IMPACT OF VIRTUAL LABORATORY DELIVERY ENVIRONMENT ON GRADE 11 LEARNERS' LEARNING OUTCOMES IN PHYSICAL SCIENCES: A CASE OF TWO LOW PERFORMING SCHOOLS IN OR TAMBO INLAND

by

MUTHANDWA CHINAMHORA SINCUBA

A dissertation submitted in fulfillment of the requirements for the degree of

MASTER OF EDUCATION (MEd)
(Science Education)

at

WALTER SISULU UNIVERSITY

SUPERVISOR: DR CD MANTLANA

AUGUST 2020

ABSTRACT

This study sought to investigate the impact of Virtual Laboratory Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland. The virtual laboratory delivery environment is an educational innovation and conventional teacher expository method in terms of learners' academic achievement in science, their acquisition of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise. The impact of such virtual laboratories was also explored in terms of the learners' attitudes towards Physical Sciences. A mixed research approach was adopted, and a quasi-experimental non-equivalent and case study research designs were adopted. 83 learners from two historically disadvantaged selected schools participated in the study. Pre-post-tests were administered to both the Experimental and Control groups to collect data on conceptual development and proficiency in the acquisition of techniques and practical expertise. A focus group interview was also used to qualitatively collect data from the group that received virtual laboratory delivery environment intervention. Data were quantitatively analyzed using Microsoft Excel, descriptive and inferential statistics and Statistical Package for the Social Sciences (SPSS) Version 22. Responses from focus group interviews were qualitatively analyzed using thematic analysis. These are some of the findings: Virtual laboratory delivery environments have a positive impact on Grade 11 learners' learning outcomes in Physical Sciences; add some more findings. It is recommended that research can be undertaken using a larger sample of schools and participants. Secondly, different activities enhanced by virtual laboratory delivery environments during teaching and learning, for example, lesson delivery, manipulation of apparatus during experiments, discipline of learners and assessment of learners to enhance quality have not been addressed in full. Therefore, it is recommended that further research should entail in-depth practical work observations to reveal if the virtual laboratory delivery environments impact positively on learners' learning outcomes in Physical Sciences.

Keywords: virtual laboratory delivery environment; conventional teacher expository method; learning outcomes; academic achievement; proficiency; sciences techniques and practical expertise; learners' attitudes.

DECLARATION

I, MUTHANDWA, CHINAMHORA SINCUBA, a Master of Education student in the Faculty of Educational Sciences at Walter Sisulu University, solemnly declare that the dissertation titled, 'Impact of Virtual Laboratory Delivery Environment on Grade 11 Learners' Learning Outcomes in Physical Sciences: A Case of two low performing schools in OR Tambo Inland' is my original own work. It is the product of my efforts through the profound professional guidance of my supervisor, whose name and signature appear below. All sources and resources used have been indicated and acknowledged by means of complete references, as per guidelines provided by Walter Sisulu University.

m.csincuba ____________ _23 AUGUST 2021_

MUTHANDWA CHINAMHORA SINCUBA Date

CANDIDATE

CDMantlana

____________________________ _23 AUGUST 2021_

DR CD MANTLANA Date

SUPERVISOR

PLAGIARISM DECLARATION

1. I am aware that plagiarism is defined at Walter Sisulu University (WSU) as the inclusion of another‵s or others' ideas, writings, works, discoveries and inventions from any source in an assignment or research output without the due, correct and appropriate acknowledgement to the author(s) or source (s) in breach of the values, conventions, ethics, and norms of the different professional, academic and research disciplines and includes unacknowledged copying from intra- and internet and peers/ fellow learners.
2. I have duly and appropriately acknowledged all references and conformed to avoid plagiarism as defined by WSU.
3. I have made use of the citation and referencing style (Harvard referencing style) stipulated by my supervisor.
4. This submitted work is my own.
5. I will not allow anyone to copy my work and present it as his/her own.
6. I am committed to uphold academic and professional integrity in the academic/ research activity.
7. I am aware of the consequences of engaging in plagiarism.

m.csincuba ___23 AUGUST 2021_

Signature Date

ACKNOWLEDGEMENTS

I wandered into this journey with a thought for what I wanted to accomplish, but had no way of knowing all that it would take to achieve my goal. Many people brightened my path, and I am so grateful to them.

Firstly, I want to thank the Divine Creator for leading me on a path toward my calling, for opening doors, placing these people along my path and sustaining me through it all.

Secondly, it was through the concerted efforts of many people that this dissertation has been successfully completed. As such, I wish to put on record my sincere thanks and profound appreciation to all those who rendered me assistance.

- To my supervisor, Dr CD Mantlana. You guided me, nudged me, challenged me, showed me my strengths, exposed my weaknesses and encouraged me. Most of all, you helped me find my voice. Thank you for your enduring professional guidance, understanding, patience, kindness and meticulous attention devoted to this study even after working hours.
- I also acknowledge Dr M John who guided me at the beginning of this MEd dissertation journey.
- I also wish to thank the following:
    - ➢ The WSU Directorate of Research Development for generously funding this research project.
    - ➢ The WSU academic personnel, libraries and administrative personnel who in various ways facilitated the means necessary to carry out the study.
    - ➢ The DBE personnel, principals of the research sites, staff, participants and their parents and/or guardians for their co-operation while I was conducting this research. This study would not have been possible without them.

- My father, brothers, sisters and the extended family for contributing a considerable amount to my progress in life.
- My in-laws for prayers and encouragement throughout this study.

- I am also greatly indebted to my wife, Limkani and my children, Nokulunga and Mbongeni for being an inspiration and putting up with my tight work schedule many times.

DEDICATION

This study is dedicated to my beloved ones who passed on, Sister Maria Benita Goller CPS, my mom, Elda Ndimande and brother in-law, Nqobizitha Mpofu, for their wisdom and being the light of my life. May their souls Rest in Peace.

I also wish to dedicate this work to my wife, Limkani, who made this dream achievable and to thank her for her love, help, support and prayers. I am also dedicating this to my sbali, Nosipho Ndlovu and my children, Nokulunga and Mbongeni; thank you for your understanding and willingness to adjust family priorities to allow me to pursue this degree.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS

SCORE	Science Community Representing Education
UNESCO	United Nations Educational Scientific and Cultural Organization
CAPS	Curriculum and Assessment Policy Statement
FET	Further Education and Training
NBPTS	National Board for Professional Teaching Standards
SBA	School Based Assessment
4IR	4^{th} Industrial Revolution
NSC	National Senior Certificate
DBE	Department of Basic Education
NDP	National Development Plan
VLDE	Virtual Laboratory Delivery Environment
ABA	Activity-Based Approach
NRC	National Research Council
NPC	National Planning Council
GDP	Gross Domestic Product
PrT	Pre-test
PoT	Post-test
NAS	National Academy of Sciences
SEPU	Science Equipment Production Unit
HOTS	Higher Order Thinking Skills
SPSS	Statistical Package for Social Sciences
GC-MS	Gas Chromatograph-Mass Spectrometer

NANSLO	North American Network of Science Laboratories Online
PSATCU	Physical Sciences Achievement Test on Conceptual Understanding
PSPST	Physical Sciences Practical Skills Test
PSAIS	Physical Sciences Attitudes Interview Schedule
CG	Control Group
EG	Experimental Group
CTEM	Conventional Teacher Expository Method
STEM	Science, Technology, Engineering and Mathematics
CR	Correct Response
ICR	Incorrect Response
UNDP	United Nations Development Program
HDI	Human Development Index

CHAPTER ONE

ORIENTATION AND BACKGROUND OF THE PROBLEM

1.1 INTRODUCTION

With the advent of information technology, the mastery of science and technology among senior secondary school learners is important to produce well-informed, scientifically literate and competent human capital (Kudenko and Gras-Velázquez, 2016). Furthermore, Falode (2016) is of the opinion that the revolution in technology has brought new innovations into classroom teaching and learning. Technology usage in schools today has influenced the way educators plan, design instruction, and assess their learners. Similarly, innovations in educational technology have changed systems of communication, learning resources, lesson ideas, and professional development and facilitate creativity and learning productivity (Garrett, 2015; Falode, Usman, Sobowale, Folarin and Saliu 2016; Mohammed, 2017). In addition, Mahya (2017) revealed that with the increasing usage of modern technologies, students are becoming better and faster at using new innovations. However, recent international studies have shown that lack of engagement with school science and motivation to choose science-related careers among senior secondary school learners is alarming and worrying, as most learners actively reject science-related careers as a future career option (van Griethuijsen, van Eijck, Haste, den Brok, Skinner, Mansour and BouJaoude, 2015). In addition, in their research findings, Gilbert and Justi (2016) found that learners' lack of engagement in science classes is used to support widespread dissatisfaction regarding learners' levels of attainment in international studies and with their disinclination to continue to study science-related disciplines in higher education institutions.

In view of the above, this study was conducted to evaluate the impact of Virtual Laboratories Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences in one district of the Eastern Cape Province of South Africa. Physical

Sciences, particularly Chemistry, serve as the interface to other sciences and to many other areas of human endeavours such as home, agriculture, health and industry. The study of Chemistry entails learning of concepts, established principles, laws and theories and substantial activity-oriented laboratory work. These laboratory experiments demonstrate practically some of the principles taught in theory, test the validity of certain empirical chemical laws and illustrate properties of substances taught theoretically in the classroom. They have also been found to be a primary vehicle for promoting formal reasoning skill and learners' understanding, thereby enhancing desired learning outcomes in learners (McFarlane, 2013).

The laboratory approach is regarded as an indispensable element of science education. Some science educationalists have suggested that rich benefits in learning accumulate from using laboratory activities. Since 1994, concerted effort has been made to improve the quality and output rate of mathematics and science in South Africa. For example, in 2015, the Department of Basic Education (DBE, 2015) developed the national strategy for improving the quality of mathematics, science and technology in General and Further Education and Training bands. However, despite important potentials embedded in learning Physical Sciences, its importance to mankind and the efforts of researchers to improve the quality of its teaching and learning especially at the secondary school level, the performance of learners in the subject in public examinations in recent times is disappointing (Department of Basic Education (DBE, 2015). Despite all the efforts, for example in 2013 the achievement was 42.7 % and in 2014 it was even less as it was 36, 9 % which clearly shows that there has been little improvement in the output rate in Physical Sciences as clearly shown in the table (see table 1.1) below.

The table 1.1 indicates the Statistics on national performance trends in Physical Sciences between 2011 and 2018.

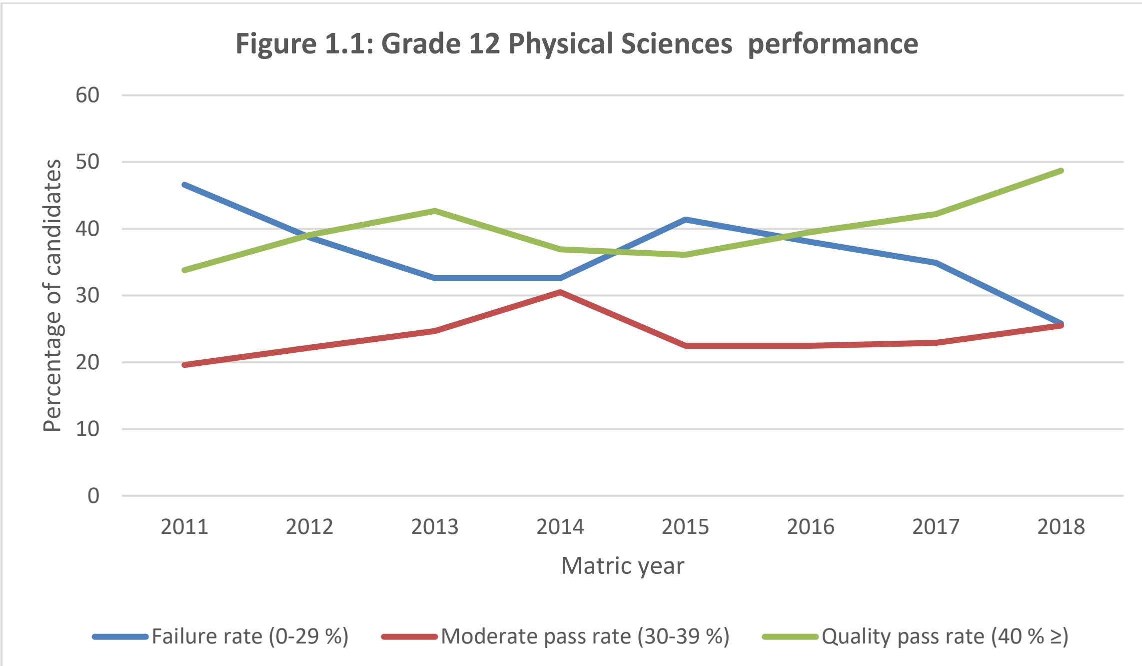
Table 1.1: Grade 12 National Performance trends in Physical Sciences

Year	Number Wrote	% failed (0-29 %)	No achieved between 30 % and 39 %	% achieved between 30 % and 39%	No. achieved at 40% and above	% achieved at 40% and above
2011	180 585	**46.6**	96 441	**53.4**	61 109	**33.8**
2012	179 194	**38.7**	109 194	**61.3**	70 076	**39 .1**
2013	184 383	**32.6**	124 206	**67.4**	78 677	**42,7**
2014	167 997	**32.6**	103 348	**67.4**	62 032	**36,9**
2015	193 189	**41.4**	113 121	**58.6**	69 699	**36,1**
2016	192 618	**38.0**	119 427	**62.0**	76 044	**39.5**
2017	179 561	**34.9**	116 862	**65.1**	75 736	**42,2**
2018	172 319	**25.8**	127 919	**74.2**	84 002	**48,7**

Source: DBE (2018, p.153), National Diagnostic Reports on Learners' Performance.

The results from Table 1.1 indicate that from 2011 to 2014, the National pass rate for Physical sciences improved from 53.4 % to 67.4 %. However, there has been a decline in the pass rate from 2014 to 2015 from 67.4 % to 58.6 %. Furthermore, there has been a decline in the number of learners taking Physical Sciences despite the increase in the number of learners who are writing grade 12 every year. The National Planning Commission (NPC) in the National Development Plan (NDP) proposes a 2030 target of 450 000 learners being eligible for a Bachelor's programme with Mathematics and Science (NPC, 2013). This target will only be a dream when considering the current number of learners who pass Physical Sciences from Table 1.1.

