skills which include formulating questions and hypothesis, carrying out experiments, measuring, reviewing what is already known in light of experimental evidence, using tools to gather, analyse and interpret data, proposing answers, explanations and predictions, and making conclusions, and communicating the results (Sutarno *et al.,* 2019; Safitri, Fahrudin & Jumadi, 2020). These science processes are important because according to Ateş and Eryılmaz (2011), learners learn better when they measure, touch, feel, make charts, manipulate, draw, record data, interpret data and make their own conclusions.

Moreover, laboratory activities serve as a vehicle for constructing, reconstructing, verifying, and strengthening scientific knowledge (Safitri, Fahrudin & Jumadi, 2020). Proper scientific experiments can stimulate the development of low-order thinking skills to higher-order thinking skills which allow students to function at the analysis, synthesis and evaluation levels of Bloom's taxonomy (Pedaste, Mitt & Jürivete, 2020). Scientific activities that can be used in the learning process of students can be in the using of experimental laboratories or Virtual Labs (Safitri *et al.,* 2020).

2.8 Conclusion

Firstly, this chapter discussed the use of ICT in Education and explored the different ways in which technology is being used in education in general. This was followed by a discussion on the role of ICT in teaching and learning and the ways in which technology has enhanced the teaching and learning process. The chapter also discussed teachers' and learners' perceptions and attitudes towards the use of ICT in teaching and learning. This was done in order to be alert to teachers' and learners' attitudes that might influence this study. This was followed by a discussion on barriers to the integration of ICT in teaching and learning. Most importantly and at the centre of this chapter was an explanation of what Virtual Lab is, what benefits and challenges are associated with the use of Virtual Lab. Literature reveals that information about the use of Virtual Lab in South African secondary schools is unavailable. As a result, literature was drawn from studies conducted in Lesotho, Zambia, Nigeria and mostly from international studies conducted in the developed world. Lastly, the researcher concluded the review of the literature with a discussion on the importance of conducting laboratory experiments since this study involves make use of Virtual Lab. The next chapter discusses the theoretical framework of this study.

CHAPTER THREE

THEORETICAL AND ANALYTICAL FRAMEWORK

3.1 INTRODUCTION

The theory is an important component of a research study. It enables researchers to move beyond descriptive reporting towards a deeper understanding of the complexities and nuances of education environments (Jaakkola, 2020). It provides a vehicle for dialogue among scholars and can position micro-level research within a broader context and a larger knowledge base (Becker & Jaakkola, 2020). A theoretical framework grounds the study and directs or guides the questions asked, the research design, and the methodology used (Hartmann, Wieland & Vargo, 2018). On the other hand, an analytical framework provides a way of capturing and interpreting data to deduce meaningful results and make sense of them (Goos, 2003). It forms a reference point for the interpretation of the research findings (Mpofu, Otulaja & Chikunda, 2013). Shepherd and Suddaby (2017), posits that an analytical framework provides focus to the research, determines data collection and structures data analysis. It provides a lens or a frame of seeing the research questions for the researcher to argue from a particular standpoint and thus make sense of the research findings (Jaakkola, 2020). The term analysis means separation of problems into their constituent elements to help make complex issues simpler (ibid.). Hence, an analytical approach is the use of an appropriate process to break a problem into small pieces. In this study, the theoretical framework is informed by Vygotsky's (1978) socio-cultural theory. The analytical framework is informed by Thompson and Mishra's (2006) Technological, Pedagogical, Content Knowledge (TPACK) theory. These theories are discussed below.

3.2 Socio-cultural theory

The Socio-cultural theory of learning draws on the work of Vygotsky (Cole, 1996). According to Vygotsky (1978), learning is embedded within social events and occur when individuals interact with other people and objects or tools in a collaborative environment. The socio-cultural approach to learning considers learning as a process that involves both cognitive activities that occur in the human mind along with what surrounds the learner in the environment and the environment can be people and/or tools (Vygotsky, 1978). This study draws on two main ideas from Vygotsky's Socio-cultural theory. First, the mediated nature of human knowledge. Second, the role of others and the Zone of Proximal Development (ZPD).

3.2.1 The mediated nature of human knowledge

Vygotsky (1978) defines mediation as the link between teachers and learners that directly affects learner understanding of knowledge and skills. Although this theory focuses more on how children learn or develop, Eun (2008), suggests that *learning* and *development* should not be restricted to children only but also take place in adults. Concurring, Shabani (2016), posits that learning in school is applicable to teachers as well, to help them to grow in their workplace. Therefore, this theory is applicable to this study where learning is intended to take place in adults who are the teacher participants in the context of this study.

The notion of mediation proposes that human knowledge is mediated predominantly using 'tools' (Vygotsky, 1978). A socio-cultural approach assumes that use of these tools potentially supports, but through their use, changes the nature of the meaning-making activity or effort. Vygotsky (1962), suggests that the specific uses of such tools are key to how a process is enacted, and the resultant and ongoing learning and/or development – tools do not simply support something that would happen anyway, but significantly alter this process by how they are used. Vygotsky (1962) identifies two types of tools as (a) human mediation tools and (b) 'technical tools' i.e. physical objects or artefacts.

The first aspect of mediation tool, which is referred to as human mediation tools is premised on learning through social interactions with other people. As Kao (2010, p. 117) states, "interaction with people, usually parents, teachers or peers, with different levels of skills or knowledge often leads to effective learning, which then encourages individuals to move on to the next stage of learning or understanding". According to Vygotsky (1978), individuals acquire knowledge because they engage with people and events at a social level, i.e., in a collaborative environment. Then later, what has been acquired through collaboration becomes assimilated and internalised at an individual level, i.e., individuals transform what has been learnt with help through interaction and become able to use that knowledge on their own. Interaction is relevant for this study because of its learning facility role in the processes of knowledge acquisition and appropriation.

This is because during workshop discussions, teachers will interact among themselves as well as with the researcher, and this might lead to knowledge sharing and acquisition. The sociocultural perspective on learning serves as a lens to demonstrate the effectiveness of mediation through Virtual Lab, given the participants' low levels of familiarity with the technology.

The second aspect of mediation involves the use of physical objects or artefacts as tools. The concept of tools elaborated by Vygotsky originates in Hegel's idea that tools served humans to fulfil their personal goals. This stresses the role of tools to provide a means for activity development (Vygotsky, 1978). Physical tools were initially used as an extension of human's capabilities. For instance, a fishing rod was conceived as an extension of a human's hand that serves the purpose to facilitate fishing; yet the theorisation of tool-use and its relation to human activities now surpassed the extension of parts of the body. Building on this concept, scholars have coined the concept of *mediation of artefacts* (Cole, 1996), expanding the initial connections between material tools and nature established by Vygotsky. Such terms allow the current examination of the interplay between learning and tools. For instance, tools can range from archaic objects such as hammers, knives, wheels to calculators, computers and a variety of digital applications yet to emerge. Thus, tool mediation contributes to changing, broadening or constraining the range of activities of mental functions (Vygotsky, 1978, p.55).

Recent studies show that technological tools are powerful devices that can provoke changes in technological knowledge levels (Geertsema, 2014; Jaakkola, 2020). For instance, studies on mediation of artefacts suggest that novices, unlike experts, have a restricted way of expressing and representing content knowledge (Wozney, Venkatesh & Abrami, 2006; Shepherd & Suddaby, 2017). However, when novices are immersed in a learning environment that promotes the use of material tools, then novices are able to engage in similar patterns of interactions to experts (Flick, 2011; Göker, 2016). This notion is relevant to the current study since the teachers who are the novices in teaching with Virtual Lab are expected to be able to teach with Virtual Lab after the study.

Additionally, Vygotsky's socio-cultural approach highlights the individual's cultural context, including the social settings, physical settings, and objects, such as technology. Tools, like technology, are devices modern-day life and are embedded within society's ideas and skills. In order to improve one's performance in an area, there need to be similar elements between that area and what a student has learned, therefore, necessitating the use of authentic activities in school to increase the transfer of student skills (Vygotsky, 1978). By utilising these tools in authentic activities, individuals become more capable of contributing to and participating in the larger society (Miller, 2011). Much of the push for technology integration in schools hinges on the idea that technology integration makes teaching more authentic. Technology abounds daily life for most people and is a significant component of success in the workforce. Therefore, utilising technology while teaching will allow teachers to adapt to emerging methods of teaching with technology.

3.2.2 The role of others and the Zone of Proximal Development (ZPD)

Arguably one of the most widely reported ideas introduced by Vygotsky is the Zone of Proximal Development (ZPD) (Vygotsky, 1962). The ZPD defines the difference between what can be achieved in isolation, and that which can be achieved with the assistance of a more-knowledgeable other (MKO). This idea stresses that learning is strictly dependent on how individuals interact with their peers and mentors to solve problems they cannot overcome by themselves. In this, Vygotsky suggests that individuals can achieve more when their efforts are supported and guided by others. This does not suggest that individuals cannot achieve on their own, but that they can achieve more by being actively involved with the concepts and with others in exploring new understandings. Figure 3. below illustrates the ZPD.

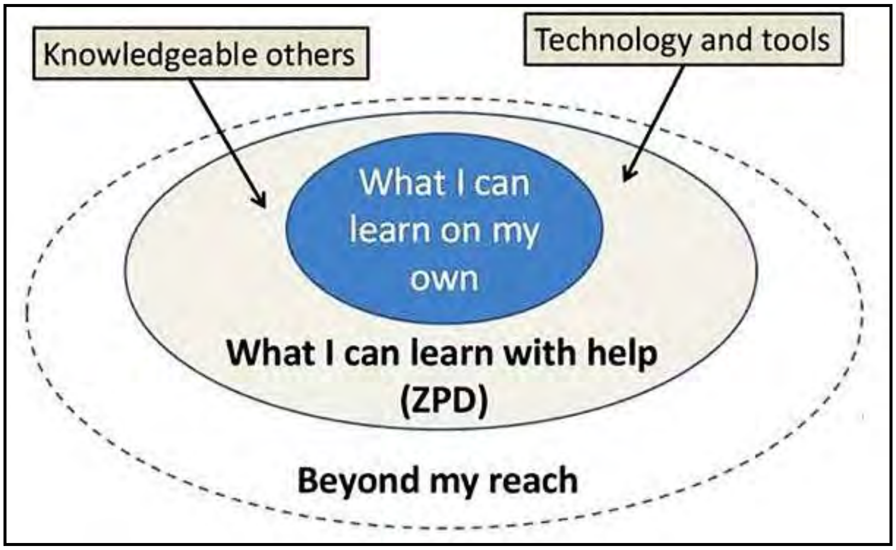

Figure 3: The Zone of Proximal Development. From: https://www.open.edu

Vygotsky's socio-cultural approach stresses the importance of stretching individuals' minds beyond their potential capabilities through working in a ZPD with a MKO, either a peer more knowledgeable in a subject or the teacher (Vygotsky, 1978). This study is grounded on the view that technology can potentially act as a MKO, as certain ways of utilising technology can direct individuals through learning, with the technology acting as a guide. From this collaboration, individuals can reach a higher level of achievement (Vygotsky, 1978). Understanding how collaboration and teacher, peer, or technology support can influence learning will inform the study on how to best utilize technology in a way that facilitates engaging an individual's ZPD and making use of MKOs. Understanding Vygotsky's theory on technology as a mediation tool allows this study to explore different ways of integrating technology in the classroom. In this study, teachers learn how to use Virtual Lab to teach during social interactions in the form of workshop discussions. The researcher (MKO) explains and demonstrates to teachers how Virtual Lab can be used to mediate the learning of experiments in Life sciences. This helps teachers (less knowledgeable) into the most proximal level of development by helping on how to use the virtual lab in the mediation of learning of life sciences. This means that after the training, teachers were able to use Virtual lab in their teaching as compared to the time before the training. Vygotsky's socio-cultural theory was utilised as a lens through which to examine and explore the ways that teachers incorporate technology into lessons. This theory facilitated understandings about the use of peers.

The researcher also notes that some aspects of Vygotsky's socio-cultural theory have attracted criticism. In terms of sources of information or interaction partners, the growing availability and scope of technologies as technical tools in learning environments led Göker, (2016, p.14) to comment, regarding pupils using ICT: "In such a process, where arguments can be gathered from many sources, the authority of a person or peer as the most knowledgeable conversation partner will be challenged". This challenges the traditional view of a ZPD as involving a more-knowledgeable individual and novice one. Clearly, when using technology, novice individuals have to do most of the construction of their knowledge but have a vast array of sources of potential expertise on which to draw. Therefore, novices are in control of their learning and can align their use of the tool and information accessed through it to their needs and interests. This is certainly not to say that the ZPD is no longer a useful concept, or that MKOs will be replaced by technology. It does, however, emphasize that the relationship between all people and tools involved in teaching-and-learning experiences may be more complex. The researcher notes that there is no "well established unified theory of ICT" in education" (Heasley, 2021, p.5). Different theories from Education and Information Technology fields have been used in the field ICT in education and they have all been criticised (Heasley, 2021). This is not to say they are all bad, but to indicate that there is no single perfect one that has remained unchallenged.

3.3 Analytical theory - Technological Pedagogical Content knowledge (TPACK)

The term TPACK refers to "the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones" (Koehler & Mishra, 2009, p. 66). Swenson, Rozema, Young, McGrail, and Whitin (2005, p. 222), indicated that TPACK "involves asking how technology can support and expand effective teaching and learning within a discipline, while simultaneously adjusting to the changes in content and pedagogy that technology by its very nature brings about".

The TPACK framework evolved from the scholarly works of Shulman (1986, 1987) on the theoretical construct of pedagogical content knowledge (PCK) (Koehler, Mishra and Cain, 2013). In 1986, Shulman introduced the model of (PCK) to the field of education. Shulman (1986) believed that content should not be separated from pedagogy (Shulman, 1990). More specifically, the model argues that pedagogical knowledge, content knowledge and the intersection of the two, referred to as PCK, are all required to successfully perform as a teacher (Harris & Hofer 2011). With the prevalence of technology, a growing emphasis has been placed on the importance of effective implementation of technology in education. The literature review shows several attempts to build upon Shulman's PCK model, adding the element of technology knowledge as another knowledge domain that is required for teachers to merge with their PCK (Angeli & Valanides, 2005; Koehler & Mishra, 2005; Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001).

Researchers produced the extension of the PCK model with different conceptualisations. For instance, Pierson (2001) described the relationships between technology, content, and pedagogy. Other researchers used different labelling schemes. For example, Margerum-Leys and Marx (2002) defined the PCK of educational technology, Gunter and Baumbach (2004) referred to implementation literacy, Franklin (2004) used the term electronic PCK, Niess (2005) described it as technology-enhanced PCK, Angeli and Valanides (2005) adopted the term information and communication (ICT)-related PCK, and Slough and Connell (2006) used the term technological content knowledge.

One adaptation of PCK with technology knowledge by Koehler and Mishra (2005) was the phrase technological, pedagogical, content knowledge (TPCK) (Koehler & Mishra, 2005; Mishra & Koehler, 2006). Koehler and Mishra realised that there was a lack of a theoretical framework in the literature regarding the use of technology in education. Koehler and Mishra believed that without such a framework, "attempts to capture the big picture of technology implementation would be unsuccessful" (Sheffield, 2009, p. 33). Based on these findings, Koehler and Mishra presented TPCK as a new theoretical framework of the knowledge base teachers require to successfully integrate technology in teaching practices (Koehler & Mishra, 2005; Mishra & Koehler, 2006). In 2007, Thompson and Mishra modified the TPCK acronym to TPACK.

According to Thompson and Mishra (2007), the new acronym, TPACK, is easier to pronounce and remember. The name TPACK was widely accepted and was referred to as "forming an integrated whole, a "Total PACKage" (Thompson & Mishra, 2007-2008, p.38). Additionally, TPACK emphasises that there are actually three kinds of knowledge (technology, pedagogy, and content) and at the main time signifying that these sets of knowledge should not be considered separately, rather as a more integrated whole (Thompson & Mishra, 2007). A teacher with TPACK expertise is superior to a scientist (content specialist), an experienced teacher (pedagogical expert) or a computer scientist (authority on technology) (Guerrero, 2010), in the sense that they can integrate all three knowledge domains and employ them in their teaching of science.

In 2008, Koehler and Mishra stated that the implementation of technology into educational practices does not occur in isolation but is situated in specific contexts. For teachers, in order to successfully teach with technology, they need to have the flexibility to integrate knowledge about students, the school, the available infrastructure and the environment. As a result, Koehler and Mishra (2008) added context to the model as an indispensable part of the TPACK theoretical framework (see Figure 4).

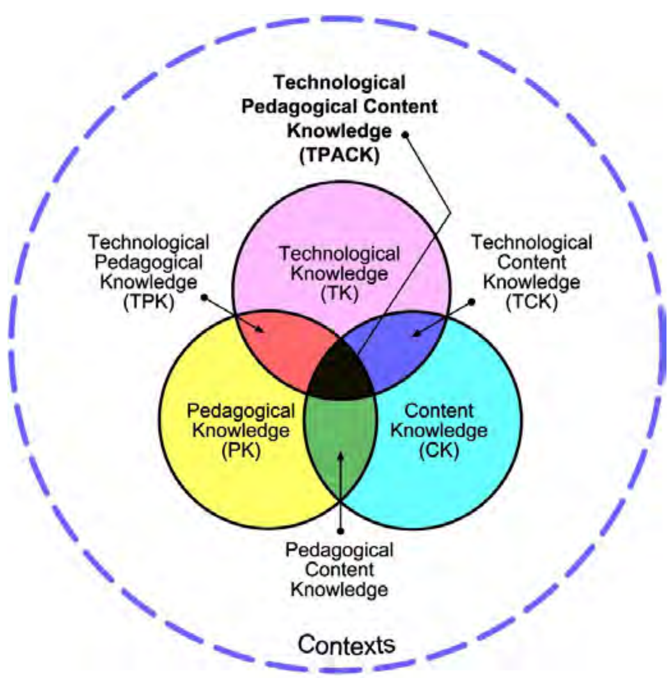

Figure 4: The TPACK framework with context. From http://www.tpack.org.

This study mainly draws from two knowledge domains of TPACK which are Technological knowledge (TK) and Technological Pedagogical knowledge (TPK). However, other domains are relevant in some context, and a description of each knowledge domain follows:

3.3.1 Technological knowledge (TK)

Technological knowledge refers to a person's understanding of how to effectively apply technology, such as the internet and software programmes, to their daily lives and at work (Koehler and Mishra 2008). These technologies include hardware such as interactive whiteboards, overhead projectors, routers, computers, tablets and software such as the internet, Microsoft Excel and Microsoft Word (Koehler and Mishra 2009). This component is particularly important for this study because the study is based on the use of Virtual Lab technology for teaching. It is, therefore, necessary for the teachers to have knowledge (Technological knowledge) of relevant technologies necessary for teaching and learning. For example, when using Virtual Lab, the teacher must be familiar with connecting the projector to a laptop or any computer, surfing the internet using the search browsers, using tablets and or computers, operating the virtual laboratory instruments, and typing and printing or emailing lab instructions to learners. The teachers were imparted with technological knowledge (TK) to operate the Virtual Lab during the workshop that was rolled out at the beginning of the study.

3.3.2 Technological pedagogical knowledge (TPK)

Technological pedagogical knowledge is the ability to understand how particular ICTs impact the way students learn and teachers teach (Koehler and Mishra 2009). In this study, TPK is critical to enable the teachers to plan and implement the lessons so that the subject matter objectives are achieved. For example, the teachers need to have an understanding of how best the Virtual Lab can be merged with particular subject content matter in a manner that ensures effective learning of the experiments by the learners. This is why in this study teachers were be trained and equipped during the workshop with skills and ideas (TPK) to integrate Virtual Lab in mediation of learning.

3.3.3 Content knowledge (CK)

Content knowledge in teaching is described as a teacher's curricular content knowledge (Shulman 1986). It entails knowledge of instructional resources that are suitable for teaching a certain content, including resources such as software and visual materials (Brantley-Dias and Ertmer 2013). Drawing from Shulman's description, content knowledge refers to the teacher's subject matter knowledge to be taught to students and the ability to identify learning outcomes of that particular subject (Koehler and Mishra 2009). An in-depth understanding of the knowledge fundamentals of the subject content is of great importance if teachers are to deliver correct information to students.

3.3.4 Pedagogical knowledge (PK)

Pedagogical knowledge pertains to knowledge of teaching and learning methodologies (Habowski and Mouza 2014). It encompasses knowing how students learn, understanding differences in learners' cognitive abilities, classroom management, lesson planning and various types and methods of assessment (Koehler and Mishra 2009). A teacher with pedagogical knowledge also understands the target audience, their age group, cognitive abilities, how the students obtain skills, and create knowledge.

3.3.5 Technological content knowledge (TCK)

Technological content knowledge (TCK) is defined as the way "in which technology and content impact each other" (Koehler and Mishra 2008:16). Teachers do not only need to master the subject matter, but also understand the way in which the subject content can be altered using ICTs. Furthermore, Jaipal and Figg (2010) argue that technological content knowledge (TCK) is the teacher's ability to match the technology tools to the subject matter to attain specific learning goals. Therefore, teachers need to know technologies which best suit certain subject content and how technology can change the subject matter, or vice versa (Koehler and Mishra 2008).

3.4 Rationale for using TPACK over other frameworks

There are various frameworks available that relate to ICT use for teaching and learning. The researcher used search engines to find studies and articles from journals and books that relate to ICT use for teaching. From the search engines, the researcher carried out a critical review of literature on various ICT frameworks that examine technology and pedagogy as the two key concepts that are central in this study. The frameworks reviewed include; the Replacement, Amplification and Transformation (RAT) framework (Hughes, Thomas & Scharber, 2006), the Substitution, Augmentation, Modification and Redefinition (SAMR) framework (Puentedura, 2006), and the TPACK framework (Koehler & Mishra, 2006). These three ICT frameworks had a common vision for integrating ICT in the context of the teaching and learning environment. They all articulated flexibility to changes in technology which impacted on changes in pedagogy. The RAT and the SAMR frameworks are briefly discussed below, with justification on why none of the two frameworks was chosen for the study.

3.4.1 The RAT model

Replacement, Amplification and Transformation (RAT) are three categories, according to Hughes, Thomas and Scharber (2006), used to understand the role of technology in education, as well as assessing teachers' adoption of technologies in their teaching. RAT has been developed based on three aspects in which digital technology use is imbedded in education: (1) Instructional methods, e.g., teachers' role, administrative tasks, professional development and interaction with students; (2) Student Learning Processes, e.g., activity tasks, student attitude and motivation, student thinking and mental process; and (3) Curriculum Goals, e.g., knowledge and experience gained, learned or applied. The RAT model addresses the role of digital technologies in teaching and learning practices whether technology replaces (R) previous practice, amplifies (A) current practice, or transforms (T) practice into something new (Hughes, Thomas and Scharber, 2006).

The three categories have been defined as follows: Technology as *Replacement* focusing on when technology is used as a direct replacement with no change of instructional practices, student learning processes or learning goals. Within this category, technology is used to replicate what is already functioning. The change consists of a medium used to achieve well-established purposes and objectives. Technology as *Amplification* concerns technology amplifying current instructional practices, student learning processes or learning goals. The idea of this category is based on the work of Pea (1985), conceptualising how technology can amplify what is already being done. The effects of using technology as amplification increase efficiency and productivity of either instruction, student learning or the curriculum. Technology as *Transformation* is the final category and focuses on the transformation of instructional practices, student learning processes and/or the subject matter. In addition to drawing upon the work of Pea (1985), the authors also have based the Transformation category on the work of Cuban (1988), who argues that digital technology should be used, without disturbing basic features of the organisation, to make what already exists more efficient and effective. Technology as Transformation is used for increasing efficiency or productivity of instructions, students learning or the curriculum (Hughes, Thomas & Scharber, 2006). Hughes, Thomas and Scharber (2006) argue teachers' reasoning and objectives, having particular ends in mind, direct their choice in adopting and using technologies. The authors stress that it is important that digital technology has explicit connection to the subject matter (Hughes, Thomas & Scharber, 2006, p.1617). RAT focuses more on how technologies, regardless if digital or traditional, fulfils specific features and tasks, rather than placing emphasis on which technologies are being used (Hughes, Thomas & Scharber, 2006).

3.4.2 The SAMR framework

The SAMR framework was developed by Puentedura (Fleisher, 2013; Geertsema, 2014; Hamilton, Rosenberg & Akcaoglu, 2016). The model stands for Substitution, Augmentation, Modification and Redefinition, and it is used as a model to discuss different ways that technology can feature in education (Geerstema, 2014). Puentedura (2006), explains the intention with the SAMR model is to describe and categorise teachers' use of technology in classrooms. Geertsema (2014), describes the SAMR model as a hierarchy in making teaching more student-centric, based on the idea that each step is better than the previous. Hamilton, Rosenberg and Akcaoglu (2016) describe the model as a four-level ladder addressing selection, use and evaluation of technology in education. The authors refer to a number of Puentedura's presentation-slides on his website (Puentedura, 2016), describing the models as encouraging teachers to "move up" from the lower levels of the ladder to the higher levels using digital technologies, "which according to Puentedura leads to higher (i.e., enhanced) levels of teaching and learning" (Hamilton, Rosenberg & Akcaoglu, 2016, p.2). Based on content from Puentedura's website, Hamilton, Rosenberg and Akcaoglu (2016) describe the levels of the model: *Substitution* has been described as when digital technology substitutes traditional (analogue by authors) technology, but substitution does not generate any functional change. The Digital Technologies and Education example given by Hamilton, Rosenberg and Akcaoglu

(2016) is, for instance, replacement of a hard copy test to a digital version. *Augmentation* is described as the exchange of technology, and the task or tool is somehow positively changed. Hamilton, Rosenberg and Akcaoglu (2016) exemplify this level with a distinction: rather than a teacher-lead read-aloud class, each student uses a hand-held device to simultaneously read and listen to individual digital stories. The third level is *Modification,* and at this level, the technology use allows for the redesign of a task, exemplified as shifting from showing students a diagram of light travel to instead show interactive computer simulations. The highest level of use is *Redefinition* and is reached when technology is used to create novel and new tasks. Hamilton, Rosenberg and Akcaoglu (2016) give the example that students, instead of writing an essay to present arguments on a certain topic, instead present arguments through videos which each student creates and edits.

Hamilton, Rosenberg and Akcaoglu (2016), offer the first peer-reviewed reference addressing the shortcomings and criticism to the work of Puentedura and the SAMR – model. In addition to lack of peer-reviewed theoretical literature explaining the model, Hamilton, Rosenberg and Akcaoglu (2016) also mention the limited explanations or details regarding how to understand, interpret and apply the SAMR model. The main criticism towards the SAMR model, according to Hamilton, Rosenberg and Akcaoglu (2016), concerns lack of context, rigid structure and focus on the technological product overuse process. Unlike the TPACK, the SAMR does not include context, which according to Hamilton, Rosenberg and Akcaoglu (2016), is important to consider for any model referring to teaching and learning. The teachers' learning, pedagogy, and practice, as well as students' learning experiences, are contextual, so including context enables addressing multifaceted, complex educational settings. The authors stress as important that no uniform solution exists for integration and use of technologies, and models that do not address context tend to ignore the complexity of technology adoption and use.

Due to lack of context, the SAMR model does not include important contextual components such as technology infrastructure, resources and support, individual and collective student needs, or teacher knowledge and support for using the digital technology (Hamilton, Rosenberg & Akcaoglu, 2016). Hamilton, Rosenberg and Akcaoglu (2016) claim the SAMR model represents one of four categories of technology integration and use. SAMR ignores the complexity of technology use and defines and categorises teachers' use of technologies in predefined ways. The SAMR model is linear and deterministic, which contrasts with the dynamic process that the model aims to represent (Hamilton, Rosenberg & Akcaoglu, 2016). Important variables pedagogy, classrooms practices, and learner characteristics are ignored. Hamilton, Rosenberg and Akcaoglu argue the effect of technology use strongly depends on the characteristics of teachers and students and their relationships, as well as the specific tasks for which the technology is used (p.5).

As a final criticism, Hamilton, Rosenberg and Akcaoglu (2016) state SAMR puts emphasis on technology-based products where the model considers education as the production of independent, stand-alone products rather than education being a process. Hamilton, Rosenberg and Akcaoglu claim digital technology has an important role in learning outcomes and, as long as learning objectives are achieved, single instructional methods or tools should not be promoted in favour of others. Hamilton, Rosenberg and Akcaoglu (2016) note that teachers need an understanding of the relationships between teaching, technology and learning in order to advance student growth and development. When teachers have this understanding, they will be better prepared to access and use technologies in order to enhance and support student learning. The critical review conducted by the researcher showed that the SAMR model has been highly discussed and criticised among academics and practitioners, mainly due to its lack of pre-reviewed scientific grounds (e.g., Linderoth, 2013; Fleisher, 2013; O'Hagan, 2015; Hamilton, Rosenberg & Akcaoglu, 2016), and therefore was eliminated for purposes of this study.

3.5 TPACK applications in this study

The search for a suitable analytical framework provided let to the RAT and SAMR models that could be adapted for this study. Therefore, there is a need to justify the selection of the TPACK framework that was used in this study, in terms of its alignment with the purpose of the study and research questions. The rationale for the selection of TPACK had to do with the possibility of the framework in helping to generate data to answer the research questions of the study.

Among the studies related to the three frameworks, the TPACK model captured all the criteria for suitability for selection and therefore was foregrounded to be used as the lens to understand the technological pedagogical knowledge and technological knowledge required to integrate technology in teaching by teachers. According to Jaipal and Figg (2010), TPACK affords a holistic approach to ICT integration in the classroom. In addition, TPACK provides a solid analytical framework with which to examine many of the issues that arise when learning to combine technology and pedagogy in teaching Life Sciences as sought by research question two. According to the TPACK framework, in order for teachers to effectively integrate ICT, they must understand how technology, pedagogy, and content can interact with one another to produce effective discipline-based teaching with ICT (Shin, et al., 2009). In the present study, TPACK better articulated the complexity of teachers' body of knowledge to effectively use ICT in their teaching. TPACK was clearer in emphasizing the connections and interactions between pedagogical knowledge (how to teach) and technological knowledge (how to do so with the use of ICT), which are the areas that this study sought to understand. Moreover, several researchers, such as Angeli and Valanides, 2009; Archambault and Barnett, 2010; Cox and Graham, 2009; Graham, 2011, have recommended the TPACK framework in providing a mirror through which to analyse teachers' ICT skills in teaching. Hence, this study opted to use a tested and recommended TPACK model.

3.6 Limitations of the TPACK Framework

The TPACK framework is widely viewed as a dominant approach to understanding teacher knowledge and technology integration. Several limitations are, however, often noted (Koehler, Mishra, Kereluik, Shin and Graham, 2014). It can be argued that knowledge of the different components of the TPACK framework does not necessarily mean the implementation of ICTs in teaching and learning. The implementation of technology in the classroom is multi-faceted. There are other factors, such as the availability of ICT infrastructure at schools and the learners' digital skills, which affect the implementation of technology in the classroom. If all factors which affect ICT adoption and use are not addressed, then implementing technology in teaching and learning might be impossible. It is further posited that the TPACK framework implies that, for instance, any content can fit into the framework and that it will have relationships to pedagogy and technology (Kereluik, Mishra & Koehler, 2010). The framework offers scanty guidance about the content to teach, which methodologies to use and the kinds of technologies to use. Thus, TPACK falls short of assisting teachers to know which content to teach in relation to specific technology and methodologies. Some teachers need assistance in assessing and selecting appropriate technology to integrate into their teaching. The TPACK framework does not assist teachers in knowing which technology to use to teach specific content.

In addition, the TPACK framework is also relatively static. It does not change over time and would be ineffective in a world where traditional technologies such as chalkboards and paper are available (Kereluik et al., 2010). Furthermore, some schools still rely on traditional teaching methods due to, for instance, the unavailability of ICT infrastructure. Therefore, the technological knowledge (TK) component of TPACK is irrelevant in such schools. Furthermore, it is argued that teachers need to understand the contexts in which they can use ICTs during the teaching and learning process. In this regard, it is posited that researchers conducting research into the application of TPACK have provided insufficient knowledge about teachers' backgrounds and culture when they examined teachers' use of ICTs in the classroom (Adams, 2017). Thus, there is a critical gap in the TPACK model when understanding technological and pedagogical practices specifically in particular cultural contexts.

Moreover, several authors (e.g., Cox & Graham, 2009; Archambaud & Barnett, 2010; Graham, 2011) claim that TPACK lacks context, excludes of the relationship between students and teachers, differences between grade levels as well as guides and paths on how to acquire TPACK, fails to take into account classroom realities such as large numbers of learners and few ICTs to use during teaching and learning, as the main shortcomings of TPACK. In a recent publication, however, Rosenberg and Koehler (2015), addressed these criticisms towards the TPACK model, stating that context is important and has been included in the framework since the publication by Koehler and Mishra in 2008. Despite the criticism surrounding TPACK, educators and researchers still consider the TPACK framework to be useful in their efforts towards effective technology implementation (Angeli and Valanides, 2009; Archambault and Barnett, 2010; Cox & Graham, 2009; Graham, 2011). Therefore, the recognition of contexts by TPACK has addressed the criticisms by Cox and Graham, (2009); Archambaud and Barnett (2010) and Graham (2011).

3.7 Conclusion

This chapter discussed the theories that underpin this study namely Vygotsky's socio-cultural theory and TPACK theory, as theoretical framework and analytical framework respectively. The chapter also explained the rationale of choosing these theories and their applications in this study. Furthermore, this chapter also reviewed RAT and SAMR model as potential frameworks that could have been chosen and highlighted reasons why these models where not used in the study. The chapter concludes by discussing the limitations of the TPACK that was used as the analytical framework. The next chapter discusses the research design and methodology used in this study.

CHAPTER FOUR

RESEARCH DESIGN AND METHODOLOGY

4.1 INTRODUCTION

The previous chapter explored theories that underpin this study; Vygotsky's socio-cultural theory and TPACK theory, as theoretical framework, and analytical framework, respectively. This chapter deals with the research design and methodology used in the study. Marcia and Vicki (2020) define research design as a set of advance decisions that make up the master plan specifying the methods and procedures for collecting and analysing the needed information. Muka, Glisic, Milic, Verhoog, Bohlius, Bramer, Chowdhury and Franco (2020) posit that an appropriate research design is essential as it determines the type of data, data generation techniques and the sampling methodology. This study adopts a qualitative research design. Lin (2020, p.14), view methodology as "the research process that shapes our choice and use of particular methods and links them to the desired outcomes". It is the specific procedures or techniques used to identify, select, process, and analyse information about a topic. On the other hand, Rahman (2020, p.9), defines methodology as "a theory of which methods and techniques are appropriate and valid to understand in the broadest possible terms not the products of an inquiry but the process itself". According to Camille and Stephanie (2020), the aim of the methodology is to help researchers to understand the processes and the outcome of the study. This is done through diverse ways of collecting data. This chapter discusses qualitative research, case study and research instruments or data generation methods used in this study. The research instruments were semi-structured questionnaires, journal reflections, observations, and semi-structured interviews. This chapter further discusses data analysis, trustworthiness, triangulation, credibility, transferability, confirmability of the study and concludes by addressing the ethical considerations of this study.

4.2 Qualitative Research Design

The choice of a research design is important to establish the boundaries of inquiry and the ultimate success of a study. This research is qualitative and was located within an interpretive qualitative research paradigm, using a case study approach. Interpretive research seeks to understand phenomena through the meanings that people bring to them. It "aims at producing an understanding of the context of the information system" (Keisha, 2020. p.4-5). As an interpretative qualitative research the focus was on the full complexity of human sense-making in each situation. This research was aimed at uncovering a teachers experiences and the perceptions that underpin it in relation to the use of Virtual Lab to mediate learning of scientific experiments (Cooper, Flescher and Cotton, 2012; QRCA, 2013). Qualitative research entails a set of methods that depend on data collected through language, as were used in this study, that is, it relies on linguistic rather than numeric data (Julie & O'Connor, 2020). This method is characterised by the collection and analyses of textual data such as surveys, interviews, focus groups, conversational analysis, questionnaires, observations and ethnographies (de Rosa & Arhiri, 2020) and focuses on the context within which the study occurs. Qualitative designs answer 'how', 'what' and 'why' questions especially when the researcher has little control over the events (Creswell, 2013), thus generalizing through thick descriptions of the context, allowing the reader to make connections between the study and his or her own situation. Given qualitative work is considered to be more inherently interpretive research, the biases, values, and judgments of the researchers need to be more explicitly acknowledged, so they are taken into account in data presentation (Creswell, 2012).

In this study, the researcher chose qualitative design as it has been shown to help reveal a "set of interpretive material practices that make the world visible" (Anu, Mattick & Croix, 2020). The visibility of how Virtual Lab might add value to the teaching of science practicals is significant in this study. A qualitative design was appropriate because of its focus on building meaning from the experiences of teachers that participate in the study (Patton, 2015). It enable the participants to describe their experiences (journal reflections, semi-structured interviews) from their own perspectives (Patton, 2015; Stenfors, Kajamaa, & Bennett, 2020) free of constraints from fixed-response questions found in quantitative studies. In the instance of this study, the researcher wanted to uncover and deeply understand teachers' pedagogical and technological insights and experiences on the use of Virtual Lab for teaching as well as what factors might enable or constrain the use of Virtual Lab. For, as Keisha (2020 p.5) explains, "qualitative researchers are interested in understanding how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences". As Julie and O'Connor (2020 p.3) reasons, “research focused on discovery, insight, and understanding from the perspectives of those being studied offers the greatest promise of making a difference in people’s lives”.

Several fundamental characteristics of qualitative research are present in this study. First, qualitative research is a social process (Denzin & Lincoln, 2011; Patton, 2015) between researcher and participant, which elicits deep understanding of real-world, lived experiences (Patton, 2015) and complex interrelationships (Patton, 2015; Lin, 2020). Second, as the main instrument of the research process (Denzin & Lincoln, 2011; Patton, 2015), the researcher immersed himself in all aspects of data collection and analysis. Qualitative research is a form of research in which the researcher goes to people and the site to collect data (Strauss and Corbin, 2015). This enabled the researcher to observe teaching in a natural setting. Also, in qualitative research, the researcher interprets collected data. This makes the researcher part of the research process, along with the participants and the data they provide (Strauss & Corbin, 2015). For as Denzin and Lincoln (2011) argue, “all research is interpretive; it is guided by the researcher’s set of beliefs and feelings about the world and how it should be understood and studied” (p. 22), therefore my engagement in all stages of research was paramount. Third, qualitative research creates meaning in context (Denzin & Lincoln, 2011; Patton, 2015), context which provides greater breadth, depth, and complexity of understanding of participants’ experiences.

Qualitative studies have been criticised (mostly by quantitative scholars) for being ‘unscientific’. However, Camille and Stephanie (2020), argue that this criticism assumes certainty and loses sight of the probability factor inherent in quantitative studies. He further notes that one need not dismiss the qualitative research design just because some studies applied it inadequately. In other words, he emphasises that the value of a qualitative research design lies in it being carried out in a rigorous manner. Against this background, the researcher list the points below that guided the study to meet standards of a good research design (see section 4.8) Although qualitative methods can examine social processes at work in particular contexts in considerable depth, the collection and analysis of this material can be time-consuming (Cohen, Manion & Morrison, 2018). Nonetheless, this research design was important in this study because the researcher:

- prolonged his engagement with participants mostly through workshops, interviews and observations more than is possible with a survey;

- had the opportunity to probe beyond the initial responses and questions from the interview using the semi-structured interview schedule; and
- had the opportunity to observe and interpret non-verbal communication (body language and facial expressions) during observations.

4.3 Qualitative Case Study

Debra and Paul (2020 p.18), defines a case study as "that process of conducting a systemic, critical inquiry into a phenomenon of choice and generating understanding to contribute to cumulative public knowledge of the topic". Bobbitt (2020, p. 11), views a case study as a "study of the particularity and complexity of a single case, coming to understand its activity within important circumstances". A case study is an "an exploration of a 'bounded system' of a case or multiple case over time through detailed data collection involving multiple sources of information-rich in context" (Creswell, 2014, p. 61). According to Mazzei and Smithers (2020 p.6), a case study design should be considered when: (a) the focus of the study is to answer "how", "what", and "why" questions; (b) the researcher cannot manipulate the behaviour in the study; (c) the researcher wants to cover contextual conditions as they are relevant to the phenomenon under study. Opting to conduct case studies as opposed to a more open qualitative research helps "in refining theory, suggesting complexities for further investigation as well as helping to establish the limits of generalisability" while providing in-depth description and analysis of the issues at hand (Miles, Huberman & Saldaña, 2014, p. 46). Patton (2015), points out the value of case study methodology for conducting a comprehensive inquiry into the structures, actors, and cultural forces which occur within specific yet intricate organisational processes.

In this study, a case study was appropriate since the researcher explored, working with teachers, the use of Virtual Lab in natural settings such as the classroom environment. Therefore, the data were context-dependent and inherently tied to the phenomenon itself (Lincoln & Guba, 2011). Yin (2014), believes that such a study should be carried out within the natural or real-life context. This research adopts this methodology as it analyses classroom practices of teachers understudy to understand their pedagogical and technological experiences and insights on the use of Virtual Lab for teaching. In addition, the purpose of case study research is "particularisation, to present a rich portrayal of a single setting to inform practice, establish the value of the case and/or add to the knowledge of a specific topic" (Rahman, 2020, p.24). In this case, the single setting refers to the technological pedagogical knowledge and technological experiences of teachers who are the units of analysis, and the case explores the use of Virtual Lab in their practice.

In choosing a case study approach, the reaseacher took into consideration some shortcommings that are associated with this approach. One common critique of case study research is that results are not generalisable (Flyvbjerg, 2011; Cohen et al., 2011; Yin, 2014). Research generalisation involves meaning extrapolation to a larger population from a smaller sample. However, the case in this research study involved unique cases of a specific situation rather than representative samples. As a result, in line with Flyvbjerg (2011); Cohen et al. (2011) and Yin (2014), the findings of this study only applies to the four schools and seven teachers who participated in the study and can not be generalised to a larger population.

4.4 Research Site and Participants

4.4.1 Selection of sites

Aspers and Corte (2019, p.17), recommend that a case study selection should, "set boundaries: define aspects of your case(s) that you can study within limits of your time and means, that connect directly to your research questions, and that probably will include examples of what you want to study". As stated in Section 1.4 of Chapter 1, this interventionist study sought to help address the challenge of unavailability of science laboratories in resource-constrained rural schools, working *with* Grade 11 Life Sciences educators, by exploring the use of Virtual Lab as a potential panacea. The criteria for the *sites,* therefore, demanded that schools to be selected must; (1) be located in a rural area; (2) offer Life Sciences in Grade 11; (3) do not have science laboratories; (4) teachers do have access to ICT devices such as laptop, tablets or mobile phones; and (5) the school has access to internet and learners do have access to computers or mobile phones at schools. The four schools (sites) for the study are in rural areas of Mount Fletcher sub-district of Joe Gqabi district. The district is in the Eastern Cape Province of South Africa. Although there are many such schools in the district that fit the selection criteria, a purposive sampling was used in the selection of the schools (Brinkmann & Kvale, 2015). The schools were selected based on proximity and easy access to the researcher (Etikan, Musa & Alkassim 2016; Guest, Namey & Chen, 2020). In addition, to reduce the sample to a manageable size, decisions relating to contextual issues of the schools were also used as a guide. The contexts and information of the selected schools were easily available to the researcher since the researcher is a District official who monitors curriculum implementation in the schools. The selected grade i.e., Grade 11 in the schools is important because it is the grade where teachers prepare learners for Grade 12 in which they would write the final matric examinations.