Figure 1.1: Summary of Grade 12 learners' performance in Physical Sciences between 2011 and 2018



Source: DBE (2018, p.153), National Diagnostic Reports on Learners' Performance.

From Figure 1.1, it emerged that the steady increase of high quality pass rate was almost parallel to that of the moderate rate between 2011 and 2013. Between 2013 and 2014, both the quality pass rate and the failure one decreased drastically while the moderate rate continued to increase. Between 2015 and 2018 the pas rate which was presumed to be of good quality increased steadily. With such a reflection of the results from Figure 1.1, it is still a cause of concern that the failure rate has been hovering above the moderate pass rate.

Most universities require a minimum of 40 % pass in Physical Sciences for prospective learners to study a science-related degree. This is represented by the green colour coding as shown in Figure 1.1. Emerging from Figure 1.1, there is a trend which shows that on average, about 40 % of learners who take physical Sciences at Grade 12 every year fail the subject (0 - 29 %), about 20 % pass with 30 – 39 % and about 40 % pass with 40

% and above. If only 113 121 learners in 2015 passed Physical Sciences with 30 % and above, it is clear that the number of learners eligible to study science degrees was even less than a quarter of the NDPs 450 000 target for 2030. The number of candidates who wrote the Physical Sciences examinations in 2018 decreased by 7 242, in comparison to that of 2017. Another observation emerging from Figure 1.1 is that the quality results have not reached 50 % pass rate in eight years. The poor performance of learners is attributed to lack of practical science experiments in which learners develop concepts, and are assumed to acquire science inquiry skills (DBE, 2012, p.166). It is imperative to investigate academic challenges experienced by learners in learning Physical Sciences to suggest appropriate learning and teaching strategies to address such challenges. If challenges are known, it will be easier to investigate appropriate intervention strategies to assist learners to achieve better results in the subject.

Physical Sciences is perceived by learners as a challenging subject since it is difficult to construct abstract concepts frequently encountered in the subject area (Gilbert and Justi, 2016) yet achievement in the subject in Grade 11 profoundly influences learners' performance and branch preferences in their subsequent education. (McFarlane, 2013; van Griethuijsen, van Eijck, Haste, den Brok, Skinner, Mansour and BouJaoude, 2015; Gilbert and Justi, 2016) discuss the issue of knowledge and learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise, particularly in science, and emphasize that many South African Science educators have little content knowledge of how to teach science. Furthermore, Gilbert and Justi (2016) asserts that many learners consider Physical Sciences as difficult, abstract and theoretical. This situation is exacerbated by the under-resourced and dysfunctional science laboratories in most South African public schools.

McFarlane (2013) testifies that practical work is not done in some schools in the country due to inadequate resources, lack of practical science skills and large science classes. Lack of facilities and resources to enhance effective teaching and learning of the Physical

Sciences subject through practical work has a direct negative impact on learners' conceptual understanding. Schools were also found to lack equipment and laboratories (Kibirige, Rebecca and Mavhunga, 2014) as well as laboratory technicians to support teachers. Aliyu and Talib (2019) further established that even some principals kept science equipment displayed in their offices but never used in the science classrooms. This further confirms that some principals lack understanding of the purpose of practical work and its role in the CAPS science curriculum (Kibirige, Rebecca and Mavhunga, 2014). The DBE (2015) attests that, "*The teaching of Science remains at a theoretical level without any experiments to enhance conceptual understanding and application of knowledge*".

From this novice researcher's point of view garnered from many years of teaching experience in Physical Sciences at senior secondary school level or further education and training (FET) Phase in South Africa, one of the reasons why historically disadvantaged learners are performing poorly in Physical Sciences is that they are not afforded well-structured and meaningful hands-on activities as supported by Gilbert and Justi (2016). The researcher observes that in spite of the myriad initiatives aimed at broadening participation in the Science, Technology, Engineering and Mathematics (STEM) disciplines, teaching and learning of the Physical Sciences subject through laboratory exposure is still gloomy in most South African schools, especially in historically disadvantaged public schools (McFarlane, 2013; van Griethuijsen, van Eijck, Haste, den Brok, Skinner, Mansour and BouJaoude, 2015; Gilbert and Justi, 2016).

An alternative delivery environment, called a virtual laboratory, has been tried, tested and recommended in other countries (Jeschke, Richter and Zorn, 2010; Kumar, 2014). Virtual laboratory delivery environments simulate a real or wet laboratory environment and processes and are defined as learning environments in which learners convert their theoretical knowledge into practical knowledge by conducting experiments (Mcfarlane, 2013). Virtual laboratory delivery environments provide learners with meaningful virtual experiences and present important concepts, principles and processes. Through virtual laboratory delivery environments, learners have the opportunity to repeat any incorrect experiment or deepen the intended experiences. The use of virtual reality in general and virtual laboratory in particular, has become a reality in the educational world in Malaysia (Mcfarlane, 2013).

Kudenko and Gras-Veláźquez (2016) indicated that the integration of technology in learning process enables learners to acquire computer skills in a meaningful way. Gilbert and Justi (2016) found in their study that learners who can integrate their learning with the technology will be able to do the following:

a) search, analyse and evaluate information better;
b) become informative users;
c) solve problems and make better decisions using productivity materials in a creative and effective way;
d) become informative, responsible citizens; and
e) contribute to the development of the country.

Evidence is, however, required on whether the VLDE, as an instructional tool, is indeed effective and whether it can continue to be developed and utilized in classrooms in the South African context. The present study was, therefore, conducted to evaluate the effectiveness of VLDE on Grade 11 learners' learning outcomes in Physical Sciences in two Senior Secondary Schools in South Africa.

1.2 BACKGROUND TO THE STUDY

The background of this study considered literature from Europe, America, Asia, Africa and the South African perspectives on the prominence of science education. From an international standpoint, Lynch and Ghergulescu (2018) assert that the disengagement of European learners from science is apparent, causing Europe to be faced with a shortage of skilled scientists in the future. Playfoot (2016) also articulates that learners consider scientific subjects too difficult to pursue, and are uncertain about how interesting and promising the career paths available for Science, Technology, Engineering and

Mathematics (STEM) graduates really are. These attitudes lead to lack of motivation and make STEM subjects seem irrelevant to learners. Sharing the same assertions, Baird (2012) states that the sciences are considered a "high need" area in the United States of America's education because there is a shortage of qualified teachers and there has been a decline in interest towards science among the learners. Achievement scores in the sciences for American learners have raised alarms about the abilities, skills, and knowledge base of the nation's future work force (Playfoot, 2016). The Programme for International Student Assessment (PISA) report also states, "*students whose proficiency in science is limited to level one will find it difficult to participate fully in society at a time when science and technology play a large role in daily life*" (Playfoot, 2016).

In Turkey, many state schools were reported to conduct chemistry practical only in rare cases or during students' final examinations due to insufficient laboratory equipment or complete absence of laboratory in a school (Playfoot, 2016). In a study, in Lebanon, the Center for Educational Research and Development (CERD), established and categorized competencies that must be developed in science into four domains: Using acquired knowledge, practicing scientific reasoning, mastering experimental techniques, and mastering communication techniques (CERD, 2015). The experimental techniques depend extremely on laboratory work and experiments that unfortunately were not used in most Lebanese schools, particularly the public ones, due to a number of barriers (Zgheib, 2013). Problems encountered in the Lebanese secondary teaching included the insufficiency or absence of laboratory facilities; the time factor in planning and performing experiments; and the inability to keep tracking of students' performance during the activities. Furthermore, in Indonesia, the reality on the ground showed that educational achievement was still far below other Asian countries. Based on the United Nations Development Program (UNDP) report, it was seen that the 2013 Human Development Index (HDI) was ranked 121 of the 187 Asian countries. Whereas in 2015, it was still around the order of 108 out of 187 (UNDP, 2015).

In a narration, Alkan (2016) state that learners need practical experiences to enable them understand abstracts concepts in science education, therefore, effective use of laboratory equipment and facilities would positively improve the mastery of science concepts. However, most of the public secondary schools in Nigeria were said to be faced with insufficient laboratories and equipment which limited teachers to perform just simple laboratory activities (Aliyu and Talib, 2019). In addition, the cost of carrying out experiments, arranging the equipment and laboratory activities were said to be laborious and were reported to be much time consuming. Checking learners' performance during the laboratory activities could be tasking and laborious especially when dealing with large class Lynch and Ghergulescu (2018). Aliyu and Talib (2019) also state that in Nigeria, the laboratory conditions in most of the science secondary schools generated a negative attitude and low academic achievement among science secondary schools' learners. These persistent problems led researchers to embark on presenting virtual laboratory chemistry as an alternative strategy for conducting chemistry practical, particularly in schools that lacked standard real chemistry laboratories (Aliyu and Talib, 2019). The government of Kenya in its economic blue print that is popularly referred to as vision 2030 has set out a long-term development policy of transforming the country into an industrialized, middle income economy by the year 2030. One of the key pillars identified to drive this transformation is quality and accessible education to its citizens that is globally competitive (Government of Kenya (GOK), 2007). This was due to the fact that performance of students in sciences in Kenya at Kenya certificate of secondary examinations (KCSE) had been recording low achievement (KNEC, 2012; 2013).

Lynch and Ghergulescu (2018) argue that science is not taught in a way that is suitable for the millennial, who are digital natives, use technology every day in their lives and believe it should be integrated into education. Many educational institutions also suffer from lack of funding and resources (e.g., time, lab space, equipment), and struggle to provide their learners with sufficient practical training, despite practical experiments being a key part of STEM education, with students required to learn essential laboratory skills throughout their schooling and degrees (Abdulwahed and Nagy, 2013).

Virtual laboratories remove the limitations set by time and geography, enable personalisation of content (Fernández-Avilés, Dotor, Contreras, and Salazar, 2016), instant feedback and automated corrections, hence making the teaching and learning experience more enjoyable for both students and teachers. Multimedia approach, combined with personalised inquiry-based exercises that allow students to learn analytical and research skills, question and practise at their own pace, are one of the benefits of virtual laboratories.

Literature from South Africa depicts that since 1994, South African educational reforms, particularly in the science education curriculum, are tailored towards improving the quality of the didactic and pedagogic approaches in science education. Instructive and instructional approaches in science education may take many forms, but hands-on application of theory via science laboratory activities for the learner is common. The National Board for Professional Teaching Standards (NBPTS) (2013) attests that learning occurs best by doing, and learners must have ample hands-on opportunities. To ensure equality in all South African schools, the curriculum prescribes the levels and the amount of practical work as well as subsequent assessments in Physical Sciences. The current Curriculum and Assessment Policy Statement (CAPS) guides educators on what content to impart, describes the number of practical tasks and prescribes the complexity of practical work for learners in Grade 11 (CAPS, 2012). Tatli and Ayas (2013) attests that practical work may be considered as engaging the learner in observing or manipulating real or virtual objects and materials. (NBPTS, 2013) also concur with Tatli and Ayas (2013) by defining practical work as, learning experiences in which learners interact with materials or with secondary sources of data to observe and understand the natural world (Tatli and Ayas, 2013).

Practical work in literature has been referred to in different ways as: 'experimental work; 'scientific investigations' (Ramnarain, 2013); 'practical and investigative activities' (Science Community Representing Education (SCORE), 2008) and 'laboratory investigations' (Kibirige and Tsomago, 2013). The broad perspective of 'learning experiences' include a wide range of practical skills, thought and processes that constitute doing science as 'what scientists do' (Ramnarain, 2013).

1.2.1 Laboratory usage

Omiko (2015, p.206) identified five groups of objectives that may be achieved through the use of the laboratory in science classes as:

i. Skills - manipulative, enquiry, investigative, organisational and communicative;
ii. Concepts - hypothesis, theoretical model, taxonomic category;
iii. Cognitive abilities - critical thinking, problem-solving, application, analysis, synthesis. A further benefit of laboratory usage includes its ability to address not only the lower-order cognitive skills (knowledge, comprehension, and application) but also higher-order cognitive skills (analysis, synthesis, and evaluation) defined by Bloom's Taxonomy (Bloom, Engelhard, Furst, Hill, and Krathwohl, 1956; Omiko ,2015)
iv. Understanding of the nature of science - scientific enterprise, scientists and how they work, existence of a multiplicity of scientific methods, interrelationships between science and technology and among the various disciplines of science; and
v. Attitudes - curiosity, interest, risk taking, objectivity, precision, confidence, perseverance, satisfaction, responsibility, consensus, collaboration, and liking science.

Similarly, Kibirige and Tsomago (2013) explicate that laboratory learning environments allow learners to interact physically and intellectually with instructional materials through hands-on experiences and through minds-on and inquiry-oriented activities. Various laboratory environments afford learners the opportunity to develop and practice the process of science such as observation, experimentation, communication of thoughts, formulation of hypotheses and classification. Furthermore, the science laboratory has been given a very distinctive role in Physical Sciences education, and researchers are of the view that there are tremendous benefits in learning from using laboratory activities

(Kibirige and Tsomago, 2013). Researchers such as Watts (2013) have expressed their view that what makes the science laboratory unique lies principally in providing students with opportunities for scientific investigation and inquiry.

Omiko (2015) observed that the use of the laboratory in science teaching has the following benefits: (1) Laboratory teaching allows the learners to learn about the nature of science and technology to foster the knowledge of human enterprise of science thus enhancing the aesthetic and intellectual understanding of the child. (2) Kibirige and Tsomago (2013) opined that science is known to be a way of doing certain things by the observation of natural phenomena, quantifying the observed phenomenon, integration of such quantities and interpretation of the results in order to make useful meaning out of the exercise.

The learners can identify cause and effect relationships and, in this process, develop important skills. (3) Learning scientific inquiry skills that can be transferred to other spheres of problem solving (that is acquisition of problem-solving skills). One of the basic goals of science education is to help learners learn skills that can be applied to other life situations in future. It thus follows that the exercise of transfer of such a learning condition must have something in common with the situation to which it will be applied. (4) Learners learning to appreciate and in fact, emulate the role of the scientist through acquisition of manipulative skills. The learners should be allowed to investigate: (a) Indirect observation of objects and materials for the acquisition of mental as well as manipulative skills, for example measuring substances, using weighing balances pictures, cylinder, etc. (b) Through multiple trials, learners can in the process of experimenting with materials and activities without stated theories arrive at useful conclusions. (c) Given a known theory, learners can be guided to observe some phenomena selected by the teacher and from such observation make predictions that are likely to occur. (d) Developing interests, attitudes and values by considering what science entails, it is clear that a field experience has the best potential for stimulating a life time interest in science in the learners when accorded the chance for personal experience by handling the real things. Learners' interest in science increases as they yearn to investigate and explore more about their environment. According to Omiko (2015), eight (8) aspects of scientific attitudes exist, all of which can be nurtured in the science laboratory.

In view of the afore-mentioned assertions, laboratory experiences are essential for learners to increase their analytical skills and understanding of chemical concepts. However, the time and economical resources often required for setting up and constructing scientific laboratories is outside the scope of many institutions, particularly historically disadvantaged senior secondary schools in South Africa. Furthermore, Woodfield, Catlin, Waddoups, Moore, Swan, Allen and Bodily (2004) are of the view that traditional laboratory activities are often taught as "cookbook" laboratories, meaning learners in a laboratory strictly follow written directions often with little thought about what they are learning or how the laboratory connects to real world applications.

The necessity to follow strict directions are factors of limited time, large numbers of learners, cost restrictions, and the need to ensure the safety of all learners in the laboratory. Laboratories should not only provide learners with the opportunity to increase their analytical skills but also to provide active learner engagement while learning. Tatli and Ayas (2013) revealed some of the factors that affect effective laboratory work in Physical Sciences:

- Poor laboratory practices that are insufficient and ineffective;
- Poorly designed and planned laboratory activities organised for learners, for learners to manipulate equipment instead of manipulating ideas; and
- Furthermore, time is usually wasted in the laboratory when learners engage in activities without knowing why they are doing so, since they are not given adequate opportunity for processing and analysing their data (Tatli and Ayas, 2013).

The National Research Council (2012) defines overall learning objectives for a laboratory experience as:

- enhancing mastery of subject matter;
- developing scientific reasoning;
- understanding the complexity and ambiguity of empirical work;
- developing practical skills;
- understanding the nature of science;
- cultivating interest in science and interest in learning science; and
- developing teamwork abilities.

The Research Council also acknowledges that no single laboratory experience will address all the objectives, but different experiences can be designed to address multiple learning objectives (National Research Council, 2014). Furthermore, research findings by Kibirige and Teffo (2014) reveal that attending laboratory sessions is important in learning Physical Sciences because practical work brings to life what is explained in textbooks.

As part of the educational process, science education has long recognized benefits of hands-on laboratories. These laboratory experiments create active-learning environments, allowing learners to practice the scientific method by varying experimental conditions and directly observing results. Although laboratory application in learners' learning has a very important place in science education, in use, it has some limits and problems, especially in developing countries. Some of the main problems faced in South Africa can be summarized as follows:

- In carrying out experiments and procuring equipment, laboratory activities become expensive;
- With regards to planning and application, it is very time consuming;
- Checking learners' performance during activities can be difficult in over-crowded classes; and

- Lack of laboratory equipment and inadequate lab conditions limit the teachers' ability to perform a simple lab activity.

Laboratory experiments constitute an important element of the research method in science education. In the process of solving problem tasks, the experiment fulfils the motivating role as well as serving the purpose of discovery and evaluation. Practical work also provides learners with evidence to support their understanding and concretise scientific principles (Kibirige and Teffo, 2014). Research has established that achievement and skills improve when learners are taught science using practical work (Watts, 2013). Furthermore, Aliyu and Talib (2019) attest that learners do practical work to expand their knowledge in an attempt to understand the world around them. Practical work develops learners' understanding of ideas, theories and models (Watts, 2013). Moreover, Bulent, Mehment and Nuran (2014) claim, "Practical work with real objects and materials not only helps learners to communicate information and ideas about the natural world but also provides opportunities to develop learners' understanding of the scientific approach to enquiry".

The researcher's observation is that in many circumstances, practical work objectives are vague and ill-defined. Watts (2013) attests that practical work, as conducted in many schools, is ill-conceived, confused, unproductive and provides little of real educational value. For many children, what goes on in the laboratory contributes little to their learning of science or to their learning about science, nor does it engage them in doing science in any meaningful sense. Kibirige and Teffo (2014) allege that educators' attitudes towards laboratory usage are poor; consequently, these educators do practical work to satisfy the minimum requirements of the syllabus. Moreover, despite the effectiveness of practical work, some educators in South African schools are not confident to teach science using practical work (Kibirige and Tsamago, 2013). Consequently, such educators rely on traditional ways of teaching (lecturing, chalk-and-talk and dictation). These traditional strategies seem to be favoured because either there are no laboratories for learners to perform practical work (Kibirige and Tsamago, 2013) or it is because educators lack skills, even if schools have laboratories (Kibirige and Teffo, 2014). Furthermore, educators who use practical work normally depend on textbooks and teach experiments like cookbook recipes. Such teaching strategies often fail to inculcate conceptual understanding and understanding of Physical Sciences in learners. Dhurumraj (2013) conducted a study with a random sample of 266 Grade 10 learners from schools across South Africa to test the general quality of practical skills. Their findings were that learners' arguments were of low quality. It is against the above assertions that the researcher sought to explore and evaluate the effectiveness of the Virtual Laboratory Delivery Environment (VLDE) on achievement and attitude towards Physical Sciences among grade 11 learners.

1.2.2 The South African Physical Sciences Curriculum perspective

The current South African Physical Sciences Curriculum and Assessment Policy Statement (CAPS) document makes reference to the importance of laboratory work and learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise. Under its specific aims, it states:

> *The purpose of Physical Sciences is to make learners aware of their environment and to equip them with investigating skills relating to physical and chemical phenomena. Some of the skills that are relevant for the study of Physical Sciences are classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem solving and reflective skills* (DBE, 2015, p.13).

Furthermore, the CAPS document prescribes assessments of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise, (science process skills), which is a critical curriculum requirement. Aliyu and Talib (2019) regard learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise as a way of thinking, measuring, solving problems and using thoughts and opinions. This implies that educators and learners should be aware of the value of acquisition of Physical

Sciences techniques and practical expertise development during Physical Sciences laboratory work. Bulent, Mehment and Nuran (2014) add that it is important to investigate the extent of utilisation of acquired Physical Sciences techniques and practical expertise by learners to accomplish the following:

- Enabling the Physical Sciences educator to determine process skills essential for effective conceptualization of the new scientific topics;
- Assisting Physical Sciences educators in knowing the nature of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise;
- Assisting educators in deciding on effective teaching strategies;
- Improving the performance of learners in acquisition of Physical Sciences techniques and practical expertise; and
- Proposing effective learning strategies for acquisition of Physical Sciences techniques and practical expertise (Bulent, Mehment and Nuran, 2014).

van Eijck, Haste, den Brok, Skinner, Mansour and BouJaoude (2015); Kudenko and Gras-Velázquez (2016) have articulated that economic and technological advancement which began in the 19th century has triggered the use of scientific methods in the curriculum process, curriculum theory and all stages of curriculum development. This means that various scientific approaches that encourage utilisation of process skills in high school have been adopted in designing the high school science curriculum. These approaches include:

- Scientific approaches to assessment such as measurable processes, which ensures assessment of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise;
- Language curriculum design that has incorporated various scientific concepts such as skills of communication and materials to develop learner abilities to identify and solve issues; and

- Science skills curriculum that has adopted technical approaches of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise to plug loopholes and setbacks in technology development.

The examiner's report (DBE, 2015, pp.15-16) attests that, *"Teachers need to understand……..the relationship between theory and experiment, the importance of empirical data and mathematical modelling of relationships. Teachers should refrain from doing practical work only for the sake of compliance to School-Based Assessment guidelines."* To redress the imbalances of the past, South Africa needs to find a way of helping its learners, particularly the historically disadvantaged, to pass the National Senior Certificate (NSC) Mathematics and Science examinations. If historically disadvantaged learners continue to fare poorly in Science, Technology, Engineering and Mathematics (STEM) examinations, then this compromises equality in education, which is one of the cornerstone goals of the democratic government. In assertion, Kudenko and Gras-Velάzquez (2016) attests that currently, South Africa does not have the capacity to expand economically without importing foreign scientific and technological expertise.

1.3 STATEMENT OF THE PROBLEM

Poor performance in Physical Sciences, more especially in Chemistry, in senior secondary schools attests to the fact that Chemistry teaching and learning have not been effective (Bulent, Mehment and Nuran, 2014). It depicts lack of acquisition of the required learners' proficiency in Physical Science techniques and practical expertise, which may be because of inadequate exposure of learners to laboratory activities (Kibirige and Teffo, 2014). Needless to mention that a lot has been reported about the inadequacy of traditional science laboratories in South Africa (Ramnarain, 2013). Furthermore, the impact of virtual laboratory environments on learner achievement has been researched extensively in other parts of the world. Nonetheless, there are still gaps and disparities in literature with regards to the South African context (Ramnarain, 2013). These gaps entail: the extent of the impact on learner achievement, generalizability of existing research, length of studies as well as the time it takes to achieve meaningful increase in learner achievement in historically disadvantaged poor-performing schools (see table 1.1 of the poor results in achievement as shown in this study). This is an indication of a gap in the system of teaching and learning of Physical Sciences in secondary school that requires investigation and remediation. Since Physical Sciences, particularly Chemistry, is a science based on experimentation, it should be taught through an Activity-Based Approach in a well-equipped laboratory learning environment (Bulent, Mehment and Nuran, 2014).

Ngman-Wara and Edem (2016) posit that in order to develop interest, curiosity, positive attitudes towards Chemistry, creativity and problem-solving ability in science and improve learners' understanding of science concepts and scientific processes, laboratories are essential. Ramnarain (2013) is of the view that laboratory work is not done in some South African schools due to inadequate resources, lack of practical science skills and large science classes. Additionally, the Department of Basic Education (DBE) (2018) attests that teaching of Physical Sciences remains at a theoretical level without any experiments to enhance conceptual understanding and application of knowledge. In order to address poor performance in Physical Sciences teaching and learning, the conditions under which they take place need to be re-examined. Such a re-examination could focus on determining the effectiveness of laboratory learning environment on learners' learning outcomes.

A learning environment that allows active participation of learners in the learning process makes it possible for learners to have control over their learning, and this leads to improvement in learners' learning outcomes. Poor matric results in Physical Sciences and other related subjects may be reflecting the inadequacy inherent in traditional laboratory learning environments at the school level (Ngman-Wara and Edem, 2016). In this technological era, it is crucial that educators make efforts to employ the latest instructional techniques capable of enhancing performance and sustaining the interest of the learners in the subject. It also appears from the review of available literature that the issue of 'alternative laboratory learning environments' on learners' learning outcomes in secondary school Physical Sciences classes has not been extensively explored in South

Africa. This paucity in literature gives room for the need to conduct a scientific study on alternative laboratory delivery environments. One such alternative delivery environment, Virtual Laboratory Delivery Environment (VLDE), may offer an engaging instructional medium, one to which many learners of the digital era are well-accustomed. Many researchers and educational practitioners believe that VLDE has provided new insights to support education. In support of this, Ngman-Wara and Edem (2016) are of the view that the Virtual Laboratory concept has been expanded to advance opportunities for integrated teaching, research and promoting cross-disciplinary research.

On the basis of the above problem, the researcher found it worthwhile to explore and evaluate the impact of VLDE to enhance conceptual understanding and understanding of Physical Sciences among Grade 11 learners from the selected schools in one district of the Eastern Cape in South Africa. As long as science education remains at a theoretical level, various repercussions may always impede the success in the subject. Shoddy practices by many science educators in South African schools have contributed grossly to the declining performance in the subject across the Further Education and Training (FET) band. In particular, these practices have contributed to poor conceptual understanding and understanding of subject matter taught in this band as well as the application of knowledge. Furthermore, substandard practices have attributed to the low enrolments in the Physical Sciences subject and negative attitudes among the majority of learners towards the subject.

1.4 RESEARCH QUESTIONS

Given the success of the VLDE in institutions in other parts of the world, the research questions guiding this study include the following:

1.4.1 Main Research Question

The main research question of the study was: What is the impact of Virtual Laboratory Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland?

1.4.1.1 Subsidiary Research Questions

The sub-questions were:

i. What is the impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners?
ii. What is the impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise?
iii. To what extent does VLDE influence the participants' attitude change towards Physical Sciences?

1.4.2 Hypotheses

The following hypotheses were formulated by the researcher to guide the study.

1. H_1: There is significant difference between the mean response on the scientific literacy among the grade 11 Physical Science learners and matching their abilities through the VLDE experiences they are exposed to.

2. H_2: There is significant deference between the mean response on development and mastering of scientific skills as roles of the use of VLDE in teaching the Physical Science subject among the Grade 11 learners.

1.5 AIM AND OBJECTIVES OF THE STUDY

This section presents the aim and objectives of the study.

1.5.1 Aim

The principal aim of this study was to determine the impact of a virtual laboratory delivery environment (VLDE) on grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland.

1.5.2 Objectives

The objectives that guided this study were:

i. To assess the impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners.
ii. To determine the impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise.
iii. To assess to what the extent the VLDE influence participants' attitude change towards Physical Sciences.

1.6 RATIONALE FOR THE STUDY

In the technological dynamic era of the 4th industrial revolution the impact of a virtual laboratory delivery environment (VLDE) on grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland has precipitated the basis of this study. By any measure of school achievement, national or international, South African schools are in a crisis (Ndlovu 2011; Carnoy and Arends, 2012; Gilmour, 2013; Clark 2014). This is not for lack of funding from the national government, as the democratic government spends more money on education in relation to Gross Domestic Product (GDP) than any other African country, and education consistently takes the lion's share of the national budget (Jansen, 2011). Neither does this underperformance in the school system stem from lack of ideas. Radical curriculum reforms from government and specific project and programme reforms from inside and outside the state have failed to stem the stagnation in educational achievement among the nation's 13 million learners (Jansen, 2011). According to the Chief Markers' report submitted to the DBE (2012), there was ample evidence that learners still did not understand the theory and basic concepts in

Physical Sciences. In addition, responses of a large proportion of learners showed evidence of serious lack of exposure to practical work and lack of mathematical skills such as interpretation and drawing of graphs, solving equations and working with trigonometric ratios and lack of problem-solving skills.

Quality practical experiments are designed to promote the engagement and interest of learners as well as developing a range of skills, science knowledge and conceptual understanding (Jansen, 2011). Learners benefit through engagement with concepts in practical work through interactions, hands-on activities, and application in science. Well-planned and effectively implemented virtual laboratories stimulate and engage learners' learning at varying levels of inquiry, thus challenging them both mentally and physically in ways not possible through other science education experiences (Hampden-Thompson and Bennett, 2013). Considerable increase over the use of technology in teaching and learning the researcher hopes for integrated virtual laboratory delivery environments in teaching and learning of Physical Sciences among the Grade 11 learners with the intent to offer virtual laboratory environment as another delivery route to laboratory experience.