4.4.2 Selection of participants

Purposive sampling was used to select the participants. A “purposive sampling” as (Ames, Glenton & Lewin, 2019, p.34), or a “purposeful sampling” as (Patton, 2015, p. 230), put it are used by researchers in order to access the “knowledgeable people” (Cohen et al., 2011) who have knowledge about certain issues. Patton (2015, p230), argues that “the logic and power of purposeful sampling lie in selecting information-rich cases for study in-depth”, from which the researchers can learn, and its great value is that it results in an in-depth understanding (Patton, 2015). A purposive sampling method is sometimes called a verdict or discriminating method because the units of the examination are grounded on the finding of the researcher. This allows the researcher to deliberate on people with specific features who are better able to contribute appropriately to the research study (Cohen et al., 2011; Andrade, 2018). With regards to sample size, Frederick (2013), discloses that there are no rules in the sample size in qualitative research. He further argues that the sample size depends on “the purpose of the inquiry, what’s at stake, what is useful, what will have credibility, and what can be done with available time and resources”. In addition, Etikan, Musa and Alkassim (2016, p.56) accentuate that the “basis for selection and sample size depends on that which will give the clearest understanding of the phenomena”.

In this study, participants were selected based on a selection criterion developed by the researcher. Although some school managers from the research sites encouraged more of their teachers to join the study as a professional development course in order to learn how to use Virtual Lab in classroom practice, the researcher purposively selected Seven (7) teachers as participants. According to Patton in Marshall and Rossman (2011), the sample size for qualitative research can differ from 4 to 35, therefore the researcher considered seven an appropriate sample size to ensure reliable qualitative research. The value of including seven teachers was to ensure that should some of them exercise their voluntary right to withdraw from the study, the researcher would still be able to get quality and reliable data from the remaining participants.

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

i. Must have been qualified Life Sciences teachers.
ii. Must have had five years or more of teaching experience.
iii. Must have been teaching Life Sciences in Grade 11 in rural schools where there are no science laboratories.
iv. Must have had smartphones and have received laptops from the Eastern Cape Department of Education.

The purposeful sample included teachers of different schools, number of years of teaching experience, gender and age, as Patton (2015, p.234), suggested that the maximum variation (heterogeneity) in the purposeful sample is a strategy that "aims at capturing and describing the central themes that cut across a great deal of variation". The seven teachers were each as an example of certain contexts that could offer insight into how different teachers adopt the use of technology in their practice. The aim was to explore working *with* Grade 11 Life Sciences educators on make use of Virtual Lab to mediate learning of Energy transformations, and to understand how the teachers would change or shift their practice through the use of technology.

The following table contains relevant information (biographical data) pertaining to the participants.

Table 1: Information about participants

Teacher (Pseudonym)	Age	Gender	Qualification	Number of years teaching Life Sciences in FET Phase
Bongi	33	Male	BEd Life Sciences & Agricultural Sciences, Honours degree in Life Sciences	9
Mpho	29	Male	BEd Life Sciences & Mathematics	5
Tumelo	37	Female	BEd Life Sciences & Agricultural Sciences	13
Clever	43	Male	BEd Life Sciences & Physical Sciences, Honours degree in Life Sciences	19
Debbie	39	Female	BEd Life Sciences & Agricultural Sciences	14
Bruce	48	Male	BEd Life Sciences	24
Candie	35	Female	BEd Life Sciences, Honours degree in Life Sciences	11

4.5 Research Instruments

To adequately capture answers to the research questions, the data was generated through carefully selected instruments. According to Anu *et. al.,* (2020), qualitative research has the following basic types of data: questionnaires, interviews, journal reflections, observations and documents. All these were used in this study. In addition, field notes were also taken throughout the study.

4.5.1 Semi-structured questionnaires

A semi-structured questionnaire is a data collection instrument consisting of a series of both closed and open-ended questions and other prompts, for the purpose of gathering data from the respondents (Mouton, 2012). Despite the fact that questionnaires take time to develop (Hinojosa-Pareja, Gutiérrez-Santiuste & Gámiz-Sánchez, 2021), they are favourable data gathering tools since they can be completed without the presence of the researcher, and they are also easier to analyse (Cohen et al., 2011). A questionnaire allows many questions to be asked and gives the researcher some flexibility in analysing the data collected (Babbie & Mouton, 2010). Furthermore, a questionnaire does not only allow a large amount of data to be collected simultaneously over a short duration but also allows a variety of information to be collected from participants (Mouton, 2012; Miles, Huberman & Saldaña, 2014).

In opting to use the semi-structured questionnaire in this study, the researcher was also aware of its shortcomings. These included the likelihood that some participants may not fill out and return the questionnaires (McMillan & Schumacher, 2010), sometimes because, as Cohen et. al. (2011) highlight, asking someone to complete questionnaires can be bothersome to participants and may require their precious time. In addition, respondents may hastily answer the questions and may not even finish to answer all the questions especially if the questionnaire is too long (Marshall & Rossman, 2011). According to Cohen et al. (2011), a questionnaire should be designed in a way that does not intimidate the respondents. They emphasise that the order of questions should encourage respondents to answer a questionnaire. Following this recommendation, the researcher designed a layout that starts with questions that may not threaten the respondents or make them lose interest in answering the questionnaire. In addition, the researcher developed a questionnaire that was not too long, but that would capture all the themes that were important for answering the research questions. Perhaps most importantly, the researcher visited the schools and hand-delivered the questionnaires to the participants in person. This gave the researcher a chance to explain the purpose and value of answering all questions. The participants (respondents) were requested to answer all the questions. The researcher further explained to the participants that participation in filling out the questionnaires is voluntary and subject to the respondents' informed consent. Important to note is that the questionnaires were piloted to two teachers in one of the schools in this study. This was done to help minimise ambiguity in questions and to test the relevance of the questions in answering the research questions (Bertram and Christiansen, 2015). The results of the pilot study showed that the questionnaire was relevant to the research and had no ambiguities. The questionnaires (see Appendix A1) were self-administered before the commencement of the study, and were used to gather data that was intended to respond to the first research question i.e. 'What are the perceptions and attitudes of Grade 11 Life Sciences teachers on the use of ICT for teaching and learning?'.

4.5.2 Semi-structured interviews

Denzin and Lincoln (2014, p.126) state that "we interview in order to find out what we do not and cannot know otherwise". Drawing from several scholars (Marshall & Rossman, 2011; Striepe, 2020; Hinojosa-Pareja, Gutiérrez-Santiuste & Gámiz-Sánchez, 2021), three main categories of interviews were carefully considered. These were, firstly, structured interviews, which often just require 'yes' or 'no' answers (or questions which require a set answer). Secondly, unstructured interviews, in which the interviewee can dictate the content and progress of the interview (the interviewer may just introduce the topic/theme, and then allow the interviewee to talk about the things within that topic/theme that he or she is interested in, and that he or she feels are pertinent to their own contexts at that time. However, Tavory (2020), argue that no interview can truly be considered unstructured, but it is the degree of the structures that varies with some assuming more defined structures than others. The third category is the semi-structured interview, which is often called a 'conversation with a purpose' (Heather & Smith, 2021). After careful consideration of the research design, the researcher opted to employ semi-structured interviews from the other types of interviews.

A semi-structured interview comprises a set of questions to be answered by the participants, flexible enough to allow the researcher to ask more questions for clarity when the need arises (McMillan & Schumacher, 2016). According to Maree (2016), semi-structured interviews allow the researcher to best define the line of inquiry, but at the same time provide room to identify emerging lines of inquiry that are directly related to the study objectives, which can further be explored and probed. Semi-structured interviews are conducted orally and recorded by the researcher or someone who is trained to do so (Mouton, 2013). With a semi-structured interview, the interviewer and interviewee are partners, even though the interviewer asked the questions (Marcia & Vicki, 2020). For interviews to be an effective data collection method, knowledge is socially co-constructed by the interviewer and participant (Brinkmann & Kvale, 2015; Johnson & Rowlands, 2012; Rapley, 2012; Roulston, 2014), although the influence each has over the process varies. While participants' power comes from their decisions about how they answer questions and what they discuss, the researcher determines interview topics and data collection practices. In this study, interviews followed an interview guide (Brinkmann & Kvale, 2015; Edwards & Holland, 2013; Hesse-Biber, 2014) (see Appendix A4). Power imbalances are more likely to be moderated when there is less structure (Edwards & Holland, 2013; Hesse-Biber & Leavy, 2011), and participants have agency during the interview (Hesse-Biber, 2014). In order to mitigate the power imbalances and to build rapport and trust (Brinkmann & Kvale, 2015; Grinyer & Thomas, 2012) during interviews, interviewees were given authority and confidence by making them aware that the researcher was going to learn from their practices before carrying out the interviews. In addition, the researcher arranged that the interviews take place at a place and time convenient for both participants and the researcher.

Semi-structured interviewing was appropriate for this study due to the nature of the topic (*Exploring working with Grade 11 Life Sciences educators on make use of Virtual Lab to mediate learning of Energy transformations*) which necessitates gathering data which also explicitly targets the selected participants' perceptions and attitudes (Research Question 2) as well as their pedagogical and technological experiences or insights (Research Question 3) in using Virtual Lab to mediate learning of scientific experiments. According to Cohen et al. (2011); Johnson and Rowlands (2012), semi-structured interviews are the most effective methods to collect data on personal perspectives, attitudes and experiences which cannot be collected as effectively by other methods such as direct observation (Patton, 2015). Semi-structured interviews with well-formulated guiding questions are well suited to capture these intersubjective views.

During the interviewing process, the researcher actively listened and although he knew the areas that he wanted to cover as dictated by his research questions, he, however, allowed the interviewee to take different paths and explore thoughts and views. Whenever necessary, the researcher brought the interviewee back to the subject under discussion by means of prompt questions, before allowing the interviewee to explore another particular aspect of the research problem. This researcher flexibility and spontaneity (DeVault and Gross, 2012; Edwards & Holland, 2013; Hesse-Biber, 2014; Roulston, 2010), and active listening (Brinkmann & Kvale, 2015; DeVault & Gross, 2012; Hesse-Biber & Leavy, 2011) ensured the relevancy of interviews for participants (Patton, 2015). It was a dialogue, as Muka, *et al*. put it (2020). It was also important to maintain a balance between flexibility and control to avoid deviating from the research questions.

In this study, the interviews with each teacher were audio-recorded and at the same time, the researcher took commentary notes in his notebook. The audio recordings were later transcribed. Denzin and Lincoln (2013), recommend paper, unlike audio or visual media, is a familiar and comfortable form; it is easier and faster to scan a paper document than listen to or view an interview; words fixed on paper ensure accuracy of quotation in print; and they confer a certain intellectual authority on what could be construed as an ephemeral form. The researcher, therefore, printed the transcripts and used them to code and highlight emerging themes as he analysed each teacher case.

Whilst there were many significant advantages in using semi-structured interviews in this study, the researcher noted that this method had its own problems. These problems included that: it was time-consuming, particularly in terms of the interview itself, transcription and analysis. From the pilot study experience, it emerged that the quality of the data obtained from an interview is very much dependent upon the skill of the researcher and the openness of the participants to reveal themselves. Moreover, despite the researcher's best intentions to create an equitable interview space, these efforts were limited. While the researcher acted with an attitude of equal respect (Miles, Huberman, & Saldaña, 2014), with the belief that the participants are the experts, they still perceived the researcher as more expert than them. In addition, another disadvantage of interviews is that the presence of the researcher might cause the respondents to provide inaccurate or incomplete information, and they might answer in ways that correspond to what is socially desirable (McMillan & Schumacher, 2010). It appeared to the researcher that at times, the participants felt under pressure to say what they thought the researcher wanted to hear. In this study, the respondents might have given the researcher answers that they thought the researcher was looking for or answers that would not make them look bad. However, the advantages realised in using semi-structured interview method remain important for the study.

4.5.3 Observation

Butler and Sinclair (2020, p.13), defines observation as "the systematic description of events, behaviours, and artifacts in the social setting chosen for study". Nind (2020), view observation as a period of intensive social interaction between the researcher and the participants, in the latter's environment. According to Rahman (2020, p.14), observation enables the researcher to describe existing situations using the five senses, thus providing a “written photograph” of the situation under study. She further adds that “observation involves active looking, improving memory, informal interviewing, writing detailed field notes, and perhaps most importantly, patience”. According to Nind, Holmes, Insenga, Lewthwaite and Sutton (2020, p.39), “the distinctive feature of observation method is that it provides the researcher with the opportunity to gather 'live' data from a natural situation”. Observation as a method of collecting data is appropriate for exploratory research (Cooper, Flescher & Cotton, 2012). According to Cohen, et al. (2018, p.71), this technique “produces a tremendous supply of high-quality data and crucial insight into community dynamics”. Although observations have been associated with extreme demands of time, tact, energy, and emotions, in this study it provide full, accurate, and clear information based on what exists in the empirical and the researcher record as it occurs naturally (Mörtberg, Bratteteig, Wagner, Sturedahl & Morrion, 2010). The observation method allowed the researcher to study the participants' behaviour in complex situations such as classrooms learning situations and technology use (Marshall & Rossman, 2011). Moreover, it also enable the researcher to understand the situations and looking closely into things that might be hidden or that the participants might not mention it in the interviews and questionnaires (Patton, 2015; Cohen et al., 2018).

Ravitch and Riggan (2017, p.22), describe three approaches for observation: (1) total participation, where the researcher’s role is kept secret, and (2) participation in normal setting where the researcher’s role is known to certain “gatekeepers” but hidden from most people (p.22). These approaches allow for observation without affecting the natural setting while at the same time distance is maintained from the research subject. In the third (3) approach, participation as observer, the researcher’s role and identity is fully open and takes advantage of “shadowing” and witnessing first-hand the study subjects’ normal life and intimate details of interest (p.23). In this study, the researcher collected data through non-participant observation. This means that the researcher was present at the scene of action, but not interacting or participating (Stake, 2010). Observations made in naturalistic settings “do not interfere with participant or activities under observation” (Maxwell, 2013, p.67). This method suited this study because the researcher wanted to see the whole process of using Virtual Lab by teachers step-by-step. The researcher wanted to appreciate the teachers' technological pedagogical knowledge and technological experiences (Research Question 2), to identify enabling and constraining factors of using Virtual Lab in classroom (Research Question 3), and to gain insights on how Virtual Lab can (or cannot) be used to mediate learning of scientific experiments (Research Question 4). Through observations, the researcher also captured the whole social interactions between teachers and their learners. The researcher found a place in each classroom where he could be a bystander yet see and hear everything. This enabled the researcher to see what happened in the classroom. A carefully designed observation guide was utilised (see Appendix A3) to capture the issues of interest for this study. In addition, field notes were also taken to record other issues of interest. The observation method was useful as it allowed the researcher also to gauge participants' feelings about using the tool, from their speech, gestures, and facial expressions.

In using the observation method, the researcher was also aware of some shortcomings that are associated with this method. For example, Mörtberg, Bratteteig, Wagner, Sturedahl and Morrion, (2010, p.110), argue that observations can be problematic in terms of "see what you see", because the researcher does not always understand people's actions and doings. Further, observations can be challenging in terms of what to observe and where to start. They state that to simplify these challenges, it is a good idea to use a carefully designed observation schedule. A carefully designed observation schedule as was done in this study. On the other hand, Nind and Lewthwaite (2020, p.13), indicate that careful observation, in natural circumstances "will always be limited by constraints of reality, and all these constraints will never be clear in advance". In this study, this was minimised by scheduling the observation in advance with each teacher. This can be viewed in other academics research as compromising the validity of the findings as teachers would then prepare to impress the researcher. This study argues that the fact that these teachers have not received guidance from policy on how to use Virtual Lab in their practice, their usage of the technology is driven by their interest in using the tool and not by their willingness to impress the researcher. Although there are reservations on the degree to which observations yield quality data, given the fact that the behaviour of the observed may change at the presence of the observer, Ravitch and Riggan (2017, p.17), maintains that "through observation it is possible to ascertain whether what people say they can do and what they do in reality tally". Therefore, observational evidence remained useful to answer the research questions in this study.

4.5.4 Document Analysis

Documents are pieces of written, printed or electronic matter that provide information. Bowen (2009, p.3), defines document analysis as a "systematic procedure for reviewing or evaluating documents, both printed and electronic (computer-based and Internet-transmitted) material" and in the context of qualitative research, documents are "examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge" (Rapley, 2012). It was fundamental that the findings for this interventionist study relate to the context of the study to enable the recommendation of customised pedagogical and technological practices. It was for that reason that document analysis of educational policies and reports in South Africa had to be done.

In the selection of documents, Bowen (2009) emphasises the importance of identifying documents that are more relevant to the enquiry and to consider what their purpose is. Purposive sampling of documents was, therefore, used in this study. The research questions for this study worked as a guide for the framework of identifying relevant documents. Maxwell (2013, p.54), posits that document analysis can "say many different things in different contexts". Therefore, policy documents in this study are interpreted in the context of the framework explained in Chapter 3, and may be interpreted differently if a different framework is used. The first document to be selected was the amended Curriculum and Assessment Policy Statement (CAPS) of 2019. This document was read in conjunction with the revised (trimmed) Annual Teaching Plan (ATP) of 2020, which was designed in response to the loss of teaching time due to the COVID-19 pandemic. The CAPS and ATP serve in making decisions on the approach to use in the classroom. They provided guidelines on *what* should be taught and *when* it should be taught. The other document selected was the White Paper on e-Education (2004). This document was useful as it provided guidelines for the integration of technology into the curriculum. Brinkmann and Kvale, (2015) argues that documents provide detailed, accurate and often unbiased data useful for qualitative research. Thus, documents could have helped uncover the official position and meaning, develop understanding, and discover insights relevant to the research problem (Brinkmann and Kvale, (2015). Document analysis is also advantageous in that data is readily available, it saves time, and it is economical (Bowen, 2009).

In sum, it is important to note that in this study, the researcher used documents to draw guidelines on how to approach the subject matter during the workshop, and not as a research instrument or data collection method. The researcher was also aware that, as Yin (2014) explains, documents have their own limitations, such as the provision of insufficient detail, low irretrievability, and biased selectivity. In addition, Cohen et. al. (2011) cautions that documents may be outdated, and records may not be relevant to the study. In this study, the researcher selected the most recent and relevant policy documents.

4.5.5 Field notes and Journal reflections

The field notes were taken by the researcher throughout all the interactions with the teachers i.e., during interviews, workshop discussions and lesson observations. According to Bergen and Labonté (2020), taking field notes enhances the data from the observations and interviews and brings more light to the events that take place. In the case of observations, field notes do not only record "what is seen and heard, but also captures events that would have occurred" (Chiumento, Rahman, Machin, & Frith, 2018). The researcher, therefore, took notes of any ideas that were of interest and had potential in making sense of the data. The data from field notes was also useful in the researcher's evaluation of the research instruments.

In addition to taking field notes, journal reflections were also carried out daily. Journal reflections are widely used in many educational contexts and considered as important tools that create understanding (Goker, 2016). During daily reflections, the teachers and the researcher had the opportunity to write down their thoughts, views, pedagogical and technological experiences and insights on what was being researched (Cohen et al. 2018). Furthermore, Goker (2016), posits that reflection plays a significant role in teachers' professional development as it affords them an opportunity to address the problems encountered to change their teaching practices. In this study, data generated from journal reflections (see Appendix A2) was important in responding to my research questions two, three and four.

4.5.6 Workshops

Workshops are an important place for learning through social interactions (Vygotsky, 1978). They create a learning environment because participants are afforded an opportunity to engage and participate in the activities (Sedláček & Sedova, 2017). More so, Sedláček and Sedova (2017), favour learning through social interactions, this is because it enhances learning as participants are afforded an opportunity to develop their own interpretations, challenge their initial understanding and grow as critical thinkers.

In this study, two workshops were conducted. The workshops were conducted at the Education district office and were attended by all the seven participants. The workshops were conducted in line with COVID-19 protocols of screening by checking body temperatures of the researcher and participants as they entered the venue, compulsory wearing of masks, sanitisation and sitting arrangements that allowed for social distancing in the workshop venue. The first workshop was used to train the teachers on how to use Virtual Lab in the mediation of learning of scientific experiments. The teachers had an opportunity to share their views and attitudes on use of ICT for teaching in general and Virtual Lab in particular. As Bertram and Christiansen (2015, p. 84) describe, "one does not have to follow through a check list, ticking off boxes or rating expected activities as they happened, but rather, one uses field notes to write free descriptions of what is happening". Participants' prior knowledge of ICT in teaching was documented through field notes and journal reflections in the first workshop and this data helped to respond to my first research question. After the half-day workshop, teachers were asked to complete a reflective activity and evaluate the workshop. The second and last workshop was used to cover a reflection on the entire research process as well as the consolidation of the research findings. The data gathered during the last workshop helped to inform answers to the second, third and fourth research questions.

4.6 Data Analysis

Qualitative data analysis is a rigorous and iterative process meant to understand how participants make sense of the phenomenon under study (Hesse-Biber, 2010). This kind of data analysis involves going through the data in search of patterns to establish what is important before synthesising the data (Marshall & Rossman, 2011). The process is premised on the principle of ensuring that the findings are trustworthy. As there is no one way of achieving this, the researcher critically followed Maxwell's (2013) advice, centred on reflecting on goals, research questions, theoretical framework, methods, and validity. Although Maxwell presents this in a linear and clear step-by-step process, in practice, this involved going forth and back with a careful review of literature on research methods and constant consultation with the researcher's supervisor.

In this study, the researcher used a thematic analysis approach, which is a method of identifying, organising, analysing and reporting patterns/themes within data (Zammit, 2020). In as much as the process of data analysis and interpretation involved distinct processes such as transcription, organisation, coding, analysis and interpretation, the process was not linear or systematic, but complex, iterative, and reflexive. For example, the interpretation and analysis were started during interviews as suggestions of themes and possible codes started to emerge. During the transcription of data, engagement with the data also provided a sense of the key issues emerging. This enabled reflexive action during and after the interviews. In the same way, during the review of journals and responses to questionnaires, and during observations, there were several concrete themes and subthemes that started to emerge. However, the notes written during the early stages of the data generation process were then used to draw up a data analysis and interpretation plan.

The codes were influenced by several sources, such as research questions, interview questions, literature review, theoretical framework, personal experiences and the data itself. The datasets were drawn from semi-structured questionnaires, semi-structured interviews, lesson observations, journal reflections as well as from field notes. Soon after transcribing and cleaning the data (a process through which transcripts are edited for grammatical constructions and filling in gaps wherever possible), the researcher manually coded the transcripts so as to determine the codes and emerging themes. The researcher then uploaded all transcripts onto NVivo software to organise and manage the data easily. The software enables easy organisation and management of the data, rather than data analysis or interpretation.

In sum, the four stages in the cycle of analysis consistent with the grounded theory that were applied to the transcripts are coding, conceptualising, categorising, and theorising (Glaser & Strauss, 1967). The step-by-step procedure followed in analysing the interviews and journal reflections was as follows:

1. Coding, which entails reviewing the transcripts sentence by sentence to identify anchors (words or phrases) that allow the key points of the data to come forward.
2. Conceptualising, which means grouping codes with similar content (where new concepts are core parameters of the data and codes can be seen as dimensions of these concepts);
3. Categorising, which is about developing categories that broadly group the concepts and constitute the basic elements to be generated into a hypothesis or a theory; and
4. Theorising, which is the process of constructing a system of explanations for the main concerns of the subject of the research.

The data analysis procedure followed the general process of inductive data analysis proposed by MacMillan andSchumacher (2006) as illustrated in figure 5:

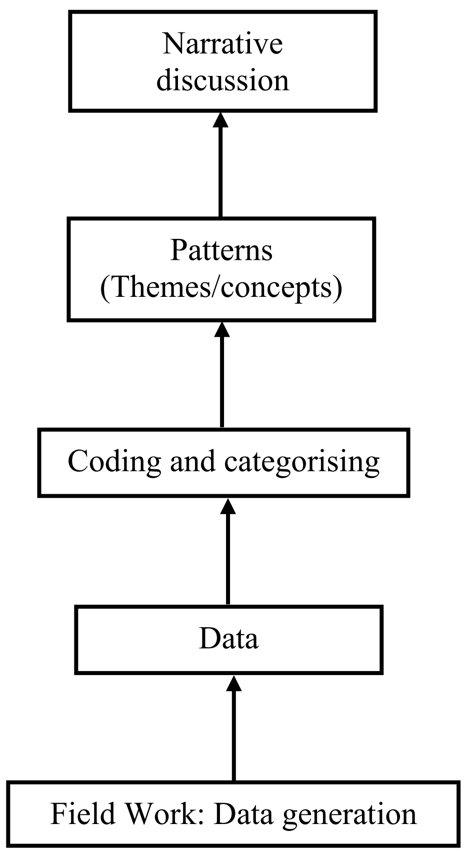

Figure 5: General process of Inductive Data Analysis
Source: Adapted from McMillan and Schumacher (2006, P. 365)

4.7 Data Triangulation

Lemon and Hayes (2020), define triangulation "as the use of two or more methods of data collection in a study" (p.41), while Kincheloe, McLaren and Steinberg (2011, p.65), define it as "multiple sources and modes of evidence" (p. 235). According to Campbell, Pitt, Parent & Berthon (2011), one of the ways to ensure validity and trustworthiness is by means of triangulation. Triangulation assumes that a variety of strategies and viewpoints are needed to fully understand and explain a problem (Carter, Bryant-Lukosius, DiCenso, Blythe & Neville, 2014). The triangulation methods' effectiveness relies on the premise that the weakness of one collecting method will be compensated by the other counter-balancing strength of the other method (Hesse-Biber & Leavy, 2011). Thus, the purpose of applying triangulation is to overcome any potential weakness or intrinsic biases and problems that might occur from single methods, as well as to obtain confirmation of findings through the convergence of multiple sources and different perspectives that represent reality in a particular context. In addition, it helps to avoid the subjectivity of certain methods such as interview over other methods. The most significant advantage of using multiple sources of evidence and data collection methods is the development of "converging lines of inquiry" (Yin, 2014, p. 94). Flick (2002) cited in Denzin and Lincoln (2013, p.7), argues that triangulation is a "strategy that adds rigour, breadth, complexity, richness, and depth to any inquiry".

Harrison, Reilly and Creswell (2020, p.29), suggests a typology of four types of triangulation: a) data triangulation which includes (time, space and person); b) investigator triangulation; c) theory triangulation; and d) methodological triangulation. Cohen et al., 2018) identified six types of the triangulation: a) time triangulation; b) space triangulation; c) combined level of triangulation; d) theoretical triangulation; e) investigator triangulation;, and f) methodological triangulation. In the present study, the researcher opted to used four triangulation methods that showed the greatest promise to help him obtain the necessary information to answer all the research questions. Thus, it was more appropriate to use Harrison, Reilly and Creswell's (2020) four types of triangulation which are also advocated by Cohen et al., (2018). The first was data triangulation in which the data was collected from multiple sources (ten teacher participants with different backgrounds and from different school contexts). This allowed the researcher to collect different views and reflections from diverse perspectives beside his own. The second was theory triangulation which refers to using more than one theory in a study. In this study, the researcher used two theories i.e., Vygotsky's socio-cultural theory and TPACK theory (see Section 3.2 & 3.3). The third was methodological triangulation which refers to using multiple data collection methods to examine a single phenomenon (Marshall & Rossman, 2011). In this study, the researcher used five data generation methods: semi-structured questionnaires; semi-structured interviews; observations; journal reflections; and as well as data from field notes. The fourth and last type of triangulation that the researcher used was investigator triangulation. This entails using different investigators and evaluators in assessing a study (Creswell, 2014). Creswell (2014) further explains that these evaluators are experts within the field of study. During the conduct of this study, the researcher submitted one research papers to journals, and reviewers' and editors' comments served to help validate the study.

4.8 Research Evaluation

A number of efforts were made to ensure the trustworthiness of the research processes and findings presented in this study, in line with the five criteria for research evaluation cited by Guba and Lincoln (1989, p.49), which are; validity, reliability, credibility, transferability and confirmability. Johnson and Onwuegbuzie, (2004), identifies the criteria types as: credibility (replacement for quantitative concept of internal validity); transferability (replacement for quantitative concept of external validity); dependability (replacement for quantitative concept of reliability); and confirmability (replacement for quantitative concept of objectivity). These criteria are key attributes of a rigorously carried out study, accepted by academic peers and wider community.

4.8.1 Validity

Validity refers to the extent to which a research instrument can measure what it is intended to measure (Richard, Sivo & Orlowski, 2021). Brooks, te Riele and Maguire (2014, p.13), note that "to ensure validity, a research instrument must measure what it was intended to measure". This means that the measuring instruments: the semi-structured questionnaires; semi-structured interviews; observations and journal reflections, measure the actual issues that the research is intended to investigate. There are seven types of validity: "internal, external, criterion, construct, content, predictive and statistical validity" (Brooks, te Riele & Maguire, 2014, p. 15). Internal validity refers to the correlation of questions (that is questions related to cause and effect) and to the degree to which conclusions about causality can be drawn. External validity refers to the degree to which it is possible to generalise the data that is collected to a bigger population or setting. Criterion validity implies comparison of the responses in a study with accepted measures of the concept under investigation. Construct validity concerns measuring abstract concepts and attributes, for instance, perceptions, attitude, and knowledge. Content validity is concerned with validating the content of the research, which means creating a link "between what is taught and what is tested" (Stenfors, et al. 2020, p.15). Predictive validity refers to how well the research can predict a future phenomenon. Finally, statistical validity is the degree to which a study uses an appropriate design and statistical methods (Richard, Sivo & Orlowski, 2021).

This study aimed to meet all the described forms of validity. To establish the validity of the research, the researcher took into consideration to make notes during the progress of the research to evaluate the effectiveness of the research process and to have accurate records of participants responds. In addition, to ensure the validity of collected data from interviews, the researcher sent the transcribed interviews to the participants to confirm the accuracy of the data (respondent validation) before analysing and building case studies. Moreover, as described above, the researcher applied the triangulation of data.

4.8.2 Reliability

According to Burton, Brundett and Jones, (2011, p. 55), reliability refers to "the extent to which a research instrument is dependable, consistent, and stable". Yeasmin and Rahman (2012, p.56), adds that reliability refers to "the sense of being consistent, stable, predictable and accurate". Yeasmin and Rahman (2012, p.56), further explain that in quantitative research, reliability aims for repeatability, stability and similarity of measurements, whereas in qualitative research it is used for the purpose of ensuring the dependability of findings when answering research questions. By showing similar results, the researcher will know that the interview questions and observations are reliable. Basically, reliability is concerned with whether the same results will be obtained if the same thing is observed twice. This is, however, highly unlikely in qualitative research. Tavory (2020), explains that we cannot measure the same thing twice, and if we try, we are measuring two different things. It is therefore suggested that dependability is more appropriate in qualitative research. "Dependability refers to the need for the researcher to account for the ever-changing context within which research occurs" (Tavory, 2020, p.13). The researcher is responsible for describing changes that occur in the setting and how these changes may have affected the study.

In this study, in the pursuit of the reliability of the coding process of the qualitative data, the researcher used the help of his research supervisor, who has an experience with coding transcribed data, to check the reliability of the development of coding system categories and sub-categories. "The code development process is typically better when it is done with others" (Burton, Brundett and Jones, 2011, p.11). The researcher provided details of data collecting and analysing, creating a coding system, the emerging categories and sub-categories, and explained procedures that he undertook in his data analysis for other researchers to follow.

4.8.3 Credibility

According to Closa (2021), credibility refers to establishing that the outcomes of qualitative research are credible or true from the perspective of the participants in the research. It is related to the question of how congruent the findings of the research are with reality (Brinkmann & Kvale 2015). That is, the findings need to reflect closely what is happening in the population of the study. This can then make the findings more trustworthy. To ensure credibility, the researcher made sure that there is a need to take steps "that can help with the task of persuading readers of the research that the data are reasonably likely to be accurate and appropriate" (Delamont, 2012, p. 97).. However, the steps offer reassurance that the data obtained have been produced and verified in accordance with good practice. The steps include triangulation, respondent validation (going back to the participants with the data after the study to check the validity of the findings) and use of grounded data (where the researcher spends a lot of time in the field and interacts with the participants, thus scrutinising their behaviour) (Delamont, 2012). Since in this perspective the purpose is to understand a phenomenon of interest from the participants' point of view, only the participants can correctly judge the credibility of the results (Closa, 2021). To be clear, there is no absolute way or truth in this type of research. Every participant was allowed to come with their own perspective, consequently, the same experience may have different outcomes for different people. The way in which data is interpreted may differ from researcher to researcher, but the important thing is credibility, being able to justify why one has come to his or her perspective. Credibility attempts to address the question, "how congruent are the findings with reality?" (Geiger, 2021, p.14).

This study explored the use of Virtual Lab by teachers. The researcher used semi-structured questionnaires, semi-structured interviews, journal reflections and lesson observations to find out answers to the research questions. The researcher also tested (piloted) the research instruments. Interviews helped the researcher to gain information that could not be observed. The interviewees were also asked to read transcripts of dialogues in which they had participated. Silverman (2011, p.68) argues that this is one of the ways in which credibility can be addressed. Furthermore, as part of the attempt to ensure credibility and trustworthiness, the researcher examined the data to determine whether the views expressed by the interviewers reflected the participants' experiences and opinions outside the interview situation, or whether they were merely a reflection of the interview situation (Silverman, 2011, p.366). There could be bias in the study from the teachers' (sample) side. The teachers may have been untruthful in the interviews and observations by showing the researcher methods they did not usually use and giving responses to avoid being judged by the researcher as a colleague.

4.8.4 Transferability

Boadu, (2021), states that transferability refers to the degree to which qualitative research results can be generalised or transferred to other contexts or settings. It is concerned with the extent to which the findings of a given study can be applied in other contexts with other respondents from the reader's perspective (Kesavan, 2021). From a qualitative perspective, transferability is primarily the responsibility of the one doing the generalising. Transferability is evaluated by "looking at the richness of the descriptions included in the study as well as the amount of detail provided about the context in which the study occurred" (Kesavan, 2021, p.24). Since the reader of this thesis is the person who must assess transferability, "richly detailed or thick descriptions enable the reader to make judgements about the similarity of participants ... and other characteristics of the research site and the reader's own site" (O'Kane, Smith & Lerman, 2021, p.76). Transferability in this thesis is not concerned with whether the study included a representative sample; rather, it is about "how well the study has made it possible for readers to decide whether similar processes will work" in their own settings (O'Kane et al, 2021, p.77). In this study, an effort was made to ensure transferability by using study approaches that have been used in the past in similar studies. This shows that a related study could also be conducted in the future.

4.8.5 Confirmability

Confirmability refers to the standard to which the results could be confirmed or corroborated by others (Closa, 2021). To achieve this, the researcher documented the procedures for checking and rechecking the data throughout the study. The researcher can also search and describe negative occurrences that contradict prior observations. Confirmability implies that “the researcher has determined the accuracy or credibility of the findings through specific strategies” (Strauss & Corbin, 2015, p. 28). Confirmability can be attained through respondent validation, triangulation, and use of strong data collection methods and other strategies (Strauss and Corbin, 2015). In this study, the use of interviews acted as a strong method of data collection since the interviews were conducted when the researcher was alone with the respondent, and this is one of the strong data collection methods noted by Okono, Sati and Awuor (2015). During the face-to-face interviews, the researcher made sure he showed respect to the participant. For example, the researcher upheld some distance, which was meant to convey respect for the respondents’ personal spaces. The researcher also requested permission to use a tape recorder during all the interviews. Additionally, transcripts of the interviews were sent for member checking (Brooks, te Riele & Maguire, 2014).

4.8.6 Trustworthiness

The characteristics of qualitative data are known to be ambiguous and require the researcher to be on the lookout for emergent key themes for the data to be organised, arranged and interpreted (Burton, Brundett & Jones, 2011, p.147). Maintenance of study trustworthiness is ongoing throughout the research process (Brinkmann & Kvale, 2015). For example, it is essential that study findings reflect participants’ voices (Hessie-Biber, 2014). As such, participants’ words are extensively and “judiciously” quoted (Hennink, 2014) in this document; participants speak for themselves. Moreover, participants were invited to validate their interview transcripts, which contributes to research credibility (Creswell, 2014). Additionally, data was collected until saturation was reached. The last three participants to be interviewed contributed nuance and depth to the overall data already collected, instead of introducing new data. This saturation establishes credibility to the data's consistency from the multiple data collection points (Hessie-Biber, 2014).

In addition, data analysis processes positively influence trustworthiness, and researcher immersion in the data is one such strategy (Patton, 2015). The discussion in section 4.6 attests to researcher data immersion and contributes transparency about the research process, thereby supporting confirmability and dependability (Lincoln, Lynham & Guba, 2011). However, researcher bias can threaten study trustworthiness (Maxwell, 2013), and researcher reflexivity is one important strategy to temper bias (Roulston, 2010; DeVault & Gross, 2012; Edwards and Holland, 2013; Hesse-Biber, 2014) and facilitate dependability (Lincoln, Lynham & Guba, 2011). Reflexivity enables the researcher to be aware of his biases and assumptions (Creswell, 2014), his role in the research process (Edwards & Holland, 2013), his impact on and relationship with participants (Edwards and Holland, 2013; Hesse-Biber, 2014), and his power over the data. Therefore, in this study, field note-taking, and journaling procedures helped document research processes and decisions.

4.9 Ethical Considerations

"Ethical principles frame the purpose of a research study and serve to maintain the rights of the research participants" (Salazar, 2021, p.13). Decker, Wolfe and Belcher (2021, p.21-24), propose a framework on principles of research ethics to ensure that "the rights of the participants are protected throughout the research". Such principles are necessary to ensure that researchers make their research "transparent, to avoid harming or deceiving the participants" (Flick, 2011, p.216). To respect and protect research participants, this research study followed all ethical standards and protocols designed to protect research participants. These protocols are according to the policies and procedures established by both the Eastern Cape Department of Education (Appendix C1, Study Approval letter), and the *Rhodes University Ethical Standards Committee* and the *Education Department Higher Degrees Committee* (See Appendix C2, Ethics Clearance letter). This study was supervised by Dr. Clement Simuja, an accomplished researcher. Ethical considerations prioritised care and respect (Bell, 2014; Brooks, te Riele & Maguire, 2014;

Farrimond, 2013) for the research participants' human dignity and focused particularly on informed voluntary consent, gaining access and confidentiality.

4.9.1 Informed voluntary consent

Participants were informed of the anticipated benefits and risks of study participation prior to their engagement in the study. The Letter of Information and consent (see Appendix B1, Letter to participants) followed Rhodes University ethical standards and requirements. The Letter of information and consent outlined the research purpose, procedures, potential benefits and risks, use of data, identity protection, and other information relevant to ensure informed consent. The researcher carefully reviewed the Letter of information and consent with each participant for understanding, discussed interview processes and research procedures, and answered questions, prior to their signing. Additionally, the researcher advised participants that they had a right to decline to answer questions or to withdraw consent from participation at any time throughout the study (Wiles, 2012). Since consent is an on-going process (Hesse-Biber & Leavy, 2011; Wiles, 2012; Brooks, teRiele & Maguire, 2014), researcher reflexivity ensured sensitivity to and vigilance of unexpected ethical issues (Wiles, 2012; Brooks, teRiele and Maguire, 2014; Hennink, 2014) and changes in consent (Wiles, 2012) throughout the research process. Participants were invited to review their interview transcripts at their convenience, either in person, by video conference, or by electronic communication, and to date, more than half requested and received their transcripts via email. In the future, participants will be offered copies of all documents and publications connected to this study, including this document. Study participation was voluntary, with no coercion involved.

4.9.2 Gaining access

In order for the researcher to access the public schools, permission from the Eastern Cape Department of Education (Chief Director for Planning, Monitoring and Research Coordination; Cluster Chief Director; District Director; Curriculum Chief Education Specialist; School Principals and teachers) had to be obtained prior to undertaking the research in the targeted schools (Cohen et al., 2018). Letters requesting access to the schools were submitted to all relevant stakeholders explaining the research title, aims, methods, and the benefits of the study for the schools, teachers, and learners. Also, the researcher’s obligations toward the participants' anonymity and data confidentiality were explained, as well as the target schools and names. The letters went through official procedures and were acknowledged. (see Appendix B2, Letter to school principal).

4.9.3 Confidentiality

Participants' confidentiality and privacy is safeguarded (Farrimond, 2013) according to Rhodes University protocols, and identifiable information has been anonymised (Wiles, 2012), including participants' names, post-secondary education institutions, and locations. In post-study emails sent to thank participants for their study involvement, participants were invited to select their own pseudonyms for anonymity in study publications. Several participants requested that their own names represent them, which presented an ethical dilemma. While it is essential that participants have power in the decision-making that determines their representation in this research, my ethical responsibilities to participants are outlined by the ethical standards and protocols from the *Rhodes University Ethical Standards Committee* and the *Education Department Higher Degrees Committee*. Therefore, the researcher acknowledged participants' preferences, declined with apologies and referenced ethical standards.

A few participants left their pseudonym decisions to the researcher, either directly instructing him to choose a name for them, or indirectly by not responding to the invitation. This unexpected responsibility to create a label to represent participants introduced a challenging prospect considering the complicated power relationships that may be found between researcher and participant. As such, the researcher's determination to assign culturally appropriate instead of anglicised pseudonyms, led to internet searches for names that are common in participants' traditions and cultures. All data (written transcripts) from research instruments have been kept in a safe place at Rhodes University , and will be destroyed after five years. All electronic files are stored in a password-protected computer by my Reseaerch Supervisor.

4.10 Conclusion

This chapter defined qualitative research, locating it within the interpretive qualitative research paradigm using a case study approach. It gave a description of the research site, the sample and how these were chosen. It also explained the logic behind the chosen methodology, including its advantages and disadvantages. Next, the research design section outlined the research instruments, which were semi-structured questionnaires, journal reflections, observations and semi-structured interviews. This chapter further discussed data analysis, triangulation, and research evaluation which focused on trustworthiness, credibility, transferability, confirmability. The chapter concludes by addressing the ethical considerations of this study. The next chapter discusses the findings of the present study.

CHAPTER FIVE

RESULTS

5.1 INTRODUCTION

The previous chapter dealt with the research design and methodology used in this study. A qualitative case study approach was used to enable an in-depth study of the teachers' technological, pedagogical, and content knowledge in teaching with Virtual Lab in a natural setting Yin (2014). In this chapter, the researcher thematically presents and analyses the study's findings based on the data generated. The chapter is divided into five sections: (5.1) introduction, (5.2) research activities, (5.3) data generation and analysis, (5.4) characteristics of research participants, (5.5) findings of the study, and (5.6) conclusion.