1.7 SIGNIFICANCE OF THE STUDY

This study may contribute to extend the frontier of existing knowledge on the VLDE intervention in science education specifically in Physical Science as a practical subject. The results of this study may also contribute in producing more competent educators through the use of current technology in assisting pedagogical approaches in the laboratory and helping learners to learn better in Physical Science. Additionally, the results of this study may positively benefit learners doing Physical Science to further exposure laboratory experience that would prepare them for scientific careers. The results of this study may also positively contribute to improve Physical Science achievement results in most historically disadvantaged schools which may be under-resourced to provide the laboratory environment necessary for hands-on application of science theory, if the schools rely on technology to provide a VLDE experience. The department of Basic

Education may benefit widely on the results of this study as it may help the department to use informed decisions on how to best teach Physical Science by informing teachers on the current technological methods to be used in the classroom.

Babateen (2011); MOE (2013) found this to be true, stating that virtual laboratories are seen as alternative methods to original and real experiments when there are financial constraints and space considerations. This relationship of education and technology is a complementary one, the success of which depends on the level of consistency and compatibility. Learners are the human capital required to fulfil a nation's vision whilst teachers are vital agents for producing quality education, moving towards the Fourth Industrial Revolution (4IR). Learners must have the skills required to meet the needs of the future 21st century technology (MOE, 2013), whereby the education system stands out as a successful education system in a developed country. This research is a call to ensure that learners are instilled with motivation, strong academic achievement as well as Higher Order Thinking Skills (HOTS). The VLDE intervention in science education is able to produce more competent educators through the use of current technology in assisting pedagogical approaches in the laboratory and helping learners to learn better as recommended from the results of the current study. In order for teachers to benefit from the results of this study, it is hoped that, with guidance and proven competent skills, it is hoped that educators will apply the approaches without hesitation as provided by the results and recommendations from this study. The VLDE offers advanced technology instrumentation so that more experiments can be carried out, compared to conventional experimental approaches. Teaching and learning sessions can be more learner-centred, and inquiry and discovery can be carried out by learners where the educator facilitates them hence, benefit both learners and teachers in Physical Science as a subject. VLDE is rooted in active learning, inquiry-based learning and engages learners in experience-based learning. When learners conduct various experiments, they grasp the activities and relate them to their own experience. This can help them understand phenomena relevant to life and retain knowledge for longer periods.

When learners learn using technology in a manner that encourages systematic thinking, based on the alternatives and possibilities, they not only interact with a new world of information and communication technology, but are able to use it creatively. With recent advances in information technologies, a new mode of laboratory known as the "virtual laboratory" has begun to revolutionise science education. This development has generated discussion on fundamental learning outcomes of laboratory training courses and, ultimately, an interest in consequent changes to the learner's learning experiences. Virtual laboratory delivery environments may be a successful model for conducting experiments among learners from schools across South Africa, hence the Department of Basic Education and the School Governing body as to which Physical Science equipment to buy for their schools therefore, would benefit from this study. Virtual laboratory delivery environments may be designed to fit into learners' schedules, are flexible and provide real experience, further benefiting learners doing Physical Sciences.

1.8 CONCEPTUAL FRAMEWORK

The conceptual framework in this study encapsulates the research route used in delivering the virtual laboratory environment to Grade 11 learners. In support of the use of a conceptual framework, Grant and Osanloo (2014) defines conceptual framework as a set of concepts put together to provide a basis of support for explaining, viewing or contemplating on research phenomena. Furthermore, he explicates that a framework is a plan of study that is mostly a tentative theory of the phenomena to be investigated. Adom, Hussein and Agyem (2018, p.439) state that a conceptual framework is a structure that the researcher believes can best explain the nature of the phenomenon to be studied. It is arranged in logical structure to aid or provide a visual display of how ideas in a study relate to one another (Grant and Osanloo, 2014). The function of such a framework is to inform the research route (design) and help assess, refine the research goals, develop realistic and relevant research questions and select appropriate research methods.

The conceptual framework that underpinned this study was a key theme that underlies developments in areas of adaptive expertise and technology-based learning. Embedded learning is the inherent shift from a traditional, proceduralised approach to learning which tends to treat the learner as a passive recipient of information, to a learner-centred approach that makes the learner an active participant in the learning process. The active learning approach aims to stimulate and shape a combination of cognitive, motivational, and emotion self-regulatory processes that characterize how people focus their attention, direct their effort and manage their emotions during learning (Bell, 2012).

Prior research has typically conceptualized the active learning approach by comparing it to more passive approaches to learning, which some refer to as transmission or conduit models of learning (Grant and Osanloo, 2014). The active learning approach is distinct in two fundamental respects. First, the active learning approach provides individuals with significant control over their learning. Whilst passive approaches to learning have an instructional system that assumes most of the responsibility for important learning decisions, the active learning approach gives the learner primary responsibility for managing his or her learning, for example, sequencing his or her learning activities, monitoring and judging progress. The important distinction is one of internal versus external regulation of learning (Grant and Osanloo, 2014).

Second, the active learning approach is grounded in the constructivist vision of learning, which argues that learning is an inductive process in which individuals explore and experiment with a task to infer the rules, principles and strategies for effective performance (Mayer, Mautone, and Prothero, 2012). In contrast, passive approaches to learning are based on conduit or transmission models of learning that assume that individuals acquire knowledge by having it transmitted to them by some external source such as a teacher or text (Bell, 2012). The important distinction is one of active knowledge construction versus the internalization of external knowledge.

The notion that the learner should be actively involved in the learning process is not exclusive to the active learning approach; it is a theme that can be found in a number of educational philosophies and approaches, including experiential learning and action learning (Kolb, 1984; Watts, 2013). However, the active learning approach is unique in that it extends beyond simply "learning by doing" and utilizes formal training components to systematically shape and support trainees' learning processes. In particular, active learning interventions that have been developed in recent years, such as error training, mastery training and guided exploration, combine multiple training components intended to selectively influence the nature, quality and focus of self-regulatory activity (Omiko, 2015). Self-regulation can be defined as processes "that enable an individual to guide his/her goal directed activities over time and across changing circumstances," including the "modulation of thought, affect, behaviour, or attention" (Bell, 2012).

Although it is clear that the active learning approach has the potential to enhance learners' knowledge and performance, it is also important to recognize that the effects of this approach are not uniform across all types of learning outcomes or at all periods of time. In particular, most active learning strategies are designed to improve outcomes after, as opposed to during, learning. Learning through error, for example, often leads to lower levels of performance because learners' experiment, make errors and sometimes arrive at incorrect solutions. The benefits of learning through error typically do not emerge until one examines learners' performance in the long run or the transfer of knowledge and skills to new problems (Bell, 2012). Similarly, mastery inductions often lead to lower levels of performance in the short-term because learners are focused on developing rather than demonstrating their competence. Again, it is often not until one examines learners' transfer performance that the benefits of mastery training become evident. The philosophy of Virtual laboratories depends on many principles, including those by Ojediran, Oludipe and Ehindero (2014) highlighted below:

- *Exceeded the true reality* - Virtual laboratories (Vlabs) were created as an alternative to reality due to the difficulty of access to it or its gravity. For example, three-dimensional science virtual labs seeking to build the worlds from symbols to simulate reality, or the establishment of the world's fantasy digital creature and multimedia which takes the learner to practise experiences that are otherwise difficult to carry out in the real world;

- *Individual learning and learner freedom* - each learner depends on him/herself, according to an individual's possessions from preparations, capabilities and needs from required variables, thus leading to interest in learning more than instruction and attention to training to produce knowledge, rather than receive it;
- *Continuity of instruction* – by providing lifelong learning, which is an urgent necessity that cannot be dispensed under the dictates of the times of the new requirements and variables, as it allows anyone to join him/her at the time that one deems appropriate to his/her circumstances, to develop acquaintances constantly and yields the best instructional outcomes and cognitive results resulting in a learner with an ability to take responsibility;
- *Instructional barriers* - temporal and spatial barriers in traditional instructional systems removal emphasizes continuity of lifelong learning, diversity of methods, means and breadth of instruction for all; and
- *Reliance on computer technology* – where the computer is used in the synthesis of sensory experience that prohibit the learner unable to distinguishing between real and virtual experience (Ojediran, Oludipe and Ehindero, 2014).

For learners, experiments and laboratory work are crucial in correctly making sense of the natural world. Virtual laboratories have become alternatives for physical laboratories, with the rising popularity of technology use in education. VLDE allows learner implementations without the necessity for safety precautions. Experiments in the virtual laboratory delivery environment can be repeated rapidly and economically (Bell, 2012). The virtual laboratory delivery environment is used as an alternative mechanism for achieving the same learning outcomes as in the corresponding wet laboratory environment. Furthermore, a virtual laboratory delivery environment, as a supportive factor to wet laboratory environments, enriches learning experiences of learners and offers learners the following opportunities:

- carry out experiments;

- control materials and equipment;
- collect data and perform experiments interactively;
- prepare reports for the experiment; and
- develop experimenting skills.

Learning occurs through experiences, and individuals do not always learn in the same way (Omiko, 2015). To increase the quality of education, learning environments appropriate for individual differences should be created. Differences in general characteristics of learners are reflected in their learning processes. Active learning theory depends on studies by Lewin, who emphasizes the importance of learners being active in the learning process and Piaget, who perceives intelligence not only as characteristics at birth but also as a conclusion of the interaction between individuals and their environments (Siew, Chong and Chin, 2014). In general, concrete experience requires full participation of individuals in the activity, while reflective observation requires individuals to develop various perspectives, abstract conceptualization requires attainment of the theoretical knowledge by the individual and active experimentation requires individuals to implement the knowledge. Implementation of the learning cycle in the classroom environment is essential in realization of effective learning (Omiko, 2015).

The active experimentation phase should allow learners to learn through implementation of what they learn. Instead of observing and listening, participating gains importance. Learners who prefer this learning approach enjoy implementing what they learn and seeing that what they learn as useful (Ojediran, Oludipe and Ehindero, 2014). As learning is a lifelong process and individuals need to learn, interpret or judge situations they experience under various conditions, scientific process skills are very important for significant learning. Scientific process skills are tools for learning science and understanding scientific studies while the setting an essential goal of learning (Watts, 2013). Scientific process skills are listed under three groups as basic skills, experimental process skills and causative process skills (Ojediran, Oludipe and Ehindero, 2014). These are not only the skills used by scientists in their studies but are also skills that show their effects on individuals' personal, social and global lives (Watts, 2013). Therefore, using scientific process skills within the experiential learning cycle would ensure the development of basic skills, experimental process skills and causative process skills.

According to research studies, the most effective and permanent learning in science is obtained through the laboratory method (Watts, 2013). Laboratory method affords learning topics through techniques such as observing, experimenting, learning by doing or presentations in laboratories or purpose-built classrooms (Omiko, 2015). Laboratory studies enable learners to participate in activities related to science and experience scientific methods, while contributing to development of skills to make observations, produce ideas and interpret topics (Watts, 2013). This method also improves individuals' skills such as reasoning, critical thinking, developing scientific perspective and problem-solving (Ojediran, Oludipe and Ehindero, 2014). Effectiveness of laboratory applications on learning science need to be investigated, and its impact on different variables needs to be determined. Laboratory applications offer individuals the opportunity of direct contact with the substance world through using tools, data collection techniques, models and scientific theories (Ojediran, Oludipe and Ehindero, 2014). Thus, it will be possible for the individuals to learn science and comprehend scientific studies.

Scientific process skills, which facilitate learning, attain research methods, ensure individuals' active participation and responsibility by increasing permanence of learning, could be developed through laboratory studies in science. Literature reviewed indicates that there are not many studies examining the effect of experiential learning on laboratory applications to enable science learners to develop the skills of observation, generating ideas and making interpretations. This study is significant in terms of revealing the importance of chemistry laboratory applications based on the model of experiential learning rather than traditional verification laboratories. This revelation is crucial in classes with scientific contents such as Chemistry whereby the laboratory method could be used to increase student teachers' achievement levels and improve their scientific process skills. The current study, which has been conducted on this basis, sought to find out the effects of experiential learning model in the Chemistry laboratory on Chemistry achievement and scientific process skills. In the light of this approach, the aim of this study was to analyse effects of the Active Learning model to be implemented in the Chemistry laboratory on Grade 11 learners' achievement in Chemistry and their scientific process skills.

1.9 LIMITATIONS AND DELIMITATIONS

Some of the limitations identified and how they were overcome in this study were:

- *Time constraints* – Because the researcher is a full time teacher, time was a constraint. However, the researcher stuck to time-frames in order to complete the research on time;
- *Delays in obtaining permission from the Provincial head office in Zwelitsha* - The researcher followed up on emails submitted to the Department of Education's provincial office; and
- *Transport challenges for the researcher* - The researcher drew up a scheduled visiting programme and arranged transport accordingly.

The delimitations in this study include geographical, sample population and the conceptual delimitations. These are briefly discussed below.

- *Geographical delimitations* - The study only focused on Grade 11 Physical Sciences learners at the two selected Senior Secondary Schools;
- *Sample population delimitation* - The participants included all learners doing Physical Sciences in Grade 11 at the two selected Senior Secondary School; and
- *Conceptual delimitations* - This study focused on the use of VLDE in the teaching and learning of Physical Sciences.

1.10 DEFINITION OF PERTINENT TERMS

Some operational terms are defined in this section to explicate their meaning and the context in which the researcher used them in this study.

Attitudes: a mental and neural state of readiness, organized through experience, exerting directive or dynamic influence upon the individual's response to all objects and situations with which it is related (Omiko, 2015). In this study, *attitude* refers to general dispositions that stand behind people's evaluations and emotional feelings. Attitudes arise from human needs and are expressions of people's intellectual processes. Steely (2012) concurs by stating that there is a link between learners' attitudes and learners' outcomes.
Curriculum: "*As a field of study, curriculum can be defined narrowly as subjects that are taught in school* (Omiko, 2015).