5.2 Research activities

The following is a summary of the research activities that were undertaken by the researcher during the conduct of this study.

Phase 1: Semi-structured questionnaires were administered to the participants (see Section 4.5.1). The aim was to lay the foundation of this study by gaining insights into the teachers' perceptions and attitudes on use of ICT for teaching and learning prior to conducting the study. All the seven participants responded within three days from the date of receiving the questionnaires. The data that was generated in this phase helped to answer to the first research question of this study.

Phase 2: To further lay the foundation of this study, the researcher conducted an orientation workshop with the teachers (see Section 4.5.3). The workshop was conducted in strict adherence to the COVID-19 protocols. The purpose of the workshop was to outline to the participants the rationale of the study, the research processs, and all the ethical issues. During this workshop the participants were trained how to download and install the Virtual Lab software on laptops. The Virtual Lab is a free, downloadable, CD-ROM-based program that provides virtual access to a variety of scientific instruments. The teachers were also trained how to use the Virtual Lab in mediation of learning. All the questions of clarity that were raised by the participants were addressed. As part of document analysis (see Section 4.5.4), the CAPS document was to get guidance on what to teach on the topic *Energy transformations (photosynthesis)*. For this study, the lessons were planned to investigate whether light intensity affects the rate of photosynthesis according to CAPS document page 42. See figure 5 below.

TERM 2				
Strand 2: Life Processes in Plants and Animals Organisms require energy to stay alive. They get this in one of two ways: by harnessing radiant energy from the sun and transforming it into chemical energy which they can use (autotrophs) or (if they cannot do this themselves), by eating other organisms (heterotrophs). The energy transformations that sustain life are include photosynthesis, (where energy is incorporated in to food), animal nutrition (where the food is processed so that it can get to the cells), and cellular respiration (how this energy is made available to organisms in order to stay alive). Gaseous exchange between an organism and its environment is necessary for photosynthesis and cellular respiration. Life processes also involve the removal of carbon dioxide and later the removal of nitrogenous wastes from the body through the kidney.				
Time	**Topic**	**Content**	**Investigations**	**Resources**
3 weeks (12 hours)	Energy Transformations to Sustain Life	**Photosynthesis** • process of photosynthesis using words and symbols: the intake of raw materials, trapping and storing of energy, formation of food in chloroplasts and its storage. The release of oxygen. Mention only of light and dark phases *(no biochemical details of light and dark phases are required)*; • importance of photosynthesis: release of oxygen, uptake of carbon dioxide from atmosphere, food production (trapping energy); • effects of variable amounts of light, carbon dioxide and temperature on the rate of photosynthesis (brief discussion together with graphs). • The role of carbon dioxide enrichment, optimum light and optimum temperatures in greenhouse systems to improve crop yields *(link to environmental issues discussed later)*. • Role of ATP as an important energy carrier in the cell.	**Essential** • Investigate photosynthesis by showing that - starch is produced during photosynthesis; and - light is necessary for photosynthesis. • *The following investigations can be done (by learners) as experiments or as demonstrations:* - carbon dioxide is necessary for photosynthesis; - chlorophyll is necessary for photosynthesis - oxygen is produced during photosynthesis; or - data can be provided and interpreted by learners.	• Textbooks • Living plants • Suitable equipment • Chemicals

Figure 5: Extract from CAPS document. Light is necessary for photosynthesis.

Phases 3, 4 and 5: These phases involved the researcher carrying out lesson observations as the teacher participants integrated the Virtual Lab in their lessons (see Section 4.5.3). A total of seven lessons were conducted using the Virtual Lab. The researcher had planned to observe the seven lessons from all the schools, however, due to the COVID-19 lockdown restrictions which also affected visits to schools, the researcher managed to observe three lessons from three different schools.

In the experiment that was taught, the learners were using computers that were loaded with the Virtual Lab software to see whether light intensity affects the rate of photosynthesis. In the simulation a plant is shown in a beaker and a test tube with bubbles to indicate the rate of photosynthesis. See figure 6 below which is a screenshot of the interface.

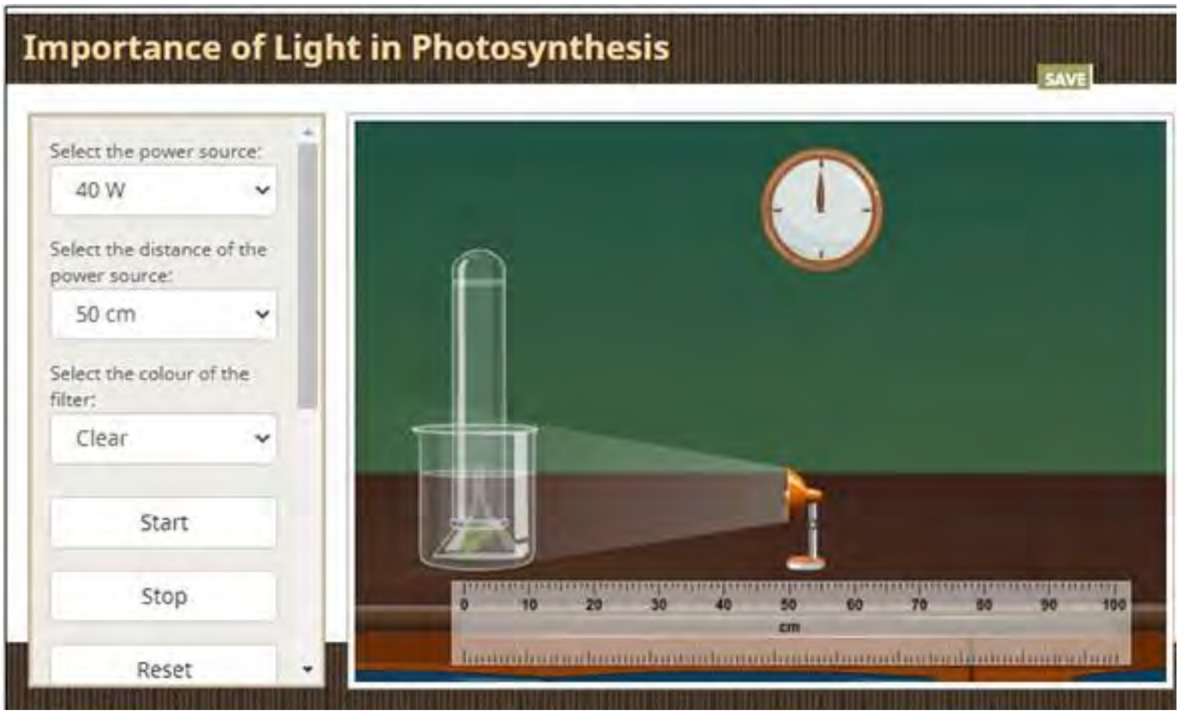

Figure 6: Virtual Lab interface on importance of light experiment

The simulation would allow learners to manipulate the intensity of light that the plant is exposed to by moving the source of light further or closer to the plant. The learners would then measure the rate of photosynthesis by counting the number of bubbles of oxygen that are released into the test tube. The number of oxygen bubbles released at each distance of light source from the plant were counted and recorded as part of their data collection and thereafter conclusions or findings were reported. These lessons took place outside of the normal teaching time in compliance to the gatekeepers's requirements (Appendix C1. Study approval letter). The data generated in these phases helped to answer research questions two, three and four.

Phase 6: The semi-structured interviews occurred after the study was completed (see Section 4.5.2). All the seven participants were interviewed individually. The data generated in this phase helped to answer research questions two, three and four. Lastly, The second and last workshop discussion was conducted virtually via Zoom. The teachers and I reflected on the entire study and recommendations that arose from the study were documented. The data generated in this phase helped to answer research questions two, three and four. Throughout all the phases, journal reflections were done and field note were taken. The next section discusses data generation and analysis.

5.3 Data generation and analysis

The data for this study were generated using semi-structured questionnaires, semi-structured interviews, journal reflections, workshop discussions, filed notes and coupled with lesson observations (Section 4.5). The generation of varying types of data helped in the triangulation of the data. Triangulation was utilised in the examination of data in a more comprehensive and integrated manner to answer all the research questions in the study. Very little editing of the audiotape interview transcriptions was done. For the purposes of clarity, the following changes were made to the original audio texts:

i. Correction of grammatical errors.
ii. Removal of long pauses.
iii. Deletion of repeated phrases.
iv. Deletion of filler sounds such as "um", "eh", and "like".

Where references were made to institutions and/or individuals, their names were withheld to ensure anonymity. Likewise, to ensure the research participants' anonymity, the interview transcripts are represented by numbers instead of their actual names. The data were examined as guided by the four research questions, which focused on:

v. Perceptions and attitudes of Grade 11 Life Sciences teachers on the use of ICT for teaching and learning
vi. Pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments.
vii. Enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments.
viii. Ways in which Virtual Lab be used by Grade 11 teachers to mediate learning of scientific experiments using the topic *Energy transformations.*

5.4 Characteristics of the research participants

A total of seven teachers from four schools participated in this study. There were three female and four male participants. All the participants attended university. Three had Honours degrees and the rest had Bachelor's degrees. As discussed in Section 4.9, the ethical principles were observed by using pseudonyms to conceal the identity of participants and their schools. To further protect the identity of the participants, the teachers are not addressed by titles that would reveal their gender (Mr. / Mrs. or Ms). Instead, the teachers are simply addressed by name, for example ("Bruce"), so that data may not be matched with any participant. Before the participants sign the consent forms, the confidentiality of data is one of the promises the researcher must make (Cohen et al., 2011). Efforts were made to keep this promise as far as possible. The table below presents the participants and their schools.

Table 2: Participants and their schools (Pseudonyms)

Participant	School
Bongi	Conwell Senior Secondary School
Mpho	Conwell Senior Secondary School
Tumelo	Thuthukani Senior Secondary School
Clever	Thuthukani Senior Secondary School
Debbie	Naledi Senior Secondary School
Bruce	Naledi Senior Secondary School
Candie	Good Hope Senior Secondary School

5.5 Findings for the reseach questions

5.5.1 Perceptions and attitudes on the use of ICT for teaching and learning

As mentioned in Section 2.4, knowing teachers' existing perceptions and attitudes could help to better understand their pedagogic practices and how their existing perceptions and attitudes could influence their adoption of the Virtual Lab as an ICT tool for teaching. In addition to perceptions and attitudes of teachers on use of ICT in classroom practice, the scope of the questionnaire also dealt with some contextual factors such as the types of ICTs available at their schools, level of teacher competence and ICT integration at school, and barriers/challenges they face in the integration of ICT for teaching and learning. As discussed in Section 3.3, this study's analytical framework, i.e. TPACK, recognises the importance of contextual factors in understanding ICT integration for teaching. Therefore, the factors that the questionnaire sought to capture were important to the researcher to have a broader spectrum of the contexts in which teachers use ICT in the classroom. In particular, these factors were used to shed light to the overall comprehension of Question 1 and helped to respond to Question 3, which dealt with enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments.

Therefore, the analysis below shows from the responses of the participants the contextual factors in which ICT integration would occur and the perceptions and attitudes of the teachers on use of ICT for teaching and learning.

Table 3: Extracted from Questionnaire, Section B, Q.1. A ppendix A1. ICTs available for teaching and learning

	Name of teacher						
Available for teaching and learning	**Bongi**	**Mpho**	**Tumelo**	**Clever**	**Debbie**	**Bruce**	**Candie**
1. A computer laboratory	No	Yes	Yes	No	No	No	Yes
2. Laptops for teachers' use	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3. Internet connectivity	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Tablets	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The conclusive observation was that every educator in this study had access to basic ICT tools for teaching and learning. Despite most of the teachers coming from schools that did not have a computer laboratory, each teacher and learners had laptops and tablets, respectively, with internet connectivity provided by the Eastern Cape Department of Education. This contextual factor of ICTs being available for teaching and learning was important to ensure the viability of this study in exploring the use of Virtual Lab. The availability of the ICT tools for teachers' use was also important as it could indicate that the teachers were acquainted with the use of technology (TK) and therefore the study would focus on use of Virtual Lab for teaching (TPK) and not on computer literacy.

As indicated above, the focus of the study was on the use of Virtual Lab for teaching, the researcher also found it necessary to understand the level of the teachers' capabilities in basic computer programmes as part of the teachers' TK. This understanding was important in this study because a fair to good ICT capability was necessary as a pre-requisite for the teachers to be able to use the Virtual Lab. The following extract from the questionnaire shows teachers' responses on their ICT capabilities.

Table 4: Extracted from Questionnaire, Section C, Q.1: Appendix A1. Teacher ICT competence

	Name of teacher						
	Bongi	**Mpho**	**Tumelo**	**Clever**	**Debbie**	**Bruce**	**Candie**
1. Word Processing (MSWord)	Fair capability	Good	Fair capability	Good	Fair capability	Fair capability	Fair capability
2. Spreadsheets (MS Excel)	Low capability	Fair capability	Low capability	Low capability	Fair capability	Good	Low capability
3. Presentation tools (MS PowerPoint)	Good	Good	Fair capability	Fair capability	Good	Good	Good
4. Emailing	Good	Good	Good	Good	Good	Good	Good
5. Internet browsing	Good	Good	Good	Good	Good	Good	Good

As shown in the summary of responses above, most teachers felt that they possess from fair to good capabilities in basic use of computer programmes, except in spreadsheets where most of them indicated that they have low capabilities. The researcher also observed that most of the teachers reported that they have good capabilities in using presentation tools, emailing and internet browsing. These programmes in which the teachers are good at are the ones that form the basis for the use of the Virtual Lab, hence, the contextual factor of ICT capability was less likely to impact on their use of Virtual Lab for teaching. This is consistent with the findings of Babu and Maruti (2020), who, in their study '*Information Communication Technology Role in Teaching and Learning',* found that most teachers now posses basic ICT skills to enable them to integrate technology in their teaching.

Lastly, before looking at the teachers' perceptions and attitudes on use of ICT for teaching and learning, the researcher needed to understand the challenges or barriers that the teachers were facing in integrating ICTs for teaching before the introduction of the Virtual Lab. As indicated earlier in Section 2.2.3, an understanding of these barriers or contextual factors could help inform a broader comprehension of part of Question 3 that dealt with constraining factors to the use of Virtual Lab for teaching. This is because certain challenges teachers face in adopting ICT in general could also affect the adoption of Virtual Lab in particular. Below is a summary of how teachers view the impact of certain barriers on ICT integration for teaching.

Table 5: Extracted from Questionnaire, Section C, Q.1: Appendix A1: Challenges/barriers to ICT integration for teaching

	Name of teacher						
	Bongi	**Mpho**	**Tumelo**	**Clever**	**Debbie**	**Bruce**	**Candie**
1. Inadequate training	Important barrier	Important barrier	Very important barrier	Important barrier	Very important barrier	Important barrier	Important barrier
2. Limited supply of electricity	Less important barrier	Important barrier	Less important barrier	Less important barrier	Less important barrier	Less important barrier	Less important barrier
3. Limited access to high speed internet	Not important barrier	Not important barrier	Not important barrier	Less important barrier	Not important barrier	Less important barrier	Not important barrier
4. Lack of time	Not an important barrier	Important barrier	Not an important barrier	Important barrier	Important barrier	Important barrier	Important barrier
5. Limited support from the school management team	Important barrier	High important barrier	High important barrier	High important barrier	Important barrier	High important barrier	High important barrier
6. Lack of confidence to use ICTs in teaching	Less important barrier	Important barrier	High important barrier	Important barrier	High important barrier	Not an important barrier	Not an important barrier
7. Lack of motivation to use ICTs in the classroom	Not an important barrier	Not an important barrier	High important barrier	High important barrier	Less important barrier	Important barrier	Not an important barrier

An analysis of the teachers' responses in the Questionnaire extract above gave rise to two themes. These themes are indicated in table 6 below.

Table 6: Barriers to the use of ICT for teaching and learning

Theme	Description
1	High impact barriers/challenges to ICT integration
2	Low impact barriers/challenges to ICT integration

High impact barriers to ICT integration

The teachers were asked to indicate the level of how certain barriers affect their integration of ICT into teaching. From the summary of their responses above, the most common high impact barriers include inadequate ICT training, lack of time, and limited support from the school management team (SMT).

On inadequate ICT training, all the teachers agreed that this is a great challenge to them. This confirms the findings of du Plessis and Webb (2012), Rabah (2015), Eshetu (2015), Young (2016), Elemam (2016) and Ngoungouo (2017). In this study, the challenge of inadequate training was brought to light by the following statements that were made in the comments space of the questionnaire:

> *"To me lack of training is a big challenge. We went for training in East London on how to use the smartboard for teaching, but the training was not sufficient. We were only trained how to open and close the smart board. I do not know how to use the smart board; I do not use it in class because I do not want to embarrass myself in front of my leaners" (Bruce).*

Furthermore, Debbie elaborated:

> "*I recently participated in a virtual training where we were trained on how to use an application called Snapplify which is installed in the tablets provided to learners by the Eastern Cape Department of Education. We were only introduced to how to create an account and to log into the app. I only realised later that there are many functions of the app that I do not know and that I cannot use the app for teaching. As a result, I am continuing to use the chalk and textbook".*

On lack of time, Candie commented:

> *"In most cases it takes me a lot of time to prepare a lesson to teach using ICT and I don't have that time. I must browse the internet from one website to another and sometimes do*

not get relevant content for the level of my learners. After that I must prepare PowerPoint slides. But with my teacher's guide and textbook I do things very quickly and that gives me time to mark and rest. Since I prepare for my lessons at home, using textbooks gives me some time to attend to my family matters".

Concurringly, Clever stated that:

"Each time I go for class I carry my laptop and data projector and connect before the lesson starts. This takes me at least 15 minutes to set up and about 10 minutes to disconnect at the end of the lesson. This means that out of a 45-minute period I have, I would be left with only 20 minutes teaching and learning time which is not enough".

On limited support from the SMT, the common response that emerged centred around the funding regime for ICT in the schools. The teachers revealed that there was far less priority given to procurement and maintenance of ICT tools in the schools. The teachers further revealed that the school management also does not put in place school-based ICT teacher development training. These areas of limited support were highlighted by the following statements:

"I am grateful to the department of education for rolling out various ICT tools to our school over time. However, most of those tools now are not in working order due to lack of maintenance. Our school management have never purchased antivirus software for the computers we have and when we ask, they simply say those things are too expensive. Moreover, some of the ICT tools have been stolen because the school never ensured their safety by procuring safes and burglar bars". (Bongi)

Sharing a similar view was Mpho who had this to say:

"The SMT of my school does not allocate enough funds to the running of ICT adoption and as a result the whole process is failing. I think the SMT lacks an appreciation of the importance of embracing ICT and that is the reason why they do not prioritise ICT in

school. They have also never arranged an internal workshop where they can invite an ICT specialist to teach us some of the latest trends in using ICT for teaching".

Low impact barriers to ICT integration

In addition to the high impact barriers to ICT integration, the teachers also made indication of challenges that they believed do not affect their integration of ICT for teaching and learning. These are the low impact challenges such as limited supply of electricity, limited access to high speed internet, lack of confidence to use ICTs in teaching, and lack of motivation to use ICTs in the classroom. Majority of the teachers noted the challenges above but however did not qualify them as major constrains to their ICT integration. These responses by the teachers were expected because of purposive sampling. This made the researcher to deduce that these factors were also less likely to negatively impact the adoption of the Virtual Lab for teaching.

Table 7: Extracted from Questionnaire, Section C, Q.1: Appendix A1: Perceptions and attitudes of teachers on use of ICTs for teaching and learning

	Name of Teacher						
	Bongi	**Mpho**	**Tumelo**	**Clever**	**Debbie**	**Bruce**	**Candie**
1. ICTs are disruptive when teaching	Disagree	Disagree	Agree	Disagree	Agree	Disagree	Disagree
2. ICTs make teaching effective	Agree	Strongly agree	Uncertain	Strongly agree	Strongly disagree	Agree	Strongly agree
3. ICTs promote learner to learner interaction	Agree	Agree	Uncertain	Agree	Disagree	Agree	Agree
4. ICTs help in improving learner performance	Strongly agree	Agree	Uncertain	Agree	Uncertain	Agree	Agree
5. Use of ICTs in teaching and learning can improve learners' critical thinking	Agree	Agree	Uncertain	Agree	Disagree	Agree	Agree
6. Knowing how to use ICTs by teachers is a good skill	Agree	Agree	Agree	Agree	Disagree	Agree	Agree
7. ICTs reduce the teachers' administration burden	Agree	Strongly agree	Disagree	Agree	Strongly disagree	Agree	Strongly agree
8. ICT-assisted instruction is more effective than the traditional method of instruction.	Agree	Strongly agree	Uncertain	Agree	Strongly disagree	Agree	Strongly agree
9. Use of ICTs puts more work on teachers	Disagree	Disagree	Agree	Disagree	Agree	Strongly disagree	Disagreed
10. ICTs arouse learner curiosity in the learning process	Agree	Strongly agree	Uncertain	Agree	Uncertain	Agree	Agree
11. ICTs engage learners' attention and motivate them	Agree	Strongly agree	Uncertain	Agree	Disagree	Agree	Strongly agree
12. Use of ICTs in teaching is enjoyable	Agree	Agree	Uncertain	Agree	Uncertain	Agree	Agree
13. Using ICTs in teaching is difficult	Agree	Disagree	Agree	Agree	Agree	Disagree	Disagree
14. I am hesitant to use ICTs in teaching and learning	Disagree	Disagree	Agree	Disagree	Agree	Disagree	Disagree

Teachers' perceptions and attitudes towards ICT use in teaching and learning

Section D of the semi-structured questionnaire (Appendix A1) sought to generate information about the teachers' perceptions and attitudes towards ICT use for teaching and learning. To get reliable data, teachers were asked to respond on a five-point scale, from (i) Strongly Disagree, (ii) Disagree, (iii) Uncertain, (iv) Agree to (v) Strongly Agree. An analysis of the teachers' perceptions and attitudes on use of ICTs gave rise to two themes. These are indicated in table 8 below.

Table 8: Perceptions and attitudes on use of ICT for teaching and learning

Theme	Description
1	ICTs enhance teaching and learning
2	ICTs constrain teaching and learning

ICTs enhance teaching and learning

This study found that majority of the teachers had positive perceptions and attitudes towards the use of ICT for teaching and learning. On teaching, most of the teachers strongly agreed that ICTs make teaching effective and that ICT-assisted instruction is more effective than the traditional method of instruction. They also agreed, though not strongly, that knowing how to use ICTs by teachers is a good skill and that using ICTs in teaching is enjoyable. These findings confirm the findings of Eze, Adu and Ruramayi (2013), Meng and Wang (2018), Graham, Stols and Kapp, (2020).On learning, most of the teachers agreed that ICTs promotes learner to learner interaction, helps in improving learner performance, engages learners' attention and motivates them, and arouses learner curiosity in the learning process. This is consistent with a study conducted by Watson (1998), in Tennessee USA, who found that learners think that the use of ICT tools increased their self-confidence on how to use the tools for their schoolwork. When they are confident, it shows that they see the value of ICT tools in their learning. In this study, Only Tumelo and Debbie were uncertain that ICTs can arouse learner curiosity in the learning process. The teachers who agreed that ICTs enhance teaching and learning did not respond to the questionnaire's comments section to further explain their responses. Research ethics dictate that questionnaires cannot be coerced into an interview and that participants have the right not to answer to any question, therefore, the researcher did not seek for further explanations. However, the responses given by the teachers provided sufficient insights to respond to Research Question 1.

ICT constrain teaching and learning

Two teachers, Tumelo and Debbie, were of the view that ICTs constrain teaching and learning. These teachers agreed that ICTs are disruptive when teaching, put more work on teachers and that using ICTs in teaching is difficult. The teachers also agreed that they are hesitant to use ICTs in teaching and learning. In elaborating why ICTs constrain teaching and learning, Tumelo stated:

> *"I foresee a drop in pass rate this year due to the tablets given to learners. I have noticed that my learners do not concentrate on educational uses of tablets but focus on entertaining themselves, taking photographs, downloading, and playing music and movies. They (learners) are over-excited because this is the first time that most of them are seeing and using tablets".*

Concurring with Tumelo, Debbie stated that:

> *"The misuse of ICT gadgets by some learners in class does not only disrupt the learners but also the teacher. Sometimes the learners shoot pictures of teachers and post them on social media, making fun of the teachers. It happened to me. Another time I was busy teaching and this leaner was busy taking pictures of me and I was so disrupted".*

From the perceptions and attitudes of Tumelo and Debbie that ICTs are disruptive when teaching, the researcher deduced that this could be the reason why these two teachers feel that using ICT for teaching and learning is difficult and that they are hesitant to use the ICTs in class. The researcher, however, is of the view that with adequate training and teacher motivation, the perceptions and attitudes of Tumelo and Debbie could change to be more positive.

5.5.2 Pedagogical and technological experiences in using Virtual Lab to mediate learning of scientific experiments

Understanding how teachers make use of Virtual Lab in teaching of science experiments was central to this study. This led the researcher to ask: What are the pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments using the topic *Energy transformations*? (Question 2) and how can Grade 11 Life Sciences teachers use virtual Lab to mediate learning of scientific experiments using the topic *Energy transformations?* (Question 4). To answer these questions, data from interviews, journal reflections and coupled with lesson observations were analysed. Analysis of the data gave rise to four themes which are summarised in table 9.

Table 9: Pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments

Theme	Description
1	Shortens the time required to teach experiments
2	Virtual Lab equipment can be manipulated to suit requirements of the teacher
3	Lack of hands-on approach
4	Lack of direct supervision

Virtual Lab shortens the time required to teach experiments

One of the aspects that all the participants agreed on was that teaching with Virtual Lab shortened the time required to teach the experiments. This confirms the findings of George and Kolobe (2014), who explored the potential of using a Virtual Laboratory for chemistry teaching at secondary school level in Lesotho. They found that this technology is generally accepted (96 % of 166 teachers) due to its ability to shorten the time required to teach experiments. In this study, the following comments, for example, by Mpho, are evident that the Virtual Lab shortens the teaching time:

> *"What motivated me most about using the Virtual Lab is that it makes more time available for the actual teaching. This is so because unlike in the real lab where my*

> *learners and I would need time to select the apparatus from cupboards where they are stored and set them up, and after the experiments clean and pack them, in a Virtual Lab the equipment are readily available and need no cleaning at the end of the experiment. This actually ensured that there is more time for me to teach".*

Clever had a similar view about Virtual Lab shortening the time required to teach experiments and stated that:

> *"What usually makes conducting experiments to require a lot of time in real labs is that learners would have to wait for lab equipment being used by others due to shortages of equipment in most of our schools. With the Virtual Lab, the equipment are sufficiently available – there is no time wasted on waiting for apparatus from other learners, and this shortens the time needed to teach experiments".*

Teaching with Virtual Lab was also reported to allow for experimental results to be realised soon. This was indicated by Bruce as follows,

> *"I think for me what motivated me the most was, if I have to make my learners to see that light is necessary for photosynthesis, that would require my learners and I to use plants and that would take several days or even weeks before we can observe the results. With the Virtual Lab, we could speed up the experimental process and did not have to wait for weeks to see the results".*

Although most teachers agreed that the Virtual Lab shortens the time to teach experiments, Debbie had a slightly divergent view as follows:

> *"I am really excited that with the Virtual Lab, experiments that can take several days or to conduct can actually be condensed and be done in a matter of minutes. My concern is that although this technology makes teaching of experiments to take shorter, does it really mean that learning of these experiments is effective? I do not think so. I think that any successful* teaching *intervention should also ensure that successful* learning *does*

indeed take place. On the part of my learners, what I noticed with the Virtual Lab is mostly to do with excitement, I am not sure if there can be really a significant difference in performance between real lab and Virtual Lab, but since we do not have a real lab, perhaps I should give the Virtual Lab the benefit of doubt".

Virtual Lab equipment can be manipulated to suit requirements of the teacher

One of the technological experiences cited by majority of the teachers was that the Virtual Lab equipment and reagents can be altered and operated beyond the specifications of the manufactures. For example, Bongi commented:

"I find using the Virtual Lab very helpful…the equipment is readily available and can be adjusted or calibrated according to user preferences and not limited to manufactures specifications as in real equipment. For example, the virtual equipment can be adjusted to operate at extreme temperatures beyond what could possibly be done in real lab".

Lack of 'Hands-On' Approach

One of the major constraints of teaching with Virtual Lab as experienced by the participants is the lack of 'hand-on' approach. Similar findings were reported by Akkan (2012), in his study '*VIRTUAL OR PHYSICAL: In-service and Pre-Service Teacher's Beliefs and Preferences on Manipulatives'* conducted in Turkey, that a major constraint of using VL as compared to the real lab is the lack of a 'hands-on' approach for learners. Comments illustrating this view from this study were:

"Although there are many benefits of the Virtual Lab that I find important but, in my view, there is an important missing dimension in the Virtual Lab and that is lack of handling of the real equipment. What I know in science practicals is that learners learn better when they touch, feel, measure, make charts, manipulate, draw, record data, interpret data and make their own conclusions. These skills are important when conducting field experiments and yet they are not acquired through using Virtual Lab". (Tumelo)

"In my opinion the whole aim of practical experiments is to make learners do *science and not* observe *science. The lack of physical interaction of learners with real apparatus makes me feel like the learners are just observing science experiments being done on their behalf by software." (Bruce)*

"A lot is not learnt when using the Virtual Lab to conduct experiments, for example in a Life Sciences lab, much is learnt from slide preparation i.e., slicing, staining, and creating a microscope slide of a sample; calibrating and using a microscope including drawing sketch-diagrams. All these important scientific skills are lost with the use of the Virtual Lab". (Candie)

"Very useful to conduct virtual experiments but I still think that the virtual activities should also be done physically so the concepts are put into practice. The virtual experiments cannot equip learners sufficiently for real-life laboratory work. However, the Virtual Lab is an amazing tool to provide laboratory simulation to the learners". (Clever)

"Hands-on is still better. But if it is not possible, then virtual is second best. Learners should learn how to physically calibrate and use any lab instrument. Virtual Lab is better in schools where there are no resources available to conduct physical hands on experiments. In schools where real labs are available, in my opinion it is best to have hands-on practicals". (Debbie)

Despite the above comments, the researcher believes that the Virtual Lab could still be an effective alternative platform to conduct practical experiments as compared to the real lab. This is because most of the rural schools do not have the traditional science lab. More importantly, in the context of the global COVID-19 pandemic, the researcher believes that the lack of 'hands-on' approach in the Virtual Lab could indeed be a benefit in stemming the spread of the corona virus by not handling lab equipment that might be contaminated with the virus. This is supported by Tobarra, Robles-Gómez, Pastor, Hernández, Duque and Cano (2020) who pointed out that using virtual teaching and learning environments can help to prevent the spread of the corona virus.

Lack of direct supervision

One of the central characteristics of conducting science experiments is direct lab supervision and facilitation by an experienced and more-knowledgeable teacher. With the Virtual Lab, some participants expressed concern that there is lack of direct supervision provided to the learners and this might lead to some learners failing to operate in the virtual environment. Similar concerns were reported by Shorrt (2010). The following comments illustrate the concern of the teachers in this study:

> *"Although I find teaching with Virtual Lab advantageous in many respects, my concern is that we teach learners who are diverse in their cognitive abilities. For example, I found that mostly the self-motivated and mature learners could handle a virtual environment with little or no supervision and guidance. Since the Virtual Lab is also useful to allow learners to conduct experiments even outside school, I do not think that majority of my learners will be able to do that on their own. I picked that most of my learners really have difficult times understanding the language and the online learning skills" (Mpho)*

When probed by the researcher to explain further about the online learning skills, Mpho explained:

> *"What I mean is that most of my learners come from poor backgrounds where it appears that they never had access to technological gadgets. In short, I would say they just lack technological skills to be able to learn online using technology".*

Sharing the same view as Mpho, Clever further commented that:

> *"Apart from the fact that I cannot directly supervise my learners who might struggle operating the Virtual Lab in a manner that I would in a real lab, what I also find as a setback with the Virtual Lab is the lack of a lab partner too. A lab partner may facilitate*

peer-learning and in the absence of such, an important learning tool is lost because peer-learning is also critical in the learning experience".

As stated in Section 5.3, another data generation method used in this study is lesson observation. From the seven teachers who participated in this study, the researcher managed to observe three teachers from three out of four schools. These teachers are Bongi, Mpho and Debbie. As indicated in the previous chapter, there are different methods of observation that is, participant observation and non-participant observation. In this study, the researcher used the later method, where the researcher was only an observer and did not take part in the teaching process. The observation data were generated using a lesson observation tool (Appendix A3) that was designed by the researcher. The observation tool attempted to generate data on socio-interactions in the class and the teachers' TPACK.

The conclusive observation was that there were high levels of teacher to learner interactions in all the lessons observed on socio-interactions. The teachers encouraged learners to ask questions and other learners would volunteer to answer some of the questions. At the beginning of the lessons, the teachers first determined the learners' prior knowledge which is an important aspect of pedagogy. The teachers were able to give clear instructions and demonstrated to learners how to carry out the experiments using the Virtual Lab. As the lessons progressed, the researcher also observed that the teachers demonstrated and developed confidence in using the Virtual Lab to teach.

5.5.3 Enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments

In examining the enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments, data from semi-structured interviews, journal reflections and workshop discussions was used. During interviews and workshop discussions, the participants were asked to describe factors that they found enabling and constraining from their experience of having used Virtual Lab. Table 10 summarises the themes that emerged from the participants' responses.

Table 10: Enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments

Theme	Description
1	Convenience and accessibility
2	Safe environment for conducting experiments
3	Affordability
4	Top-class lab equipment and up-to-date reagents

Convenience and accessibility

An important feature of the Virtual Lab is that it can be operated from mobile devices such as tablets and smartphones and can be used in and out of school time. Because of this feature, the teachers unanimously pointed out that the Virtual Lab is a convenient platform to perform science practical experiments. This supports the findings of Arista and Kuswanto (2018), who investigated the potential of Vitual Lab application to improve learning independence and conceptual understanding. Results of their study indicated that Virtual Lab could be used both in and outside the school and could improve learners' learning independence. Similarly, the findings of this study also confirms the findings of Aliyu and Talib (2019), who studied Vitual Lab as a solution to challenges of conducting chemistry practicals in secondary schools in Nigeria, found that with Virtual Lab, teachers and learners do not need to be in a lab to conduct experiments. In this study, for example, Bongi had this to say:

> *"Unlike the real laboratory where my learners and I have to be physically present in a lab at specified times, with the Virtual Lab, we can carry out our experiments at our convenient time and place and do not need to be in a lab building that we don't even have at my school".*

Comments illustrating the benefits of convenience as perceived by the research participants were:

> *"Virtual Lab allows learners to work at their own pace and my slow learners will not be intimidated by the fast learners. Also, the Virtual Lab can allow my learners to repeat an*

experiment as many times as may be required for them to understand the experiment". (Bongi)

"In cases where I have to demonstrate an experiment to a larger group in class, Virtual Lab allows me to do so by simply using a data projector to project to the wall instead of moving from one small group to another. This serves me a lot of time". (Clever)

On accessibility of the Virtual Lab, another Bruce commented:

"What I find useful about the Virtual Lab is its ability to be accessed simultaneously from different locations in an unlimited way. This means that my learners can perform their experiments simultaneously even from their homes".

Bruce added that:

"Since the Virtual lab can be accessed by learners from their homes through mobile devices, this will ensure that learning of science practical experiments will not stop even when schools temporarily close due to the current COVID-19 pandemic".

The above comments by the teacher participants on the accessibility of the Virtual Lab support the findings of Castelló, Pellegrino, Argente, Gomez-Marquez, Gaudenz, Randall, Pereira, Alonso, Calvelo, Young, Acosta, Albarran, Gimenez, Sedraschi, Umpiérrez, Figares, Sagastizabal and Radmilovich (2020) in their study conducted in Uruguay, *'Real and Virtual Biological Science Living Laboratory for Science Teaching',* that that the Virtual Lab has the ability to be accessed simultaneously from different locations in an unlimited way. This means that many learners can perform their experiments simultaneously without having to be in the same physical space.

Safe platform for conducting experiments

One of the most emphasised enabling factors of teaching with Virtual Lab from the participants' responses is safety. The teachers acknowledged that the Virtual Lab eliminates the physical dangers that are associated with a real lab. Debbie, for example, explained:

> *"From my training as a Science teacher, I am aware that conducting experiments in a real science laboratory can expose learners to danger and those dangers cannot occur when using a Virtual Lab"*

When probed by the researcher to explain further on the nature of the danger, Debbie continued:

> *"The most common dangers that can occur in real labs happen especially when fire, flammable or corrosive chemical reagents or animal specimens are involved. Some of the dangers that might occur include burns, electrical shocks, gas leakages, adverse chemical reactions, and infections. In a Virtual Lab, all these lab accessories are virtual representations of the real ones and they do not cause any dangers that can happen in a physical lab".*

Mpho pointed out that:

> *"I have learnt that Virtual Lab enables learners to conduct experiments that could otherwise be too dangerous to perform in a real lab. For example, the Virtual Lab allows learners to simulate and understand behaviours of biotic or abiotic things at extremely high or low temperatures – environments which are too dangerous or impossible to create in a real lab".*

Candie indicated that:

> *"Virtual Lab also allows learners to visualise places that could be dangerous or impossible to visit, such as the deep ocean floors, high mountains and even outer-space".*

The comments above are in line with George and Kolobe (2014), who reported that Virtual Lab enables learners to conduct experiments that could otherwise be too dangerous to perform in a real lab. Later in the analysis, Tumelo raised a factor that he/she considered to be an important aspect of safety that the Virtual Lab can offer in the context of the COVID-19 pandemic. The teacher did not refer to the physical dangers that are associated with the traditional lab and eliminated by the Virtual Lab. The teacher had the following to say:

> *"With the current rising in COVID-19 infections in schools, I think when it comes to conducting science practicals the Department of Basic Education needs to promote use of Virtual Lab. This is because in a Virtual Lab there is no sharing of lab instruments as in the real lab where there is a risk of handling contaminated instruments or surfaces. In addition, unlike the real lab where learners must be in the lab building, with Virtual Lab learners can perform experiments even at home. This allows for physical distancing too and enables those learners that might be in isolation or quarantine to perform their experiments".*

Affordability of teaching using the Virtual Lab

The findings from the teachers revealed that conducting practical experiments in the Virtual Lab platform is much more affordable and that resource-constrained rural schools can make use of the Virtual Lab as an alternative to the real lab. This is supported by Diwakar, Radhamani, Sujatha, Sasidharakurup, Shekhar, Achuthan, Nedungadi, and Raman (2014), Gambari, Obielodan and Kawu (2017), Lestari and Supahar (2020). The following comments by the teacher participants show that the Virtual Lab is an affordable alternative to the conventional lab. These comments contradict the findings of Tatli and Ayas (2012), who indicated that the Virtual Lab is not as affordable. They argued that development of Virtual Lab and constant maintenance (i.e., debugging), the price of devices, instruments, servers, and expertise needed to develop the software and its updates could potentially be a major cost factor and this cost should be considered when deciding whether Virtual Lab is affordable. The following are the comments from the teachers in this study. Bruce, for example, stated:

"The reason why I do not teach practical experiments to my learners is because my school does not have a science lab. Even if my school had a science lab, I would still be unable to teach practical experiments because conducting lab experiments in real labs can be very costly especially for under-resourced rural schools such as mine. The cost arises from procurement of up-to-date lab equipment, maintenance of the equipment and constant replenishment of lab consumables. Virtual Lab experiments may be a great alternative to the physical lab in terms of lowering lab costs, while still providing good laboratory experiences".

In addition, Bongi explained:

"What I find helpful about the Virtual Lab experiments are that they are conducted within a virtual environment that uses simulations, this means that once developed, the simulations can function at no extra operational cost as many times as required. This is because in Virtual Lab applications, lab equipment do not wear out and chemical reagents do not expire. This feature of the VL allows learners from resource-constrained schools to be able to perform standard experiments which they would otherwise be unable to perform due to the cost associated with the real lab".

One of the teachers, Tumelo, expressed a concern that:

"The majority of my learners come from poor communities where their parents are farm workers who may not be able to buy the gadgets or smartphones that are needed to operate the Virtual Lab. Whilst I appreciate that Virtual Lab lowers running costs for the school, but the cost is exorbitant on the part of most parents to buy the gadgets".

To this concern, the researcher informed the teacher that the Eastern Cape Department of Education is in the process of rolling out tablets to all learners and that these tablets will have sim cards that will be loaded to a monthly allowance of 4GB of data. Hence, the parents will not be incurring any costs.

Top-class lab equipment and up-to-date reagents

Another enabling factor in the use of Virtual Lab that was reported by the participants is the availability of top-class lab equipment and up-to-date reagents in the Virtual Lab. Clever pointed out that:

> *"In my previous two schools we had real labs, but those labs, just like most rural schools, were equipped with out-dated equipment and expired chemicals which often gave inconsistent and inaccurate results. That's when I realised that in science experiments, modern instruments and up-to-date chemical reagents should be used and in this regard, the Virtual Lab is most ideal as it is more likely to give reliable results with minimum chances of error and reporting incorrect results because of the modern apparatus that it uses"*.

Lastly, Bruce stated that:

> *"Virtual experimentations have the benefit of reducing error because they use modern top-notch equipment. The modern instruments are very expensive that most rural schools cannot afford them. the Virtual Lab replaces the expensive real equipment with up-to-date simulated versions of the equipment*.

These statements indicate that the teachers find the Virtual Lab to be beneficiary in their teaching of science experiments in terms of vailability of top class laboratory equipment. This supports the findings of Triona and Klahr (2003) cited in Bhukuvhani, Kusure, Munodawafa, Sana, and Gwizangwe (2010) in their study on '*Pre-service teachers' use of improvised and virtual laboratory experimentation in science teaching'*, that virtual experimentations have the benefit of minimization of error due to the use of top-notch equipment. This also confirms the findings of Rani, Mundilarto, Warsono and Dwandaru (2019), in their study conducted in Indonesia *'Physics virtual laboratory: an innovative media in 21st century learning',* in which they found out that the Virtual Lab can replace the expensive real equipment with up-to-date simulated versions of the real equipment.

5.6 Conclusion

This chapter presented research findings from the data generated from seven research participants. Data generated through semi-structured questionnaires, semi-structured interviews, non-participatory observations, and journal reflections were all at the centre of this chapter. The data were examined as guided by the four research questions, which focused on: Perceptions and attitudes of Grade 11 Life Sciences teachers on use of ICT for teaching and learning , Pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments. Enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments. Ways in which Virtual Lab be used by Grade 11 teachers to mediate learning of scientific experiments using the topic *Energy transformations*. The results of the study, which are consistent with the methodology, have been clearly and correctly presented. The results were presented according to themes that emerged from the analysis of the data based on the research questions. The next chapter presents a discussion of this study's findings.