Pedagogy: Methods and practice of teaching or strategies and styles of teaching (Steely, 2012).
Laboratory: A laboratory has been found to be the scientist workshop where practical activities are conducted to enhance a meaningful learning of science concepts and theories (Omiko, 2015). In the context of this study, a laboratory consists of various tools and equipment used by science learners either for the finding of new knowledge or to ascertain previous findings.
Alternative delivery methods: Other ways of delivering a Chemistry laboratory experience outside of the traditional teaching laboratory setting (e.g. using laboratory kits) (Steely, 2012).
Impact: According to the OECD (2002), impact refers to positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended. According to Omiko (2015); Ören, Turnitsa, Mittal and Diallo (2017) there are six dimensions in the measurement of impact, namely, application, scope, subject and level of change, degrees of separation and immediacy, rate and durability of change and homogeneity of benefits. In the case of this research,

impact refers to positive and negative effects as well as primary effects produced by the VLDE intervention directly, as intended with dimensions of the application.

Simulation Based Learning: Simulation-based learning integrates cognitive, technical, and behavioural skills into an environment where learners believe the setting is real, act as they would be responding in the field, and feel safe to make mistakes for the purpose of learning from them. Ören, Turnitsa, Mittal and Diallo (2017) state that a simulation lab enables the students to learn and acquire the new skills in a relatively shorter time. Students can repeat a set of actions and exercises as many times as they want.

Blended laboratories: Combines technology-mediated, classroom instruction and/or virtual laboratories National Research Council (NRC), 2012). Additionally, Steely (2012) define blended learning as the integrated combination of traditional learning with web-based online approaches. In another attempt to provide a more focused definition of the term, National Research Council (NRC), 2012) states: "Blended learning describes learning activities that involve a systematic combination of co-present (face-to-face) interactions and technologically mediated interactions between students, teachers and learning resources". A similar definition is offered by (Steely, 2012; Ören, Turnitsa, Mittal and Diallo, 2017), where they defined blended learning as, "The thoughtful integration of classroom face-to-face learning experiences with on-line experiences.

Best instructional/teaching practices: "*a superior method or an innovative process that contributes to improved performance*" (Fraser 2012) in instruction and teaching or manner in which "*a science teacher uses materials, media, setting and behaviours to create a learning environment that fosters desirable outcomes*" (Fraser 2012, p.70).

Traditional laboratory: classroom laboratories or field work where learners can interact directly with data collected by others or natural phenomena whereby earners can manipulate real equipment, chemicals and specimens (National Research Council (NRC), 2012).

Virtual laboratory delivery environment: virtual studying and learning environments that simulate real laboratories. They provide learners with tools and materials; learners access the laboratory via a computer to perform experiments subjectively, or within a group, anywhere and anytime (Babateen, 2011). In this study, a virtual laboratory is a learning environment where learners can perform learning activities.

Virtual laboratory experience: A virtual laboratory is defined as an interactive environment in which simulated experiments can be carried out. A laboratory can be characterized as "*a playground for experimentation*" (Fraser 2012) providing tools that can be used to manipulate objects relevant to a specific scientific domain (such as chemicals in a chemistry laboratory). "*Virtual laboratories have been proposed to reduce cost and simplify maintenance of lab facilities while still providing learners with access to real systems*", (National Research Council (NRC), 2012; Collins English Dictionary, 2012).

Achievement Testing: Achievement testing refers to the practice of using achievement tests to efficiently measure the amount of knowledge and/or level of academic skills an individual has acquired or mastered through the planned instruction that typically occurs in educational settings (Bell, 2012; Ören, Turnitsa, Mittal and Diallo, 2017). The practice of administering achievement tests may take place in the fields of school psychology, clinical psychology, and special education to assist in assessing academic proficiency or diagnosing learning disabilities, as well as in the field of clinical neuropsychology to assist in detecting individual strengths and deficits in patients with neuropsychological disorders affecting reading, computation, or writing skills (Bell, 2012; Collins English Dictionary, 2012).

Achievement test: it is a test developed to measure the cognitive achievement of the participants in both the experiment and control group or a psychological test designed to measure the effects that learning and teaching have on individuals (Collins English Dictionary, 2012; Bell, 2012; Ören, Turnitsa, Mittal and Diallo, 2017). In this study, an achievement test refers to a test designed to measure the knowledge or proficiency of an individual in something that has been learned or taught.

Sciences techniques and practical expertise: These are rational activities that contribute to learner achievement in Physical Sciences in this study. National Research Council (NRC) (2012) defines sciences process skills as "*sequence of events which are engaged by researchers while taking part in a scientific research investigation generally* *related to proficiency in the doing aspects of science associated with cognitive and investigative skills*" (National Research Council (NRC), 2012).

Learning environment: The learning environment includes all facilities and infrastructure available where the school is located and all that can be found within the school surroundings. In this study, the learning environment refers to the physical location or teaching delivery (National Research Council (NRC), (2012; Ören, Turnitsa, Mittal and Diallo, 2017).

Teaching materials: These are instructional materials used to support learners and teachers in the process of teaching and learning (National Research Council (NRC), 2012).

Learner Performance: "*This refers to the learner's ability to demonstrate understanding and show that learning has taken place through an activity or task*" (Bell, 2012). Performance is the accomplishment of a given task measured against pre-set standards of accuracy, completeness, cost and speed.

Outcome: The outcome entails meeting the needs of the society as a result of achievement in Physical Sciences. Bell (2012) states that in educational institutions, success is measured by academic achievement or how well a learner meets standards set out by local government and the institution itself.

1.11 STRUCTURE OF THE STUDY

This part outlines the structure of this study as follows:

Chapter 1: Orientation and Background of the Problem

Chapter one provides the background and purpose of the study. The focus of the study is to evaluate the impact of the VLDE on learning outcomes in Physical Sciences among Grade 11 learners. In this chapter, the introduction, problem statement, significance, aim, research questions and organisation of this study are explicated.

Chapter 2: Literature review

Chapter two provides a more detailed review of relevant literature with respect to practical work in science education and various delivery environments, including the virtual laboratory delivery environment.

Chapter 3: Research Methods

Chapter three presents the research processes carried out to collect data to provide answers to the main and sub-research questions of this study. In this chapter, the research paradigm and approach, research method, research designs, population, sampling techniques, data collection procedures, ethical considerations, validity and reliability of the data-collecting instruments are explicated. Furthermore, the chapter presents the development of the instruments (Physical Science Achievement Test on Conceptual Understanding (PSATCU), the Physical Practical Skills (PSPST), to assess learners' proficiency in the acquisition of techniques and practical expertise, and the Physical Sciences Attitudes Interview Schedule (PSAIS).

Chapter 4: Presentation, analysis and discussion

Chapter four presents the results of the study. Furthermore, the chapter analyses the data presented to make meanings from the data. Quantitative and qualitative data are presented, analysed and discussed.

Chapter 5: Summary of the findings, conclusions and recommendations

This chapter summarises the findings arrived at by the study. The chapter also includes conclusions and ends with recommendations and possible suggestions for future studies.

1.12. SUMMARY OF CHAPTER ONE

In summary, background details of the study and the statement of the research problem for this study have been discussed in the present chapter. In addition, it presented the research aims, objectives, main research question and its related subsidiary research questions. It further presented the following research study components: rationale for the study, significance of the study, conceptual framework for this study, definitions of pertinent terms and acronyms and abbreviations and presented the research structure used in this study. The next chapter will present reviewed literature.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 INTRODUCTION

In Chapter one, the background to the study and other key concepts were discussed. Based on assumptions that virtual laboratory delivery environments play in the science education, a study of their impact on learner achievement, acquisition of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise and attitude towards Physical Sciences is likely to provide useful insights as an alternative delivery environment in South African schools. Chapter two presents the role of Active Learning Strategies in science education, literature on practical work, wet laboratories, alternative laboratory delivery methods, virtual laboratories, potentials and impact of virtual laboratories in Physical Sciences education, strengths and weakness of virtual laboratories in science education, best practices for virtual science laboratories and Virtual ChemLab application, all in line with research objectives.

2.2 THE PURPOSE OF PHYSICAL SCIENCES AND IMPACT OF TEACHING APPROACHES

Predominantly, the struggle over the South African curriculum is centred on the purpose of Senior Secondary school science education. Was the point to provide learners with some general practical knowledge, to equip learners with the knowledge, skills and values necessary for self-fulfilment and meaningful participation in society as citizens of a free country, to prepare them for tertiary education and careers, to facilitate the transition of learners from education institutions to the workplace or to solve the problems of society in the next generation? There is continuous debate on this theme, although there have been repeated shifts in which argument appears to have the upper hand. The Current Physical Sciences CAPS curricula continue to support the development of collaborative and reasoning skills, both featuring in lists of so-called valued 21st-Century skills (Stott and Hobden, 2019). The purpose of physical science is to make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena (DBE, 2011, p. 8). The initial introduction of Outcomes Based Education (OBE), with associated educator training workshops, emphasised experimental work as effective in enhancing conceptual learning and skill development. The study of Physical Sciences is aimed at contributing towards holistic development of learners by:

i. Giving learners the ability to work in scientific ways - The difference between the cognitive load offered by inductive and deductive tasks can be understood in terms of the randomness as genesis and the borrowing and reorganising principles (Kirschner, Sweller, Kirschner and Zambrano, 2018).). Borrowing information, followed by reorganising it, from sources such as an educator, textbook, or peer, is required during deductive reasoning. This offers less cognitive load than does the hypothesis generation and testing required in inductive reasoning (Stott and Hobden, 2019).

ii. Stimulating their curiosity, deepening their interest in the natural and physical world in which they live;

iii. Developing useful skills and attitudes that will prepare learners for various situations in life such as employment and entrepreneurial skills - According to the CAPS document (DBE, 2011), the procedural knowledge is regarded as a set of skills that learners can practice and learn through repeated exposure to experimental work under the guidance of an educator; and

iv. Enhancing understanding that the technological applications of Physical Sciences should be used responsibly towards social, human, environmental and economic development both in South Africa and globally (DBE, 2018, p.3).

Learning effectiveness is dependent on which outcomes are valued. The outcomes valued in this study are: (a) learners display critical thinking during the learning, (b) learners are interested and actively engaged in learning, (c) tasks are attainable with effort and (d) the curriculum objectives are met.

2.3 PHYSICAL SCIENCE AND ACTIVE LEARNING

Physical science as a discipline is guided by rules and principles, following a vertical discourse in what Gamble (2009, p. 23) refers to as 'conceptual coherence'. A curriculum that is conceptually coherent is one in which the concepts build on one another with new themes based on previous ones in a logical manner. Sequencing of topics, their pacing and progression are of great importance in ensuring that concepts are understood by learners (ibid). Physical Science, as one of the subjects that equips learners with scientific knowledge and scientific knowledge, is the foundation for science education. According to Dadach (2013, p.907), there are different active learning strategies, and inductive learning is one of them. Dhurumraj (2013, p.21), in his research study based on "contributory factors to poor learner performance in Physical Sciences", mentions "lack of school-based and home-based resources" in the teaching and learning of the Physical Sciences. This lack of resources can affect learner performance in many aspects such as conceptual development, proficiency in the acquisition of techniques and practical expertise, and attitude towards the subject. The laboratory is seen as a place where active learning occurs (Ojediran, Oludipe and Ehindero, 2014). In a laboratory with equipment, learners do the experiments and interact with each other. In order to position oneself from the outset, the researchers tend to agree with the following guiding principles regarding laboratory learning:

1. The overarching purpose of laboratory learning is to teach learners how to 'do' science;
2. Preparing students for learning in the laboratory is Beneficial;
3. Explicit consideration needs to be given to teaching experimental techniques; and
4. Consideration of learners' emotions, motivations, and expectations is imperative in laboratory settings (Galloway, Malakpa and Bretz, 2016; Seery, Agustian and Zhang, 2019).

Laboratory work encourages learners to approach problems and solve them, find facts and new principles, develop ability to cooperate and develop critical attitude towards the subject" (Ojediran, Oludipe and Ehindero, 2014). During laboratory work, the educator plays an active role of organizing a learning space that enables all learners to be productively engaged in individual and cooperative learning. Learners can be actively involved and are free to exchange ideas. Ojediran, Oludipe and Ehindero (2014) conclude that the use of laboratory-based instructional intervention method of teaching should be embraced as a good asset to Physics learners and teachers in the senior secondary schools.

2.4 PRACTICAL WORK AND ITS ROLES IN SCIENCE EDUCATION

Practical work has gradually acquired an increasingly prominent place in Physical Sciences within the National Curriculum Statement (NCS) (Ngema 2011). Conducting practical work in Physical Sciences remains an important aspect of the subject. However, many teachers experience problems with conducting these practicals despite their importance. In spite of the accrued benefits of practical work in science education, several challenges are associated with the availability and use of traditional laboratories in schools (Ramnarain, 2014; Penn and Ramnarain, 2019). Some of the challenges include, the dangers associated with handling chemicals, overcrowding of students, little time allocated for experimentation within syllabi and lack of physical laboratory resources for sustaining student practical experiences (Chiu, DeJaegher and Chao, 2015; Faour and Ayoubi, 2018). Although there have been incremental improvements since the advent of democracy in 1994, these have been insufficient to address the huge backlogs that continue to exist (Reddy, Menon and Thattil, 2016). Historically disadvantaged schools remain poorly resourced and have scant facilities for practical work in science. Therefore, one of the main challenges in the implementation of experimental chemistry has been the non-availability of physical resources such as apparatus and chemicals at these historically under-resourced schools (Lelliott, 2014).

In an effort to address this deficit in school science, the emphasis has largely been on the provision of new technologies in educational environments, which has thus far been resource-poor (Wallet, 2015). While some studies have explored effectiveness of practical work, characteristics of practical work, teachers' views on practical work and teachers' understanding of nature of practical work, none of the studies explored the effectiveness of VLDE and how it permeated the science classroom practice. To a large extent, there has not been exploration of VLDE as an instructional strategy. On these grounds, the focus of this study was on how Grade 11 Physical Sciences learners were exposed to practical work in the form of laboratories.