CHAPTER SIX

DISCUSSION

6.1 INTRODUCTION

The previous chapter reported on the findings of this study. In this chapter, the researcher presents a discussion of the findings. The findings are contrasted with prior literature that was reviewed in Chapter Two. The discussion of the results provides insights and shows originality by, like that of Lestari and Supahar (2020), detailing teachers' perceptions and experiences on the use of Virtual Lab to teach scientific experiments. This chapter is divided into three sections. It begins with (6.1) an introduction, followed by (6.2) a discussion of key findings, and lastly, (6.3) a conclusion.

6.2 Discussion of key findings

Overall, the objective of the study was to explore working *with* Grade 11 Life Sciences educators on making use of Virtual Lab to mediate learning of Energy transformations. To achieve the research objective, four research questions were asked, and these are summarised together with the research instruments in table 11 below.

Table 11: Summary of research questions and instruments used

Research Question	Research instrument
1. What are the perceptions and attitudes of Grade 11 Life Sciences teachers on use of ICT for teaching and learning?	Semi-structured questionnaire
2. What are the pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments?	Semi-structured interviews, Journal reflections, Lesson observations
3. What are the enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments?	Semi-structured interviews, Journal reflections, Lesson observations
4. How can Virtual Lab be used by Grade 11 teachers to mediate learning of scientific experiments using the topic *Energy transformations*?	Semi-structured interviews, Journal reflections, Lesson observations

The findings reported in chapter five are discussed in relation to research questions earlier summarised.

6.2.1 Perceptions and attitudes of Grade 11 Life Sciences teachers on use of ICT for teaching and learning

The findings of this study on the perceptions and attitudes of Grade 11 Life Sciences teachers on use of ICT for teaching and learning are encouraging. As indicated in the previous chapter, majority of the teachers are of the view that ICTs enhance teaching and learning. This can be seen in the teachers' responses from Questionnaire extract (Appendix A1) where Bongi, Mpho, Clever, Bruce and Candie all agreed and, in some cases, strongly agreed that: ICTs make teaching effective; ICTs help in improving learner performance; ICTs promote learner to learner interaction; ICTs help in improving learner performance; use of ICTs in teaching and learning can improve learners' critical thinking; knowing how to use ICTs by teachers is a good skill; ICTs reduce the teachers' administration burden; and that ICT-assisted instruction is more effective than the traditional method of instruction. The views of these teachers are consistent with the findings of Akkan (2012), Tatli, Z. and Ayas (2012), Herga, Grmek, and Dinevski (2014), George, and Kolobe (2014), Musawi, Ambusadi, Al-Balushi, S. and Al-Balushi, (2015), Bogusevschi, Muntean, and Muntean (2020), Monita and Ikhsan (2020) and Tobarra, Robles-Gómez, Pastor, Hernández, Duque and Cano (2020). These researchers focused on teacher attitudes towards using technology for teaching and reported positive teacher attitudes.

On the other hand, however, it should be noted that although the majority of the teachers demonstrated positive disposition towards using technology for teaching, two teachers, that is, Tumelo and Debbie, had different perceptions and attitudes. These teachers were of the view that ICTs are disruptive when teaching. This attitude explains why both Debbie and Tumelo disagree with the view that ICT-assisted instruction is more effective than the traditional method of instruction. The view that technology-enhanced teaching is not more effective than the traditional methods of instruction has been cited in previous studies (du Plessis and Webb, 2012; Rabah, 2015; Eshetu 2015; Young, 2016; Elemam 2016; and Ngoungouo, 2017) as the most important contributor to teacher resistance in adopting technology for teaching. For example, Ngoungouo (2017), in his study *'The use of ICTs in the Cameroonian school system: A case* *study of some primary and secondary schools in Yaoundé'* found that most teachers still believe that ICT-enhanced instruction is not more effective than the traditional chalk and talk instruction. This is contradicted by the findings of this study in that most teachers in this study believe that ICTs enhance the effectiveness of teaching.

6.2.2 Pedagogical and technological experiences of Grade 11 Life Sciences teachers in using Virtual Lab

When examining the pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments, this study's findings revealed both positive experiences and some disapproval from some teachers. From the findings, most of the teachers indicated that the Virtual Lab is an effective tool to teach experiments because it shortens the time required to teach the experiments. This observation is in the same direction with the findings of Rani, Mundilarto, Warsono and Dwandaru (2019), from their study conducted in Indonesia *'Physics virtual laboratory: an innovative media in 21st century learning',* in which they reported that with the Virtual Lab processes can be speeded up thereby shortening the time to see the results. Similar findings were also reported by Bogusevschi, Muntean and Muntean (2020) from their study *'Teaching and Learning Physics using 3D Virtual Learning Environment: A Case Study of Combined Virtual Reality and Virtual Laboratory in Secondary School'* conducted in Dublin, Ireland. On the contrary, however, Tatli and Ayas (2012) reject the finding of this study that the Virtual Lab shortens the time required to learn scientific experiments. They argue that the lack of direct supervision by a more experienced teacher in the Virtual Lab leads to longer time required to learn science concepts especially by slow learners. Like Tatli and Ayas (2012), Ateş and Eryılmaz (2011) also reject the findings of his study that the Virtual Lab enhances mediation of scientific experiments. They argue that the lack of 'hands-on' approach and absence of lab partner, as in conventional lab, also negatively affects the effectiveness of the Virtual Lab in mediating learning of science experiments.

In addition, one of the common technological experiences cited by majority of the teachers was that the Virtual Lab equipment and reagents can be altered and operated beyond the specifications of the manufactures. This is in line with the findings of Oliveira, Behnagh, Ni, Mohsinah, Burgess, and Guo (2019) who reported that Virtual Lab equipment can be operated in conditions beyond what the physical lab equipment can be used. This feature of the Virtual Lab is important because it may enable learners to understand the behaviour of experimental objects or organisms at extreme conditions.

As indicated earlier, this study also found some pedagogical limitations of using Virtual Lab as experienced by most teachers such as lack of 'hands-on' approach during Virtual Lab experimentation. This supports the finding of Akkan (2012) in his study *'VIRTUAL OR PHYSICAL: In-service and Pre-Service Teacher's Beliefs and Preferences on Manipulatives'* conducted in Turkey in which he reported that a major handicap of using Virtual Lab as compared to the physical lab is the lack of 'hands-on' practice by learners. The researcher pointed out that in a biology lab, for example, much is learnt from hands-on experience which the Virtual Lab cannot offer such as slide preparation (i.e., slicing, staining, and creating a microscope slide of a sample). Likewise, Ateş and Eryılmaz (2011), indicated that learners learn better when they measure, touch, feel, make charts, manipulate, draw, record data, interpret data and make their own conclusions. This study, however, asked the question: Is there experiential evidence to show that learners are at a disadvantage when they do not experience a hands-on lab? This question was answered by Oloruntegbe and Alam (2010) in their study conducted in Malaysia *'Evaluation of 3D environments and virtual realities in science teaching and learning: The need to go beyond perception referents'* who discovered that there was no statistical difference between mean score marks of post-tests of two groups of learners exposed to virtual and 'hands-on' experimentation. The lack of 'hands-on' experiences, therefore, may not be a pedagogical limitation after all. In fact, in the context of the global COVID-19 pandemic, this study suggests that the lack of 'hands-on' in Virtual Lab could indeed be a benefit in stemming the spread of the corona virus by not handling lab equipment that might be contaminated.

Lastly, from the findings of this study, the researcher noted that some teachers expressed concern that there is lack of direct supervision provided to the learners and this might lead to some learners failing to operate in the virtual environment. This concurs with previous findings of Akkan (2012), Tatli, Z. and Ayas (2012), Herga, Grmek, and Dinevski (2014), George, and Kolobe (2014), Musawi, Ambusadi, Al-Balushi and Al-Balushi (2015), Bogusevschi, Muntean, and Muntean (2020), Monita and Ikhsan (2020), and Tobarra, Robles-Gómez, Pastor, Hernández, Duque and Cano (2020). It is noteworthy from the findings of this study that although teachers raised the above concerns with the use of the Virtual Lab to teach experiments, the teachers, in general, however, expressed approval for the use of Virtual Lab in science teaching when considering the benefits that they have experienced in teaching with the Virtual Lab.

6.2.3 Enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments

Some of the enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments as investigated by Castelló, Pellegrino, Argente, Gomez-Marquez, Gaudenz, Randall, Pereira, Alonso, Calvelo, Young, Acosta, Albarran, Gimenez, Sedraschi, Umpiérrez, Figares, Sagastizabal and Radmilovich, (2020) in their study conducted in Uruguay, *'Real and Virtual Biological Science Living Laboratory for Science Teaching',* were confirmed in this study. For example, this study found that the Virtual Lab offers improved convenience and accessibility for conducting practical experiments. This is because, contrary to the physical laboratory where teachers and learners have to be physically present in the lab at specific times, with the VL, teachers and learners can conduct their experiments at their convenient time and place and do not need to be in a lab building. This is also consistent with the findings by Arista and Kuswanto (2018), who investigated the potential of VL to improve learning independence and conceptual understanding. Results of their study indicated that VL could be used both in and outside school and could improve convenience when conducting experiments. In addition, Aliyu and Talib (2019), studied VL as a solution to challenges of conducting chemistry practicals in secondary schools in Nigeria, and like this study, they also found that with VL, teachers and learners do not need to be in a lab to conduct experiments. On accessibility of the VL, the findings of this study concur with Martin and Parker (2014), in that VL could be accessed simultaneously from different locations in an unlimited way. This means that many learners can perform their experiments simultaneously without having to be in the same physical space. This also means that even learners from those schools that do not have real laboratories can still be able to conduct science practicals. This is particularly more important in maintaining social distancing by avoiding being in the same physical building in the context of the COVID-19 pandemic.

Another enabling factor that this study found in using Virtual Lab to mediate learning of scientific experiments is safety. All the seven teacher participants agreed that VL provides a safe environment for conducting experiments. Like Muhamada, Zaman and Ahmad (2012), and Aliyu and Talib (2019), the teacher participants in this study acknowledged that conducting experiments in real science laboratories can expose learners to danger especially when fire, chemical reagents or animal specimens are involved and that some of the dangers that might occur include burns, electrical shocks, gas leakages, adverse chemical reactions, and infections. The teachers further acknowledged that use of the VL eliminates the physical dangers that are associated with the use of the physical lab. This confirms the findings of George and Kolobe (2014), who, in their study on the exploration of the potential of using Virtual Lab for chemistry teaching at secondary school level in Lesotho, found that VL enables learners to conduct experiments that could otherwise be too dangerous to perform in a real lab. They also reported that VL allows learners to visualise places that could be dangerous or impossible to visit, such as the deep ocean floor and high mountains. This study suggests that the VL is not only safe against the physical dangers but could also be a safe environment against contagious pandemics such as the current COVID-19.

As far as affordability of using the Virtual Lab for teaching is concerned, the findings of this study contradict Tatli and Ayas (2012), who pointed out that using VL for teaching is very costly. They argued that development of VL and constant maintenance (i.e., debugging), the price of devices, instruments, servers, and expertise needed to develop the software and its updates could potentially be a major cost factor and this cost should be considered when deciding whether VL is affordable. On the part of learners in rural schools, the researcher had fears that most of them could be disadvantaged as they may not afford mobile devices and data. However, the experiences of the COVID-19 contagion have led the Government to fast-track provisioning of ICT tools for teaching and learning. For example, the Eastern Cape department of Education (ECDoE), has rolled out 72 000 sim cards loaded with 4GB of data per month and 55 000 Samsung 8″ tablets to learners. This means that learners would not pay for devices and data. On the other hand, this study confirms the findings of Diwakar, Radhamani, Sujatha, Sasidharakurup, Shekhar, Achuthan, Nedungadi and Raman (2014); Gambari, Obielodan and Kawu (2017), and Lestari and Supahar (2020), who indicated that VL experiments may be a great alternative to the physical lab in terms of lowering lab costs, while still creating good laboratory experiences. This is because in Virtual Lab experiments are conducted within a virtual environment that uses simulations, this means that once developed, the simulations can function at no extra operational cost as many times as required. In addition, in VL, equipment do not wear out and chemical reagents do not expire. This feature of the VL allows learners from resource-constrained schools to be able to perform standard experiments which they would otherwise be unable to perform due to the cost associated with the real lab.

Lastly on enabling factors of using the Virtual Lab to teach experiments, this study revealed that the availability of top-class lab equipment and up-to-date reagents is a feature that the teacher participants considered to be very important. Like Herga, Grmek and Dinevski (2014), the participants in this study appreciated the fact that in science experiments, modern instruments and up-to-date chemical reagents are necessary as they are more likely to give reliable results with minimum chances of error and reporting incorrect results. The participants further appreciated the fact that modern instruments are very expensive and that most rural schools cannot afford them and as a result many of the schools have out-dated lab equipment and expired chemical reagents, which have greater chances of yielding inaccurate experimental results. This is consistent with Rani, Mundilarto, Warsono and Dwandaru (2019), in their study conducted in Indonesia titled '*Physics virtual laboratory: an innovative media in 21st century learning'*, in which they found out that the VL has the benefit of replacing the expensive real equipment with top-notch and up-to-date simulated versions of the equipment. Furthermore, this study concurs with the view of teachers in the study conducted in Zimbabwe by Bhukuvhani, Kusure, Munodawafa, Sana, and Gwizangwe (2010) on *Pre-service teachers' use of improvised and virtual laboratory experimentation in science teaching*, in which they reported that virtual experimentations have the benefit of minimization of error due to the use of top-class equipment.

When examining the constraints of using Virtual Lab in teaching and learning practical experiments, this study did not find challenges except those discussed under pedagogical and technological experiences of teachers in using the Virtual Lab. The expected constrains as reported in previous studies where teacher resistance (du Plessis & Webb, 2012), poor connectivity (Rabah, 2015; Eshetu 2015 & Young, 2016), and electricity outages (Elemam 2016 & Ngoungouo 2017). These constrains, however, were not experienced in this sudy probably because the research sites and participants were purposively sampled as explained in Chapter four.

6.3 Conclusion

In this chapter, the findings of the study were contrasted with prior literature that was reviewed in Chapter Two. It is encouraging to note that the findings supported those of several previous studies as discussed above. It is also encouraging to see that not all is lost with regards to teacher attitude towards the use of ICT in general and Virtual Lab in particular, for teaching. Most of the teachers reported positive attitudes and experiences from the use of the Virtual Lab. It would also be interesting to examine how the Virtual Lab would impact on the performance of learners of the teacher participants. The next chapter presents the conclusions, and recommendations of the research study.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

The previous chapter offered a discussion of this study's findings. This final chapter presents an overall summary of this study. It begins with (7.2) a summary of the study, followed by (7.3) a summary of the study's chapters, and (7.4) a summary of the research findings. Next are (7.5) the limitations of this study and (7.6) a conclusion. This chapter concludes with (7.7) recommendations for practice, and (7.8) recommendations further studies.

7.2 Summary of the study

This study sought to explore working *with* Grade 11 Life Sciences teachers on make use of Virtual Lab to mediate learning of Energy transformations in rural resource-constrained secondary schools in Eastern Cape Province. To achieve this goal, the following research questions were asked:

1. What are the perceptions and attitudes of Grade 11 Life Sciences teachers on use of ICT for teaching and learning?
2. What are the pedagogical and technological experiences or insights of Grade 11 Life Sciences teachers in using Virtual Lab to mediate learning of scientific experiments using the topic *Energy transformations*?
3. What are the enabling and constraining factors of using Virtual Lab to mediate learning of scientific experiments using the topic *Energy transformations*?
4. How can Virtual Lab be used by Grade 11 teachers to mediate learning of scientific experiments using the topic *Energy transformations*?

The study was designed as qualitative research using a case study approach. The choice of a research design is important to establish the boundaries of inquiry and the ultimate success of a study. Reasons for choosing a qualitative research design and case study approach were discussed and justified. A purposive sampling method was used to select seven Life Sciences teachers from four secondary schools in Joe Gqabi district. The criteria for selecting the research sites and participants was sufficiently explained. This study employed the following research instruments: semi-structured questionnaires, semi-structured interviews, non-participatory observation, daily journal reflections and field notes. The instruments were guided by the constructs of Vygotsky's (1978) socio-cultural theory, and Thompson and Mishra's (2006) Technological, Pedagogical, Content Knowledge (TPACK) theory, as theoretical and analytical frameworks, respectively. The choice of using these theories in this study was explained and justified. Results were thematically analysed, and the emerging themes were noted.

7.3 Summary of the study chapters

Chapter One of the study presented the context and background, which provided the overview of the study. In this chapter, the problem statement and research question were clearly stated and the importance of these was justified. Furthermore, the purpose and significance of this study were adequately explained in this chapter. In addition, important terms were defined to provide their contextual application.

Chapter Two drew on the latest and most relevant literature related to the study. The research questions from chapter one directed the literature review process. Literature reviewed was drawn from authoritative electronic databases such as Google Scholar, Science Direct and Web of Science. Scarcity of literature on Virtual Lab in South African context led to the review of literature mostly from the international context. Literature reviewed focused on Virtual Lab in Science teaching in secondary schools, and science practical experiments. Literature showed that although significant research has been done on use of Virtual Lab for teaching science experiments, most of the work was done in university context and very little done in secondary school level in rural context. Lastly, most of the literature reviewed showed that using the Virtual Lab enhanced the teaching of science experiments.

Chapter Three discussed the theoretical and analytical frameworks that underpinned this study. A theoretical framework grounds a study and directs or guides the questions asked, the research design, and the methodology used (Hartmann, Wieland and Vargo, 2018). On the other hand, an analytical framework provides a way of capturing and interpreting data to deduce meaningful results and make sense of them (Goos, 2003). It forms a reference point for the interpretation of the research findings (Mpofu, Otulaja and Chikunda, 2013). Shepherd and Suddaby (2017), posits that an analytical framework provides focus to the research, determines data collection and structures data analysis. It provides a lens or a frame of seeing the research questions for the researcher to argue from a certain standpoint and thus make sense of the research findings (Jaakkola, 2020). This chapter presented Vygotsky's socio-cultural theory and TPACK theory, as theoretical framework, and analytical framework, respectively. The chapter also explained the rationale of choosing these theories and their applications in this study. Furthermore, this chapter reviewed RAT and SAMR model as potential frameworks that could have been chosen and highlighted reasons why these models where not used in this sudy. Lastly, the researcher concluded this chapter by acknowledging the limitations of the TPACK that was used as the analytical framework.

Chapter Four provided an account of the research design used, locating it within the interpretive qualitative research paradigm using a case study approach. The decision to use the qualitative design through a case study approach was discussed and justified. The sample size and sampling criteria were also explained and justified. In addition to this, the strengths of the data generation methods used was explained and shortcomings were also acknowledged. Data generation methods used were semi-structured questionnaires, journal reflections, field notes, observations, and semi-structured interviews. This chapter clearly showed how the study is consistent and coherent, for example, how the methodology is appropriate to the research question, as well as how the design and execution of the methodology is adequate in relation to the research questions and data analysis. In addition, the chapter discussed the thematic data analysis process, and triangulation, and research evaluation which focused on trustworthiness, credibility, transferability, and confirmability. The chapter concludes by addressing ethical considerations of this study.

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

Chapter Six presented a discussion of the findings of the study. The findings were contrasted with prior literature that was reviewed in Chapter Two. Previous findings that are consistent with the findings of this study were cited and those previous findings that the findings of this study contradicted were also acknowledged. The discussion of the results shows insight and originality by suggesting implications and making recommendations that are applicable and useful. The research questions are comprehensively answered in this chapter, and the conclusions that the study comes to are justifiable in terms of methodology and the applicable results presented and discussed in this chapter.

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

7.4 Summary of key research findings

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

7.4.1 Perceptions and attitudes of teachers towards the use of ICT for teaching and learning

This study found that most teachers had positive perceptions and attitudes towards the use of ICT for teaching and learning. The teachers believe that ICTs enhance the quality of teaching and learning. The study also found that few teachers still hold the view that the use of ICTs does not significantly contribute to enhanced teaching and learning due to low ICT skills by teachers. Overall, the study concluded that the integration of ICT into teaching and learning is largely embrased by most teachers.

7.4.2 Pedagogical and technological experiences of Grade 11 Life Sciences teachers in using Virtual Lab

In examining the pedagogical and technological experiences of the teachers in using the Virtual Lab to mediate learning of scientific experiments, the key finding that emerged is that the teachers had positive experience in teaching with the Virtual Lab. The teachers indicated that the use of the Virtual Lab has several benefits which include shortening the time required to teach experiments, and that the Virtual Lab equipment can be manipulated to suit the requirements of the teacher. On the hand, it is worth noting that the study also found that using the Virtual Lab has some disadvantages such as lack of 'hands-on' approach, and lack of direction supervision by a more knowledgeable teacher.

7.4.3 Enabling and constraining factors in using the Virtual Lab to teach science experiments

When exploring the enabling and constraining factors in using the Virtual Lab to teach, it was encouraging to note that the Virtual Lab has several enabling factors. These include that it offers convenience and more accessibility; provides a safe environment to conduct experiments that would otherwise be too dangerous to carryout in a conventional lab; and availability of top-class lab equipment and up-to-date reagents. The study did not find any constraining factors except those reported under pedagogical and technological experiences of the teachers in using Virtual Lab to teach.

In summary, the current study has contributed to the research about the use of Virtual Lab in the context of teaching scientific experiments in rural secondary school. The findings of this research have given more attention to the use of Virtual Lab to increase and encourage the use of Virtual Lab by Life Science teachers.

7.5 Limitations of the study

While a lot of care and rigor was applied in the preparation and conduct of the study, there are limitations which should be acknowledged by the reader.