Practical work is defined as "…*learning experiences in which learners interact with materials or with secondary sources of data to observe and understand the natural world*." (Toplis and Allen, 2012; Arabacioglu and Unver, 2016). Practical work in literature has been referred to in different ways: 'experimental work, scientific investigations, (Penn and Ramnarain, 2019) and 'laboratory investigations' (Kibirige and Tsomago, 2013). The broad perspective of 'learning experiences' will be understood to include the wide range of practical skills, thought and processes that constitute doing science as 'what scientists do' (Arabacioglu and Unver, 2016). Some authors in science education contend that practical work in science has many purposes (Astutik and Prahani, 2018). For example, Watts (2013, p.4) lists some of these purposes required by the General Certificate of Education as:

> *"motivation for learners –the excitement of discovery, consolidation of theory, development of manipulative skills, knowledge of standard techniques, general understanding of data handling, development of other skills (e.g. analytic, evaluative, planning, applied, mathematical) and understanding of how science works- concepts of scientific process, collaborative working, reproducible results, fair testing."*

Another purpose of practical work is the understanding of errors and how to design practical procedures to improve precision and accuracy. Learners acquire skills for safety; risk and precaution against hazards in the laboratory (Bose2013). Practical work also provides learners with evidence to support their understanding and concretise scientific principles (Ramnarain, 2014). Thus, learners are exposed to basic processes of science through practical work. Practical work has traditionally been a '*recipe-like'* activity that had minimal cognitive engagement and did not inspire originality in learners (Bigelow, 2012). Research by The National Research Council (NRC, 2012); Bulent, Mehment and Nuran (2014) have recommended that when during practical work, learners should be investigative, design their own experiments, record and analyse as well as find their own answers. Njoroge, Changeiywo and Ndirangu (2014) suggested that instead of learners dealing with already known answers, such as determining known constants, they need to investigate novel problems. In this way, practical work supports development of scientific skills, thinking skills and how scientists work (Njoroge, Changeiywo, and Ndirangu, 2014).

Learners benefit through engagement with concepts in practical work through "interactions, hands-on activities, and application in science" (Hampden-Thompson and Bennett 2013, p. 1340). However, other researchers found that the inquiry approach in practical work requires much time, and a session of one hour is never enough (Kibirige, Rebecca and Mavhunga, 2014). Practical work caters for learning in different ways such as experiential, independent, team and peer dialogue (Zimbardi, Bugarcic, Colthorpe, Good and Lluka, 2013). Different learning styles have the pedagogic benefit of enabling correct concept development. They underscore the empirical nature of science, measurement, repeatability of experiment and learners may enquire as real scientists do. While these pedagogic benefits have yielded encouraging results in science classrooms, elsewhere, this has not been the case in South Africa (Buthelezi, 2012).

Kibirige, Rebecca and Mavhunga (2014), using mixed methods research with 53 practising teachers in Venda, Limpopo, established that most teachers had '*little experience, meagre training, and operated in large and poorly resourced science classrooms".* Consequently, teachers resort to chalk-and-talk, lecturing and demonstrations when teaching Physical Sciences. Many weaknesses are inherent in the South African science teacher education enterprise. Kibirige, Rebecca and Mavhunga

(2014) reported that teachers emerged from an education system that did not groom them to do experiments or practical work. The lecturers in pre-service training lacked knowledge and experience in conducting practical work. Schools were also found to lack equipment and laboratories (Kibirige, Rebecca and Mavhunga, 2014) as well as laboratory technicians to support teachers. Kibirige, Rebecca and Mavhunga (2014) further established that some school principals even kept science equipment for display in their offices and never used them in the science classrooms. This confirms that principals lack an understanding of the purpose of practical work and its role in the CAPS science curriculum. One of the major requirements of CAPS is that teachers should do at least one practical in Physical Sciences per term for purpose of formal assessment (CAPS, 2012). The combined effect of poor resources in schools and the CAPS requirement result in an observable lack of practical work in science classes.
Literature is awash with the observation that practical work produces good performance in science (Muwanga-Zake, 2020). Despite such observations, Kibirige, Rebecca and Mavhunga, (2014) noted that schools are only as good as their teachers, regardless of how high their standards, how up-to-date their technology, or how innovative their programs. Similarly, low level content, lack of practical skills and negative attitudes towards innovative science teaching are problems besetting teachers and consequently, teachers do not use practical work in their science classes (Kibirige and Tsomago, 2013).

When well-planned and effectively implemented, science education laboratory and simulation experiences situate learners’ learning in varying levels of inquiry requiring learners to be both mentally and physically engaged in ways that are not possible in other science education experiences (Lelliott, 2014). There are many espoused objectives for doing practical work in school science. Some of the most frequently stated by teachers are:

- to encourage accurate observation and description;
- to make phenomena more real;
- to arouse and maintain interest; and

- to promote a logical and reasoning method of thought (Kibirige, Rebecca and Mavhunga, 2014).

Practical work may be considered as engaging the learner in observing or manipulating real or virtual objects and materials (Hofstein and Kind, 2012). Appropriate practical work enhances learners' experience, understanding, skills and enjoyment of science. Practical work enables learners to think and act in a scientific manner. The scientific method is thus emphasized. Practical work induces scientific attitudes, develops problem-solving skills and improves conceptual understanding (Hofstein and Kind, 2012). Practical work in Physical Sciences helps develop familiarity with apparatus, instruments and equipment. Manipulative skills are acquired by learners, and expertise is developed for reading all manner of scales. The observations made and results obtained are used to gain an understanding of Physical Sciences concepts. Physical Sciences process skills necessary for the world of work are systematically developed (Griffin and Care, 2015). First-hand knowledge is generated, and abstract ideas can be concretized. Naïve, neonate and scientifically primitive ideas can be challenged while tacit knowledge of scientific phenomena can be gained (Finstein, Darrah, and Humbert, 2013).

Practical work creates motivation for and interest in learning Physical Sciences. Learners tend to learn better in activity-based courses where they can manipulate equipment and apparatus to gain insight into the content. Hofstein and Kind (2012). suggested that practical work should be viewed as the mechanism by which materials and equipment are carefully and critically brought together to persuade the Physical Sciences learner about the veracity and validity of the scientific worldview. If practiced in the right manner from the early secondary school period, critical thinking skills can be attained from practical work in Physical Sciences. Practical work puts learners at the centre of learning where they can participate in, rather than being told about Physical Sciences. In this way, the desire and eagerness to know more about what the subject can offer is developed. However, the reality on the ground is that most experiments are sterile, un-illuminating exercises whose purpose is often lost on the learners.

In many countries, practical work is ill conceived, confused and unproductive (Finstein, Darrah, and Humbert, 2013). Whatever goes on in the laboratory has little to do with actual learners learning Physical Sciences. Teachers, who often miss the point of the demonstration, usually do demonstrations. Small group work is done, but follow up discussions on the purpose of the exercise are usually counterproductive. There is usually limited planning and formulation of hypotheses, mostly done by teachers. In many cases, the experiments are derived from mostly irrelevant cultural settings with the attendant equipment disasters. The learners follow a fixed programme of experimental manipulations and observations set by the teacher, cookbook style.

This study acknowledges the great role that well planned and delivered practical work in Physical Sciences can play in influencing learners learning Physical Sciences in other countries such as Kenya. For this to happen, practical work has to form a central part of classroom learning of Physical Sciences. Deliberate effort has to be made to attract and retain learners in the Physical Sciences class by appealing to a curiosity raising element and discovery component of practical work in the subject. Meaningful practical work is always embedded in a discussion of ideas that makes it necessary to check observations and findings against experience and theory. Teachers hold the key to this interchange of ideas. Studies show that secondary school science teachers' education correlates positively with their learners' achievement in matriculation examinations.

The theoretical and pedagogical content knowledge of the teacher, the ways in which the teacher delivers instruction, and the teacher's attitudes toward science have been shown to have an impact on student learning and achievement (Miller and Dumford, 2016). This is especially so in the laboratory where the essence of the practical instruction is not immediately abundantly clear to the learners. Drawing meaning out of practical and experimental work requires guided higher level abstraction. Learners can benefit from an inspirational and knowledgeable teacher. All of these factors are related to the teacher's own education, both as a teacher and as a former school pupil.

When ideas about laboratory education are discussed, purposes of laboratories are of topmost importance. In the early years of laboratory education, the emphasis of laboratory was on teaching of techniques and analytical skills related to reproducing results. In the early 1900s, the focus on laboratory education changed to reproducing conceptual ideas in the laboratory and laboratories became a "cookbook" demonstration of the concepts during a physical science class. Many debates over demonstration versus individual laboratory argued with different purposes in mind, indicating that the problem was not which method is best, but what do we want learners to learn in laboratories. The defining goal for the laboratory continues to be a problem. Hofstein and Kind (2012). pointed out that purposes of laboratories are not defined specifically for the lab component of science education. While some have tried to define the goals of laboratory education, these goals tend to match the overall goals of science education in general and do not reflect the specific goals that need to be accomplished by laboratory work. Prahani, Limatahu, Winata, Yuanita and Nur (2016), for instance looked at the purposes of laboratories in English schools and stated that while these objectives were good, they are ever-changing. Hofstein and Kind (2012) demonstrated this when he used a survey to show how educators have changed their ranking of goals for laboratories over the years. These differences can be seen across disciplines and can be seen in the validation of different styles of laboratory education. While the number and importance of these goals has changed, the categories of goals outlined by several sources (Bretz, Fay, Bruck and Towns, 2013) were as follows:

- Technique - Understanding and manipulation of instruments and materials in the lab;
- Method - Understanding of the scientific method and its processes of accumulating and evaluating information;
- Critical thinking - Ability to design experiments, evaluate results, and problem solve;
- Conceptual knowledge - Understanding the underlying concepts of science;
- Factual knowledge - Knowledge of facts regarding chemicals and materials;
- Positive attitude - Increase curiosity and positive attitudes toward science;
- Cooperative learning - Ability to work in groups to problem solve; and
- Communication skills - Ability to read, write and present orally in the discipline.

Practical work in senior secondary school science education takes the form of laboratory experiments, demonstrations, fieldwork and excursions. The National Research Council (NRC) (2014) states, "laboratory experiences provide opportunities for learners to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science." The NRC (2014) also clearly defines overall learning objectives for a laboratory experience as:

- enhancing mastery of subject matter;
- developing scientific reasoning;
- understanding the complexity and ambiguity of empirical work;
- developing practical skills;
- understanding the nature of science;
- cultivating interest in science and interest in learning science; and
- developing teamwork abilities

The American Chemical Society attests, "to learn chemistry, learners must directly manipulate chemicals, study their properties and reactions, and use laboratory equipment and modern laboratory instruments" (Fadzil and Saat, 2017). Common outcomes from the general chemistry laboratory component should include competence in basic laboratory skills such as laboratory safety, keeping a laboratory notebook, using electronic balances and volumetric glassware, preparing solutions, chemical measurements using pH electrodes and spectrophotometers, data analysis and report writing. More specifically, throughout the general chemistry laboratory series, learners should be:

- Anticipating, recognizing, and responding properly to potential hazards in laboratory procedures;
- Keeping accurate and complete experimental records;
- Performing accurate quantitative measurements;
- Interpreting experimental results and drawing reasonable conclusions;
- Analysing data statistically, assessing the reliability of experimental results, and discussing the sources of systematic and random error in experiments;
- Communicating effectively through written and oral reports;

- Planning and executing experiments through the use of appropriate chemical literature and electronic resources; and
- Synthesizing and characterizing inorganic and organic compounds.

Teacher innovativeness and creativity could also introduce novel modes of practical investigations. In Kenya, these innovations include: Physical Sciences micro-kits, specifically prepared Science Equipment Production Unit (SEPU) kits, as well as crude improvisations (Prahani, Limatahu, Winata, Yuanita and Nur, 2016). Of late, efforts are being made to utilize virtual laboratories that rely on the interplay of the computer and the internet (Miller, 2014). Clearly, every effort should be made to create interest in the learners to study Physical Sciences. Even though the above efforts can be lauded, this study concentrated on exploring the role traditional laboratory experiments could play in developing interest in learning Physical Sciences amongst Form two girls. This research investigated how such an interest may be ignited in average performing secondary schools in the Western part of Kenya.

2.5 PERSPECTIVES ON PRACTICAL WORK

The concept of practical work, as it is used in science education, may be cause for confusion, as one might ask how practical work differs from laboratory work or experimental work. Miller (2014) refers to practical work as "any teaching and learning activity which, at some point, involves learners in observing or manipulating real objects and materials they are studying." Miller's definition implies that practical work can be conducted by the teacher or performed by learners. The manipulation of objects as suggested involves both "hands-on and minds-on" activities. On the other hand, the author clarifies preference of the term 'practical work' to 'laboratory work' or 'experimental work' since for laboratory work, location is not the critical feature in characterising this kind of activity. According to Miller (2014), observation and manipulation of objects can also occur outside of school setting such as home or field.

He further argues that experimental work is often used to mean testing of a prior hypotheses.

Miller (2014) gives a similar definition of practical work that is more inclusive as a "hands-on" learning experience, which prompts thinking about the world in which we live. This definition considers practical work as activities that assist learners in making sense of the world through interaction with the world around them. Furthermore, Woodley classifies these learning experiences into two main categories, which are:

- core activities that support the development of practical skills and understanding of scientific concepts such as investigations, laboratory procedures and techniques; and
- directly related activities closely related to core activities providing valuable first-hand experience for learners, such as designing and planning investigation, analysing results and teacher demonstration.

Using the same classification, Science Community Representing Education (Fadzil and Saat (2017) adds a third category: "complementary activities which include surveys, simulations, presentation and science related visits".

Wicaksono, Wasis and Madlazim (2017) define laboratory activities as "learning experiences in which learners interact with materials or with secondary data to observe and understand the natural world." However, contrary to Miller (2014) definition, Wicaksono, Wasis and Madlazim (2017) do not differentiate between the terms 'practical work' and 'laboratory work'. Wicaksono, Wasis and Madlazim (2017), in their definitions, put emphasis on making observations and manipulating materials when learners construct scientific knowledge, whether it inside or outside the laboratory. Furthermore, the definition of practical work by Wicaksono, Wasis and Madlazim (2017) gives examples of activities such as interacting with "aerial photographs to examine lunar and earth geographical features; spectra to examine the nature of stars and atmosphere; sonar images to examine living system."

Some of these activities can take place out of school or the laboratory setting. Writing in the nineties, Miller (2014) suggests that the concept 'laboratory' should not be limited to a physical building, but it defines any place where a scientist can work to investigate natural phenomena. According to Miller (2014), "a laboratory exists wherever and whenever investigators are working." Astutik and Prahani (2018) adds the same evidence that practical work need not always comprise activities at the laboratory bench, but is any learning method that requires being active rather than passive, according with the belief that learners learn best by direct experience. Wicaksono, Wasis and Madlazim (2017) clarifies practical work as those teaching and learning situations that offer learners ample opportunity to practice processes of investigation. Wicaksono, Wasis and Madlazim (2017) further explains that this would involve "hands-on or minds-on" practical learning opportunities where learners practice and develop various process skills. According to Wicaksono, Wasis and Madlazim (2017), the process skills referred to are, amongst others, questioning, observing, hypothesising, predicting and collecting, recording, analysis and interpretation of data. According to this definition, it appears that practical work is a way of teaching and learning that gives learners an opportunity to practise and develop process skills.

Astutik and Prahani (2018) define practical work in terms of the perspective of the movements influencing it. First, they define the discovery approach, which perceives practical work as means for discovery learning, where learners find things for themselves to develop their thinking. Second, they define the process approach, which perceives practical work as the methodology that will give opportunities to learners to practise what scientists do when they are acting as a scientist. Lastly, they define the investigation approach, where practical work is seen as a more holistic approach of problem-solving activities in which "learners have to be thinking about what lies behind what they are doing rather than simply applying a practiced process" (Astutik and Prahani, 2018). From the ideas of these authors, it is worth noting that there is a similarity between the process approach movement and the investigation movement in terms of a definition of practical work. Both movements are concerned with how science is practiced; however, the investigation movement moves a step further by being concerned with the thinking behind the practice of science. Hence, according to the investigation movement, practical work is an approach to teaching and learning that will enable learners to develop process skills (procedural understanding) and enhance their understanding of concepts, laws and theories of physical science (substantive understanding).

There is no specific consensus about what is meant by the term *practical work*. The above meanings infuse a variety of terms or explanations to describe practical work. However, these meanings are based on a similar perspective, regardless of the use of the term 'practical' or 'laboratory' work. Miller (2014) and Astutik and Prahani (2018), in their definition of practical work or laboratory work, develop the meaning of strategies or activities that can be conducted by a teacher or a teacher together with learners or learners on their own, either individually or in groups that give learners an opportunity to practice and develop process skills. Miller (2014) defines practical work in terms of types or categories, and Astutik and Prahani (2018) define practical work in terms of movements. Regardless of different meanings, most definitions include investigations along with laboratory procedures and techniques. Nadelson et al. (2015) substantiated evidence for enhanced student efficacy and efficiency in the laboratory, but the extent to which pre-laboratory videos could be used in support of learning, not only performative tasks, is still unknown. In a slightly different context, van de Heyde and Siebrits (2019) argue for blended learning to manage the flow of information between instructors, students, and the increasingly digitalised platform on which pre-laboratory exercises are made available. The role of laboratory in illustrating key chemical concepts and deepening students' theoretical understanding. The extent to which it serves these ideals depends on various factors, including the laboratory curricula and corresponding instructional designs, but research demonstrates that some insight into the substantive structure of chemistry could be gained through laboratory work (De Korver and Towns 2015; Bretz, 2019).

2.6 PERSPECTIVES ON VIRTUAL LEARNING DELIVERY ENVIRONMENTS

Teaching in the 21st century must develop an educating vision using technology integration to creative such a creative thinking (Anderson and Krathwohl, 2018). The teaching framework in the 21st century should depict learner's knowledge, science processing skills, and the ability required to reach success while entering professional zone today. The framework shall include: (1) the core subject and theme of the 21st century; (2) learning and innovative skill; (3) informational, media-related and technological skill; and (4) life skill and career (Bellanca, 2011). A successful creativity teaching process on physical sciences subject requires such a learning environment that can encourage the learners to answer with all possible answers available based on the right concept. A creative thinking must be activated during the process of investigation or process of scientific knowledge application. Scientific creativity has three dimensions consisting of products, creative characteristics, and processes (Park, 2013). Scientific creativity consists of two main spaces, namely the hypothesis space (looking for possible hypotheses) and the experimental space (doing experiments to get new hypotheses generated from the data). The activity that supports the improvement of scientific creativity can be held through a creative experiment, a search for scientific problem solution, and creative activity.

Researchers and policymakers recommend that a modern learning environment should incorporate media and technology, including virtual experiences (Tamim et al., 2011; Astutik and Prahani, 2018). However, this environment must be characterized by understanding the relationship between tasks and resources, integration, establishing and maintaining good study habits, building confidence, including enrichment, annotation, tracking, and feedback (Miller, 2014). Naturally, these dimensions of a learning environment differ from a traditional one; this is referred to as a Virtual Learning Environment (VLE) or 'v-learning' (Astutik and Prahani, 2018). In table 2.1, Tatli and Ayas (2013) tabulate the advantages of Virtual Learning Environment.

Table 2.1: Problems encountered in chemistry courses and solutions offered by virtual laboratories

Reason for teachers' lack of use of the lab	***Alternatives offered by virtual laboratories***
Safety concerns	Experiments that involve risks in the real environment due to poisonous or unsavoury gas releases can be safely performed in virtual laboratory environment / uncontrolled explosions (e.g. NI3) have no real-world consequences
Lack of self-confidence	Virtual laboratories help students and teachers with little or no laboratory experience in terms of selecting laboratory equipment, setting up experimental apparatus, and completing the procedure. With the exception of starting the computer or accessing the website hosting the virtual environment software, virtual environments require no prior preparation of laboratory equipment.
Lack of equipment	As virtual laboratory equipment is not at risk of being broken or lost, users can use virtual laboratories freely. Experiments that cannot be conducted in a real laboratory due to shortages of equipment and materials can be repeated in a virtual lab without any loss.
Time shortage	Time loss is reduced in virtual laboratories compared to time lost in real laboratories. The experimental procedure in virtual laboratories is similar to that of real laboratories. Understanding and following the experiments is easier in virtual media. After the experiment, it is not necessary to devote time to tidying the virtual laboratory. Students who become accustomed to the virtual laboratory environment can easily repeat the same experiments in the real laboratory environment.

Weaknesses of Confirmation method	The interactive format of the virtual laboratory environment presents the problem case by arousing students' curiosity. They are made to put forward and test hypotheses, and are also given the opportunity to make generalizations. Since the subsequent experimental steps in the virtual laboratory are pre-planned, based on algorithms, there is no risk of the experiment producing improper results or no results at all. The students are able to research freely within a largely determined framework (Astutik and Prahani, 2018).

2.6.1 Transformation of Laboratory Delivery Methods

Alternative laboratory delivery settings may include a learner's home, a classroom or laboratory that lacks the materials, funding, or infrastructure to conduct traditional general chemistry laboratories. There are different ways in which alternative laboratory experience can be delivered:

Hybrid Courses: Hybrid chemistry courses are a blend of online course content and face-to-face laboratories conducted in schools. These laboratory components are often intensive weekend sessions packed full of experiments and other laboratory experiences (Faour and Ayoubi, 2018).

Computer Simulations: These are computer-based platforms of laboratory delivery. Simulations are graphic virtual representations. Astutik and Prahani (2018) describe a web-based learning environment for simulated chemistry experiments. Late Nite Labs offer virtual laboratory simulators for Chemistry and Biology (REACTORtm and RADIANCEtm, respectively). These are online simulations for high schools, colleges and universities, and distance education.

Virtual Laboratory Delivery Environments: Virtual experiments are computer-based methods of laboratory delivery. Unlike computer simulations, virtual laboratory delivery environments have added levels of interactivity in which learners actually "perform" an exercise or experiment (Faour and Ayoubi, 2018). Learners conduct experiments virtually either in a web browser or through other software. Wicaksono, Wasis and Madlazim (2017) describe a computer-based Chemistry laboratory for conducting virtual titrations.

Remote Laboratories: Remote laboratories are when learners connect to and manipulate actual analytical instrumentation via the Web. They can do this from home, classroom, or laboratory. Prahani, Limatahu, Winata, Yuanita and Nur (2016), describe the remote use of a spectrometer to analyse unknown chemicals. Astutik and Prahani (2018) incorporated a remote gas chromatograph-mass spectrometer (GC-MS) laboratory into a newly re-designed pharmaceutical analysis class at the University of British Columbia. The North American Network of Science Labs Online (NANSLO) is an example of a consortium that provides remote laboratories using robotic manipulation of samples. Learners can perform laboratory experiments in biology, physics, geology and chemistry and interact with technicians in the laboratory while manipulating the instruments. They can also interact with other students logged in on the same experiment (NANSLO, 2012).

The PEARL project is a European Union funded project that developed a system of remote experiments and instrumentation for learners in science and engineering (Prahani, Limatahu, Winata, Yuanita and Nur, 2016). The experiments and software interfaces were designed to be accessible and usable by people with disabilities. Astutik and Prahani (2018) conducted a remote laboratory case study assessing inquiry learning with the use of the Massachusetts Institute of Technology's Microelectronics WebLab. This remote laboratory allows learners to control instrumentation to characterize micro-electronic devices. Learners perform experiments in real-time through the Internet. The authors used quantitative surveys and qualitative interviews and found that WebLab allowed learners flexibility to learn at their own pace and time, making this approach an effective "instrument of learning." Massachusetts Institute of Technology (MIT) also has the iLab project where learners can remotely conduct experiments in microelectronics, chemical engineering, polymer crystallization, structural engineering and signal processing (MIT, 2012).

2.6.2 Virtual laboratories

Woodfield, Caitlin, Waddoups, Moore, San, Allen and Bodily (2004); Fern'andez-Avil'es, Dotor, Contreras and Salazar (2016) at Brigham Young University have successfully implemented virtual inorganic chemistry experiments (called Virtual ChemLab) that reportedly provide a realistic experience. They stress that the point of the Virtual ChemLab is not to teach a technique; rather, the point is to focus on the process. They also argue that the technique itself should be experienced in a laboratory situation, but that the laboratory setting is not necessary to connect theory with practice or to teach critical thinking skills. But the authors state that if effectively used, the Virtual ChemLab provides practical experience and a realistic learning environment, teaches student the cognitive processes necessary in laboratory sciences, and reduces costs and environmental and safety considerations.

Virtual Laboratories are quickly replacing hands-on laboratory activities as the norm for teaching and learning science in the high school setting (Prahani, Limatahu, Winata, Yuanita and Nur, 2016). Prahani, Limatahu, Winata, Yuanita and Nur (2016) describe three main reasons for this shift. First, materials for hands-on laboratory activities are very expensive. Second, the use of chemicals in the classroom could potentially lead to lawsuits if chemicals are not properly handled by either the teacher or student. Third, virtual labs can provide a quality experience for learners, especially if the teacher lacks in-depth knowledge of the subject being taught. Furthermore, Kolloffel and Jong (2013) found virtual laboratories to be an easy and effective means to present the laboratory experience. The virtual laboratories provide the learners' learning environment as well as their laboratory environment, and are located on a website that usually contains a main page with links to the activities, achievements, and laboratory evaluation.

In an article from Digital Learning, Joseph (2012) agrees that virtual laboratories are effective, stating that they "have slowly and gradually become meaningful alternatives to physical labs" (para.2). The latest computer technologies allow for web-based laboratories to be used as a substitute to actual labs. The article continues by discussing how engineering and scientific disciplines use virtual laboratories in Indian educational institutes. Organizations such as armed forces and medical fields successfully create and use virtual laboratories for training. As reported by Kolloffel and Jong (2013), via the National Education Association, "Doctors use them to practice surgery" (para.1). If these organizations deploy virtual laboratories successfully, why not extend them to the school classroom?

2.7 THE POTENTIALS OF VIRTUAL LABORATORIES IN SCIENCE EDUCATION

Research findings by, Prahani, Limatahu, Winata, Yuanita and Nur (2016) suggest that learners learn most effectively in an active engagement learning environment. Virtual laboratories, if used properly, can create and foster this kind of active learning environment. Virtual laboratories also provide a cheaper alternative to school systems struggling with tight budgets Kolloffel and Jong (2013) and eliminate the potential for lawsuits associated with the use of strong or potentially poisonous chemicals (Miller, 2014). Despite the numerous potential benefits associated with using virtual laboratories to teach science in the high school setting, few studies have been conducted to assess teachers' practical experience with using virtual laboratories and how these experiences can be used to identify best practices for improving praxis among teachers, especially for new science teachers. Results from several studies suggest that online labs and videos can be as effective as physical or hands-on laboratory activities (Tatli and Ayas, 2013).

A study among high school learners identified a number of positive effects associated with using technology in the classroom (Astutik and Prahani, 2018). These positive effects include improved learner achievement and better learner engagement. Furthermore, the individualized nature of technology empowers learners to take more risks in their learning and to be more willing to make mistakes. Controversy around virtual labs remains, however, as some researchers (Faour and Ayoubi, 2018) have found online laboratories to be less effective than hands-on labs. These researchers also found that learners preferred face-to-face laboratories over virtual labs. Despite mixed evidence around effectiveness of virtual laboratories, use of these laboratories in senior secondary school science classrooms continues to rise (Faour and Ayoubi, 2018).

Prahani, Limatahu, Winata, Yuanita and Nur (2016) studied the effectiveness of virtual laboratories used in Chennai, India. The study analysed whether there was an increase in learning skills and a better understanding of concepts by implementing virtual laboratories for school learners. The study also focused on whether virtual laboratories help increase self-paced learning among the learners. The study showed that the majority of learners were familiar with and liked virtual laboratories. The learners seemed to prefer computer assisted tools rather than textbooks for learning. A member of the study team, Suresh Kumar, stated that "the animations (visuals) have a huge impact in the minds of the learners, even though they might not recognize the technology behind them" (Prahani et al. 2016). Kumar (2014) views virtual laboratories as a very interactive component that helps the learners understand concepts. Kumar also believes that "future generations will use computer based tutorials with embedded virtual laboratories and the number of learners reading books will be negligible." He felt strongly that multimedia formats will surpass all other media (Prahani et al., 2016).

Pyatt and Sims (2012) found that learner performance showed very little difference when comparing the virtual laboratories and the physical lab. Their study took place in a public suburban high school in the South Western Unites States over a two-year period. They reviewed assessment data to determine the instructional value of physical and virtual laboratories experiences as they relate to learner performance and attitudes. The researchers found that "learners showed a preference towards the virtual medium experiences...learners found virtual experiences to have higher equipment usability as well as a higher degree of open-endedness" (Pyatt and Sims, 2012, p.133). This study reviewed learning dimensions that occur in physical and virtual hands-on, inquiry-based lab investigations for first-year secondary school chemistry classes. The results demonstrated "virtual laboratories experiences resulted in greater learning gains…equal to, if not greater than physical lab experiences" (Pyatt and Sims, 2012, p.143). Learning outcomes appear to show that virtual laboratories experiences can be equal to, or better than the traditional lab experiences. This study also indicated that learners had a preference towards the virtual laboratories simulations. The study of Amin and Hazif (2012) was aimed at investigating the effect of using the Virtual Laboratory in physics and chemistry experiments in the development of observation and cognitive achievement. They found that there were statistically significant differences between the experimental and control groups in chemistry's cognitive achievement, favouring the experimental group.