- The sample size used in the study was adequate. However, because purposive or convenience sampling was used instead of random sampling, the result cannot be generalised to all schools in the country (only limited to the seven teacher participants and four schools).

- Moreover, this study was conducted in a resource-constrained rural school context. Therefore, the findings of this study cannot be generalised to resource-privileged schools.
- Furthermore, the period of data generation for this study was affected by the period of lockdown due to the COVID-19 pandemic. This is because the Eastern Cape department of Education suspended all visits to schools to curb the spread of the deadly corona virus. The suspension was only lifted in August, a time when teachers where busy preparing for preparatory and final NSC examinations. This meant that only three in-class lesson observations could be conducted.

7.6 Conclusion

This study explored working with Grade 11 Life Sciences teachers on make use of Virtual Lab to mediate learning of science experiments. The study falls within an interpretive qualitative paradigm, using a case study approach. The data generation methods used were semi-structured questionnaires, semi-structured interviews, non-participatory classroom observation schedules, journal reflections, and filed notes. Seven Life Sciences teachers participated in the study. The findings of the study indicated that the use of Virtual Lab improves the teaching of scientific experiments. This study concluded that using the Virtual Lab enhances the quality of teaching scientific experiments in the selected under-resourced rural secondary schools.

7.7 Recommendations for practice

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

- Teachers need to be given sufficient training on how to use ICT with the teaching and learning process to acquire the requisite knowledge and skills in integrating technology into classrooms. The training should not be a once-off training but a continuous process. Training should not be limited to how to use technology but should also show teachers how they can make use of technology in improving the quality and effectiveness of their instruction, as well as how such technology resources can be effectively integrated into teaching and learning. The training provided should be well structured and must assist teachers to not only develop ICT skills but also to be able to fully integrate ICT into classroom practice, that is, the training should develop the teachers' TPACK as a whole.

- Administrative support is needed for the successful integration of ICT into teaching and learning processes. Policy makers need to provide conditions that are needed, such as ICT policies, incentives, and resources. The number of technology gadgets should be increased, and their use encouraged within the classroom.
- It is important for all teachers to know the existence of ICT facilities and services and their importance in relation to their teaching tasks.
- Awareness campaigns need to be put in place to make teachers and school managers to be aware of the potential benefits of using Virtual Lab to teach.

7.8 Recommendations for further studies

- Use of Virtual Labs is a relatively newer concept in science education. Its utilisation was adopted firstly in the developed world to address many issues school face such as lack of physical laboratory infrastructure and high cost of lab maintenance. However, research on its effectiveness in learner achievement is in its infancy. Understanding the impact of Virtual Labs on learner achievement at secondary school level is critical to inform the adoption of the Virtual Labs. This study only explored the use of Virtual Lab for teaching from the perspective of the teachers and did not investigate the experiences of learners in using the Virtual Lab for learning. Therefore, further research should be geared towards exploring with learners on make use of Virtual Lab to *learn* scientific experiments.
- In addition, this research was designed as qualitative. Future research could employ a mixed-method approach involving both qualitative and quantitative designs. The quantitative design aspect would help to better quantify learner achievement in terms of analysing performance in pre-tests and post-tests. It is, therefore, recommended that further research be exercised to empirically determine if there is any impact of Virtual Lab on learner achievement, whether positive or negative.
- The use of Virtual Lab science subjects has proven to provide safe environment for conducting experiments, convenience and accessibility, positive teacher and learner attitudes and improvement on learner performance, elimination of physical limitations of a real lab and availability top-class lab equipment and up-to-date reagents. Likewise,

traditional labs also have benefits such as providing learners with experiences that involve concrete hands-on manipulation of physical materials which are essential for learning, availability of lab partners and peer-learning, and availability of direct supervision by a more knowledgeable facilitator. Weighing the advantages and disadvantages to choose between Virtual and traditional labs could be difficult because this can be, to a certain extent, subjective.

- If Virtual Labs and traditional labs both offer valuable benefits, possibly the use of "hybrid" labs may offer a viable option. These labs could exploit the best of both laboratory instructional types: Virtual Labs and traditional labs. For example, for the Virtual Labs that perhaps lack pertinent content or do not link with the lesson material in a robust way, demonstrations, models, observation, etc., may be added to the hybrid lab teaching. bring in a more "hands-on" approach and have a positive impact on learner achievement. The traditional side of the hybrid laboratory would not have to be time consuming or costly. Therefore, further research is also needed to investigate the effectiveness of using the 'Hybrid Lab' for teaching and learning of science experiments.
- In conclusion, it must be acknowledged that this piece of research has just scratched the surface on use of Virtual Lab for mediating learning of scientific experiments. It is hoped that more studies of an empirical nature will be conducted at macro levels (district, provincial or national) with a larger sample teachers and learners to produce more detailed and generalisable findings.

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APPENDIX A1: Semi-structured questionnaire

Date: __________________
Phone: ________________
Email: _________________

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

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

SECTION A: BACKGROUND INFORMATION
Please indicate your gender by ticking an **(x)** in the spaces provided.

Male	
Female	

Please indicate your highest qualification by ticking an **(x)** in the spaces provided.

Masters Degree	
Honours	
Bachelors Degree	
Post-matric Diploma	

How many years of work experience do you have in teaching Life Sciences? Indicate by ticking an **(x)** in the spaces provided.

Less than 6 months	
6 months to 2 years	
2 years to 5 years	
5 years to10 years	
More than 10 years	

SECTION B: AVAILABLE INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTs) INFRASTRUCTURE AT SCHOOL
For the purposes of this study, ICTs refers to technology used in teaching and learning, such as tablets, computers, the internet and data projectors.

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

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

Available for teaching and learning	**Yes [1]**	**No [2]**
1. A computer laboratory		
2. Computers/laptops for teachers' use		
3. Internet connectivity		
4. Tablets		

Comment on any issues raised above
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SECTION C: TEACHER COMPETENCE AND ICT INTEGRATION INTO TEACHING AT SCHOOL

1. Information and communication technologies (ICTs) competency

   Rate your level of ICT skills by putting an **(X)** under the appropriate heading.

	Excellent 5	**Good** 4	**Fair capability** 3	**Low capability** 2	**No capability** 1
1. Word Processing (e.g. Use of programs like MSWord)					
2. Spreadsheets (e.g. Use of programs like excel)					
3. Presentation tools (e.g. Use of programs like PowerPoint)					
4. Emailing					
5. Internet browsing					

Comment on any issues raised above
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5. How often do you use the following computer applications in your teaching? Put an **(X)** under the appropriate heading.

Computer applications	**All the time 5**	**Often 4**	**Sometimes 3**	**Seldom 2**	**Never 1**
1. Use of presentation tools (e.g. PowerPoint)					
2. Use of simulation programmes (e.g learners carrying on experiment on photosynthesis)					
3. Use of internet browsing					
4. Use of multimedia (e.g Windows Media Player or VLC)					
5. Use of the spreadsheets (e.g. excel)					

Comment on any issues raised above

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6. To what extent do you integrate information and communication technologies (ICTs) when teaching? Indicate your response with an **(X)** appropriately.

ICTs integration	**To a large extent 4**	**To a reasonable extent 3**	**To a small extent 2**	**Not at all 1**
1. I am aware of ICTs available for teaching and learning				
2. I use various ICTs in my teaching				
3. I have access to ICTs that I use in my teaching and learning				
4. I know how to integrate ICTs in my teaching and learning				
5. I use ICTs to actively engage learners				
6. I use ICTs to promote learner to learner interaction (e.g. interaction between learners) during the lesson				

7. I have adequate ICT skills to enable me to use technology in my teaching and learning				

Comment on any issues raised above

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SECTION D: TEACHER PERCEPTIONS AND ATTITUDES ON ICT INTEGRATION FOR TEACHING

1. Your perceptions and attitudes on ICTs adoption and use in the classroom?

   Please respond by putting an **(X)** to indicate your level of agreement from strongly agree to strongly disagree

	Strongly agree 5	**Agree 4**	**Uncertain 3**	**Disagree 2**	**Strongly disagree 1**
1. ICTs are disruptive when teaching					
2. ICTs make teaching effective					
3. ICTs promote learner to learner interaction					
4. ICTs help in improving learner performance					
5. Use of ICTs in teaching and learning can improve learners' critical thinking					
6. Knowing how to use ICTs by teachers is a good skill					
7. ICTs reduce the teachers' administration burden					
8. ICT-assisted instruction is more effective than the traditional method of instruction.					
9. ICTs help teachers save time during lesson					

preparation					
10. Use of ICTs puts more work on teachers					
11. ICTs arouse learner curiosity in the learning process					
12. ICTs engage learners' attention and motivate them					
13. Use of ICTs in teaching is enjoyable					
14. Using ICTs in teaching is difficult					
15. I am hesitant to use ICTs in teaching and learning					

Comment on any issues raised above

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16. How often do you practise the following in your lessons? Indicate by putting an **(X)** appropriately.

	Always 5	**Often** 4	**Sometimes** 3	**Lesser extent** 2	**Not at all** 1
1. I select ICTs which best suit the content that I will be teaching					
2. I use ICTs in my lessons to facilitate higher order thinking skills, including problem solving and decision making					
3. I use ICTs to engage learners with work that requires investigation of complex questions over a long period of time					
4. I adapt my teaching methods					

to suit different learners when teaching using ICTs					
5. When I teach, I use methods which encourage learners to create knowledge through ICTs					
6. I use ICTs in teaching and learning without anyone's help					

Comment on any issues raised above

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SECTION E: BARRIERS/CHALLENGES IN THE ADOPTION AND USE OF ICTs IN TEACHING AND LEARNING

1. How important are the following barriers to the adoption and use of ICTs in your school? Indicate by putting an **(X)** appropriately.

	Not an important barrier at all 5	**Less important barrier 4**	**Important barrier 3**	**High important barrier 2**	**Very high important barrier 1**
1. Inadequate training on ICT use in the teaching of my particular subject					
2. Limited supply of electricity					
3. Limited access to high speed internet					
4. Lack of educational software for my particular subject					
5. Lack of time					
6. Limited					

support from the school management team					
7. Negative teacher attitudes towards the use of computers in teaching and learning					
8. Challenges to integrate ICTs in teaching					
9. Lack of confidence to use ICTs in teaching					
10. Lack of motivation to use ICTs in the classroom					

Comment on any issues raised above and/or suggest possible solutions to the challenges that you are facing in the integration of ICT in your school.

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APPENDIX A2: Journal Reflection on daily activities

Instruction: Please reflect on the following points

1. Briefly outline what you have you learned so far from your participation in the study

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2. Could you please explain how you introduce the topic Energy transformation using Virtual Lab

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2. Please indicate what do you do to make learners understand what you teach using Virtual Lab

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3. Please write about how you know that learners have understood what you have you have taught

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4. Briefly explain your views on the need to make use of Virtual Lab in mediation of learning of Life Sciences

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5. Briefly highlight what you find as enablers and constraints in making use of Virtual Lab in mediation of learning of scientific experiments

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APPENDIX A3: Observation tool

Part A (Teachers Profile)

Current profession…………………………Position………………………
Age ………   Gender………………………
Years of teaching experience…………….. Grades………………………
Subjects………………………………………………………………………
Place of employment ………………………Region………………………..

Socio- interactions	
Measure	**Notes**
Teacher- Learner interactions.	
Learner activities promote participation.	
Learner's opinions considered	
Questions and responses from learners considered.	
Teacher encourages learners to participate.	
Teacher allows learners to talk more.	
Teacher's Pedagogical Knowledge	
Measure	**Notes**
Consider learner's prior knowledge	
Teacher demonstrates to learners how to carry out experiments using Virtual Lab	
Teacher's clarity of instructions	
Teacher ensures that no learner is failing to	

carry out experiments using Virtual Lab	
Teacher's Technological & Pedagogical Knowledge	
Measure	**Notes**
Teacher selects and makes use of appropriate technologies that are suitable for the content	
Teacher demonstrates confidence in using Virtual Lab to teach	
Teacher uses Virtual Lab with little or no problems	

Observer's name______________________ Date ___________ Signature____________
Teacher's name_______________________ Date___________ Signature ____________

APPENDIX A4: Semi-Structured Interview

Conducted at the end of the interventional study to collect data on teachers' pedagogical and technological experiences on use of Virtual Lab.

1. In your lesson presentation of the topic Energy transformation how did you use Virtual Lab to enhance understanding of the scientific method to your learner?

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2. What did you find challenging in your use of Virtual Lab in teaching Energy transformations?

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3. Based on your experience of using Virtual Lab to teach, what do you think was advantageous and what do you think was disadvantageous about the use of Virtual Lab in your teaching?

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4. Do you feel the use of Virtual Lab has made your teaching of scientific experiments using the topic Energy transformation easier? Explain your answer.

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5. From your experience of teaching using Virtual Lab, what factors do you think.

   (a) Can you encourage teachers to use Virtual Lab in their teaching?

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   ……………………………………………………………………………………………
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(b) Inhibit teachers from using Virtual Lab in their teaching?

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6. Was the training on use of Virtual Lab prior to your interaction with learners adequate for you to teach using Virtual Lab? Explain.

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7. In your view, what do you think should be done to make effective use of Virtual Lab in teaching of sciences subjects in general and Life Sciences in particular?

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8. Do you think Virtual Lab should be used in teaching of scientific experiments? Give reasons for your answer.

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9. What are your views about how technology influences teaching?

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

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APPENDIX B1: Letter to teachers (Participants)

Dear Sir/Madam

Re: Participation in research on make use of Virtual lab to mediate learning of *Energy transformations* of Grade 11 Life Sciences.

I Brian Shambare, a part-time student doing Master of Education in ICT in Education with Rhodes University, Student number 19S3620, hereby humbly request your permission to be a research participant in my research project. I plan to conduct the study for about six weeks in July/August 2020.

The focus of the study will be on *use of Virtual Lab in mediation of learning of scientific experiments* and it will be conducted in six phases. The first phase will involve me requesting you to complete a questionnaire. This to find out your views and attitudes towards use of ICT for teaching and learning. In phase two there will be an orientation workshop of which I am going to give an overview of the study and also demonstrate to you how to use Virtual Lab to mediate learning. Phases 3, 4 and 5 will involve myself observing you as you make use of Virtual Lab in mediation of learning in your classroom. On the last workshop we will reflect on our pedagogical and technological experiences of using Virtual Lab in the classroom.

Your participation in this research study is completely voluntary and you can withdraw at any time you wish. I ask for your permission to take videos of the demonstrations so that I can be able to analyse the data later. I will ensure that your identity and views will be treated with high degree of confidentiality and anonymity, and data that will be collected will not be used for other purposes apart from this study.

This research has been approved by both the Rhodes University Ethical Standards Committee and the Education Department Higher Degrees Committee. During the research any concerns may be directed to Mr Siyanda Manqele, Ethics Coordinator, Research Office, Rhodes University +27 (0) 46 603 7727, s.manqele@ru.ac.za

If you have any question about the research, please feel free to contact me at 073 541 4193, brianshambare@gmail.com or my supervisor Doctor C. Simuja c.simuja@ru.ac.za.

Consent: I am aware that

- I will be the participant for the above-mentioned topic.
- I am willing to be interviewed and make time for it.
- I am free to withdraw at any time I may wish without negative or undesirable consequences.
- The information provided will be used only in the research project.
- I am also aware that the information provided by me will be strictly confidential and the findings will be reviewed in the research thesis.

- My identity in this study will be protected with the code of ethics stipulated by Rhodes University
- Having taken note of the above information, I freely and volunteer to take part in the research process and acknowledge that I have not been forced to do so.

Declaration

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

Signature of participant …………………………………………. Date……………………….

Yours Sincerely
Brian Shambare
Master of Education in ICT in Education

APPENDIX B2: Letter to School principal

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

The principal

Dear Sir /Madam

Re: Request for permission to conduct educational research *with* Grade 11 Life Sciences teachers in your schools on make use of Virtual lab to mediate learning of *Energy transformations* through scientific experiments.

I, Brian Shambare, a part-time student doing Master of Education in ICT in Education with Rhodes University, Student number 19S3620. I am a Subject Advisor (SES) for Life Sciences in Joe Gqabi district. I hereby humbly request your permission for me conduct a research study with ten teachers from ten schools in your district. The participants will be engaged outside the normal teaching time to protect teaching time. I plan to conduct the study for about six weeks in September/October 2020.

The DBE Diagnostic report of 2019 states that "An area of poor performance in Life Sciences remains the questions on scientific investigations, as evidenced once again in Papers 1 and 2 of 2019". The same observation was also reported in previous diagnostic reports of 2012 to 2018. This trend is worrying especially that the Curriculum and Assessment Policy Statement (CAPS) directs that learners must be able to plan and carry out investigations as well as solve problems that require some practical ability (DBE, 2011). However, mediation of learning of science has been restrained by the deficiency or inadequacy of laboratory equipment in schools. There is therefore a need for a new unconventional alternative laboratory environment where learners can conduct required experiments. One of the solutions can be the use of Virtual Laboratories as an ICT tool. Virtual Lab involves interactive multimedia objects that simulate traditional laboratory experiments into a computer as computer software. International research has shown that use of Virtual Lab can offer learners the opportunity to investigate situations that cannot be tested in real time by speeding up or slowing down time, conduct experiments that would be too dangerous to perform in traditional lab and eliminate the need for physical lab equipment.

This research has been approved by the following institutions: the Rhodes University Ethical Standards Committee, the Rhodes University Education Department Higher Degrees Committee, The Eastern Cape Department of Education (Chief Director – Corporate Planning, Monitoring, Policy and Research Coordination), and the Offices of the Cluster Chief Director, District Director and Chief Education Specialist – Curriculum, have been informed of this research. During the research any concerns may be directed to Mr Siyanda Manqele, Ethics Coordinator, Research Office, Rhodes University +27 (0) 46 603 7727, s.manqele@ru.ac.za

Thus, this interventional study aims to explore working *with* teachers in your schools on make use of Virtual Lab to mediate learning of scientific experiments in science. The study is under the supervision of Doctor Clement Simuja (E-mail: c.simuja@ru.ac.za).

I would further like to assure your office that, should I be granted permission, the research ethics will apply throughout the process of the study. Identity of participants and their views will be treated with the highest degree of confidentiality and anonymity.

Declaration by School Principal

I……………………………………………………. (full name and surname of Principal) hereby confirm that I give permission to the researcher to conduct the study with a teacher in our school.

Signature of Principal…………………………………………. Date……………………….

SCHOOL STAMP

Yours Sincerely

Brian Shambare (Master of Education in ICT in Education)

APPENDIX C1: Study Approval Letter

Province of the
EASTERN CAPE
EDUCATION

CORPORATE PLANNING MONITORING POLICY AND RESEARCH COORDINATION
Steve Vukile Tshwete Complex • Zone 6 • Zwelitsha • Eastern Cape
Private Bag X0032 • Bhisho • 5605 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)40 608 4537/4773 • Fax: +27 (0)86 742 4942 • Website: www.ecdoe.gov.za

Enquiries: B Pamla Email: babalwa.pamla@ecdoe.gov.za Date: 31 July 2020

Mr. Brian Shambare

P.O. Box 92718

Mount Frere

5090

Dear Mr. Shambare

EXPLORING WORKING WITH GRADE 11 LIFE SCIENCES EDUCATORS ON MAKE USE OF VIRTUAL LAB TO MEDIATE LEARNING OF ENERGY TRANSFORMATIONS

1. Your application to conduct the above mentioned research involving four schools under the Joe Gqabi District 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. no minors will participate;

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

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

    f. no physical contact with educators and learners, only virtual means of communication should be used and that should be 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;

building blocks for growth

PGDP EASTERN CAPE

Ikamva eliqaqambileyo!

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 the Mrs. B Pamla on the numbers indicated in the letterhead or email babalwa.pamla@ecdoe.gov.za should you need any assistance.

T MASOEU

CHIEF DIRECTOR: CORPORATE STRATEGY MANAGEMENT

FOR SUPERINTENDENT-GENERAL: EDUCATION

APPENDIX C2: Ethics Clearance Letter

RHODES UNIVERSITY
Where leaders learn

Education Faculty
P.O. Box 94, Grahamstown, 6140, South Africa
t: +27 (0) 46 603 8393
f: +27 (0) 46 603 8028
e: e.rosenberg@ru.ac.za
www.ru.ac.za

15/10/2020

Dr Clement Simuja

Education Department

C.Simuja@ru.ac.za

Dear Dr Clement Simuja and Mr Brian Shambare

Research Ethics Approval for the M.Ed study **"Exploring working with Grade 11 Life Sciences educators on make use of Virtual Lab to mediate learning of Energy transformations"**

I hereby grant full research ethics approval for the above M.Ed research study.

The application has been reviewed by three senior staff and tabled at the Education Faculty Ethics Clearance Committee meeting of 18 June 2020. The letters indicating permission from the Eastern Cape Department of Education and the school principals have been received and you may proceed with the study.

Approval is granted for one year. A progress report will be requested in order to renew approval at the end of 2020. An e-mail reminder will be sent in this regard to your Rhodes-registered address.

Please notify the Committee Chair should any substantive change(s) that deviate from this application, be made during the research process. Please also provide a brief report to the Committee on the completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, or if any problems arose that the ethical standards committee should be aware of. If the research results in the completion of a thesis lodged in the Rhodes University Library, please provide the Committee with the details of the submission as well.

The Ethics Clearance Number for this study is 2020-1515-3520. Kindly safeguard this approval letter for the duration of your study, and for publication purposes.

Sincerely,

Sincerely,

Prof Eureta Rosenberg

Chair: Education Faculty Research Ethics Committee

Page 1 of 1