In their Virtual ChemLab Project study, Woodfield, Caitlin, Waddoups, Moore, San, Allen and Bodily (2004) found that the virtual laboratories can meet most if not all of the learning objectives in a science lab. The purpose of the Virtual ChemLab Project is "not to teach laboratory technique…" but "…instead focus on the 'what', 'when', and 'why' of experiments" (Woodfield et al., 2004, p.1672). The Virtual ChemLab Project used observation and interviews, both online and live, of 1400 learners enrolled in freshman-level chemistry, in computer labs employing virtual assignments. The study found that two thirds of the learners thought simulation programs allowed them more freedom to explore and repeat experiments because they were easy to use.

Aliyu and Talib (2019) performed a study on assessing student learning in a virtual laboratory environment at the graduate student level using Open Network Lab. The results of the study indicate that learning occurs during lab sessions, compared to live lectures, but the numbers are very close, 45.9 % of learners learning in labs as compared to 54.1 % in lectures. Schools in Turkey experience limitations to hands-on experiments due to lack of equipment, but could experience the labs virtually. A study of ninth grade learners investigated their achievements with and attitudes toward virtual laboratories. For this study, the test group completed sixteen virtual experiments using a flash program. The results of the study showed that the virtual laboratories oratory had a positive impact on learners' achievement and attitudes compared to traditional teaching methods (Aliyu and Talib, 2019).

Another similar study was conducted in Turkey by Alkan (2016). This study focused on learning styles and use of web-based virtual laboratories for elementary learners (Turkey by Alkan, 2016). Alkan considered the virtual laboratory to be an "experimental teaching method." His study concluded that:

(i) virtual laboratories learners achieved better grades than those in the traditional labs;

(ii) the web-based virtual learning environment accommodated well for various learning styles; and

(iii) the majority of learners (75%) preferred web-based virtual laboratories to reading textbooks.

Virtual laboratories reflect a movement among educational institutions to make the equipment and elements of a traditional science laboratory more accessible to learners from any location, via the web (Turkey by Alkan, 2016).

Johnson (2012) found in his research that virtual laboratories allow learners to practice in a "safe" environment rather than attempting to use actual lab equipment. He concluded that virtual laboratories are a viable substitute when lab equipment is inaccessible. He also found that virtual laboratories could relieve the financial burden imposed by actual labs. In a study by Chen, Chang, Lai and Tsai (2014), virtual laboratories were found to be acceptable ways to model authentic laboratories. Furthermore, Bretz (2019) found that virtual laboratories can provide advanced individualized learning to meet educational needs and provide flexibility. He also found that one of the most important features of the virtual world is how easily one can update the content to address changes in learning objectives, unlike physical labs where changes require financing and construction.

Siew, Chong and Chin's (2014) article reviewing an online microbiology lab at the University of Texas, reports on the effectiveness of virtual laboratories. In the article, he interviews Vicki Freeman, chairwoman of clinical laboratory science. She remarks on how learners can perform bacterial studies virtually using more variables than would be allowed in a clinical lab. Siew, Chong and Chin (2014) noted the high cost of materials and time necessary for clinical laboratories. They noted, "With virtual laboratories, learners don't have to worry about messing up," and they do not have to fear wasting time and materials." Siew, Chong and Chin (2014, p. 3) highlighted a program run by Professor J. Reeves at the University of North Carolina and Professor D. Kimbrough at the University of Colorado. In their program, learners at a local community college performed remote chemistry experiments. Professor Reeves commented that "they are also learning at least as much as they would learn in an on-campus chemistry lab". Siew, Chong and Chin (2014, p.3) also noted that "online learners outperformed on-campus learners on the final exams and on the in-lab practical exams that Reeves gave to some of the distance learners". This study supports virtual laboratories as an equivalent to traditional labs.

The effectiveness of technology for lab experiments has been studied broadly to determine the benefits. Chen, Chang, Lai and Tsai (2014) remarked that rapid development in technology demand that schools offer greater opportunities for science education that include the internet. Miller (2014) found that computer-based simulations helped learners focus more on the process of experimental planning and data interpretation than the setup and safety needs of the experiment. Johnson (2012) reviewed and cited several studies where researchers found that employing technology allowed learners more time to observe and reflect in ways that provided greater understanding of the concepts.

Johnson (2012) presented findings that indicate technology can provide real-world, authentic experiences for learners, that it is effective regardless of gender, and that technology can enhance learning. Johnson's review of selected studies also provided cautionary evidence that technology, used inappropriately, can interfere with learning. This can occur with the introduction of technology before the learner has acquired a solid understanding of the underlying science concepts. In discussing teacher readiness, Johnson (2012) found evidence that the teacher's attitude and ability to incorporate technology in successful studies was very positive.

2.8 STRENGTHS AND WEAKNESSES OF VIRTUAL LABORATORIES IN SCIENCE EDUCATION

In a study by Reese (2013), the researcher found that several studies indicated that higher education institutions are replacing traditional laboratories with virtual laboratories to conserve resources. Although a virtual laboratory can never completely replace a traditional lab, the study supported the view that the benefits of a virtual laboratory are just as equivalent to the learner. In addition, virtual laboratories can offer a more flexible environment for the experiments. Campbell (2012) cited various reasons for replacing what they described as "place-based education" with alternatives like virtual laboratories. The main reasons they cited were that:
(i) Authentic labs are time-consuming and difficult to work into schedules;
(ii) Inconsistencies exist between lab sessions and teaching methods among educators; and
(iii) Up-to-date lab equipment and supplies are costly (Campbell, 2012).

In concurrence, Reddy et al. (2016) argued for benefits of virtual laboratories. Their study found the same advantages of space and funding as well as support for hands-on activities. Reese (2013) cited several advantages and disadvantages to using virtual laboratories. The benefits mentioned included ease with which a student could repeat experiments, a safe environment that presented no danger to the student, no chemical disposal threats to the physical environment and the extra time allowed to conduct the experiments in general. Reese (2013) saw disadvantages as not being able to gain true hands-on experience and lack of feedback from onsite instructors. In addition to lack of an onsite instructor, he cited lack of interaction with an onsite lab partner. Some difficulties were experienced by learners from other cultures because they struggled with the language or learning styles.

Siew, Chong and Chin (2014) used two classes with a total of 33 learners split into two groups. In these two groups, they both did hands-on and virtual labs; however, one group took the virtual lab first and the second group did the hands-on lab first. After each lab, the learners took a post-test. This experiment only tested them on one concept of gas laws. They also only tested conceptual learning in the form of a post-test. They found that learners increased their conceptual knowledge significantly after the hands-on or the virtual lab. After both groups completed the other lab, they also increased their scores. They conclude that it is better if learners perform both the hands-on and virtual labs. In addition, they tested high school learners who were somewhat more computer-inclined, and these learners did not have as much science background knowledge, so their increase in post-test scores could be due to this lack thereof. It is clear there are advantages and disadvantages to virtual laboratories in the science class. The cost of running a traditional lab is high while the human interaction
within virtual laboratories is low. Kumar (2014) noted how few studies are available to get a true measure of the virtual laboratories' value. Traditional and virtual experiences have their advantages and limitations (Bretz, 2019).

Virtual Lab Concept: It is defined as, "laboratory experiment without real laboratory with its walls and doors. It enables the learner to link between the theoretical aspect and the practical one, without papers and pens. It is electronically programmed in order to simulate real experiments inside the real laboratories" (Chen, Chang, Lai and Tsai, 2014). In addition, it is defined as, "A virtual studying and learning environment aims at developing the lab skills of learners. This environment is located on one of the internet pages. Usually, this page has the main page and many links, which are related to laboratory activities and its achievements (Reese, 2013). Through the above-mentioned definitions, the virtual lab can be defined as a virtual studying and learning environment that stimulates the real lab. It provides learners with tools, materials and lab sets on computer to perform experiments subjectively or within a group anywhere and anytime. These experiments are saved on CDS or websites.

2.9 COMPONENTS OF VIRTUAL LABORATORIES

The main components of virtual labs are determined to have the following:

a) Lab sets and equipment - The virtual lab is considered integral to the traditional lab but not an alternative to it. The existence of the traditional lab is very necessary, but in lower numbers and requirements, which help in the possibility of using it by several users outside the lab;
b) Computer devices - They are represented in personal computers, which are linked to the local net or to the international net so that the student can work directly in the lab, or distantly at anywhere and anytime;
c) Communication network and the related hardware- In case of performing experiments electronically, all the sets should be linked to the computer, because the link between the users with lab will be through digital communication;
d) Programs of the Virtual Lab- These programs are represented in the simulation programs, which are designed by professionals. It is necessary to design this program in an interesting and attractive form as these programs were designed to attract learners' attentions and urge them to complete the experiment. This is maintained by the animation techniques, video, and the three dimensional pictures;
e) Co-operation Programs and Management - These programs are concerned with the method of managing the lab and the ones who perform the experiment, including learners and researchers. These special programs register learners in the lab program and determine the kinds of access that should be provided to each user in the different experiments; and
f) Technical Staff - It is important to have a technical team to support educators in preparing and assessing scientific materials. In addition to evaluating the program to determine its efficacy (Johnson, 2012).

2.10 VIRTUAL LABORATORIES CURRICULUM

The virtual laboratory curriculum is designed to address the issues associated with expository experiments (George-Williams, Ziebell, Kitson, Coppo, Thompson and Overton, 2018). Compared to the traditional expository curriculum, the virtual laboratory curriculum puts more focus on the learner than on the manual and instructions during the laboratory (Russell and Weaver, 2011). When properly developed, Hofstein and Mamlok-Naaman (2013) argue that virtual laboratories have the potential to enhance learners' constructive learning and conceptual understanding, particularly when conducted in the context of the conceptual development of the topic taught (Russell and Weaver, 2011).

a) **Pre-laboratory**

With the advent of ubiquitous information technology in the 4IR era, the laboratory increasingly becomes digitalised. Weibel (2016) deployed all-electronic formats for obtaining introductory materials, preparing pre-laboratory reports, recording and analysing data in a simulated electronic laboratory notebook, and submitting the final report. Platforms such as Google Drive and Google Docs were used to facilitate file sharing and storing. He found that learners preferred this entirely online system once they got accustomed to working within the new platform. A significant increase in laboratory grades was also observed. In the same year, O'Sullivan and Harrison (2016) found that computer-based pre-laboratory resources aimed at supporting pre-university students of Chinese origin offer considerable benefits.

b) **Rationale for Incorporating Pre-Laboratory Activities**

Agustian and Seery (2017) have reviewed literature on pre-laboratory in the last five decades. Based on the analysis of the research development in this area, pre-laboratory activities have been used on the ground of at least three rationales, i.e. to introduce chemical concepts, to introduce laboratory techniques, and to address affective dimensions. Referring to the literature, there are at least five overarching themes of how and why pre-laboratory has been used. Firstly, it fosters learning of chemical concepts (Nadelson et al., 2015; Gryczka et al., 2016; Whealon, 2016). Secondly, it improves laboratory skills and efficiency (Fung, 2015; Towns et al., 2015). Thirdly, it raises awareness of safety in laboratory (Abdulwahed and Nagy, 2011; Gregory and Di Trapani, 2012). Fourthly, it enhances affective experiences in the laboratory (Donnelly, O'Reilly, and McGarr, 2013; Galloway and Bretz, 2016; O'Sullivan and Harrison, 2016). Lastly, it facilitates post-laboratory aspects such as report writing and corresponding calculations (Limniou, Papadopoulos and Whitehead, 2009). Some of these themes will be elaborated in the following subsections.

2.11 VLDE AND THEIR POTENTIAL FOR CONCEPTUAL DEVELOPMENT AMONG SCIENCE LEARNERS

These virtual laboratories are designed to help learners visualize this world and relate that to the macroscopic and representational world of science. Virtual laboratories have other advantages such as providing simulation of experiments that could not be done in normal wet laboratories. In Woodfield's ChemLab design, he incorporated experiments about quantum chemistry that only a few laboratories in the country would have machines or materials to accomplish (Woodfield et al., 2004; Woodfield et al., 2005). In this case, learners can perform experiments virtually, which they would otherwise never be able to do. Virtual laboratories, in this case, may offer more educational approaches to increase the learning of concepts by learners in laboratories.

Several virtual laboratories are designed with the purpose of helping learners feel more confident when they actually visit the laboratory (Chen, Chang, Lai and Tsai, 2014), thus helping to overcome some conceptual learning problems with chemistry (Amin and Hazif ,2012), replicating real experiments, and giving learners some open-ended problems (Woodfield et al., 2004). These virtual simulations range from simple paragraphs with small applet pictures that depict the experiment to having a virtual laboratory where one can manipulate glassware and travel around the laboratory to get things. Each design is different and created with different purposes in mind, making it hard to compare virtual laboratories to each other for research purposes.

Woodfield et al. (2004), at Brigham Young University, created a virtual laboratory for many different disciplines, but his first virtual laboratory creation was for chemistry. His group created two virtual laboratories, one for general chemistry and the other for organic chemistry (Woodfield et al., 2004; Woodfield et al., 2005). In both studies, he had learners take a questionnaire and a personality test and interviewed a few learners. In the general chemistry virtual lab, they compared the student's personality and learning types with their responses on certain questions from the questionnaire (Woodfield et al., 2004). They found that learners who are more cerebral (can approach problems from different perspectives) tended to enjoy the virtual lab more and explore them more than other learners. Cerebral learners also spent more time exploring the virtual lab. In the organic virtual chemistry lab, they also noticed that more learners that semester achieved an A in the class at the end of the semester than in any previous semester (Woodfield et al., 2005). They also found correlation between the student's enjoyment of the virtual lab and their performance in the class. From both virtual labs, it is clear that learning styles play a role in the success of virtual labs. However, Woodfield concluded that virtual labs were the best when used as a supplement but did not give evidence to support that conclusion.

2.12 PHYSICAL SCIENCES TECHNIQUES AND PRACTICAL EXPERTISE

This part discussed the following:

2.12.1 Metacognitive and self-regulatory skills

Apart from learning tactics and strategies, success in science learning is further conditioned by availability of control level learning skills and determination to succeed. Metacognitive skills have to do with a particular student's awareness and controll of his or her learning and development of personal learning styles (Palmiero, Giacomo and

Passafiume (2016). Miller and Dumford, (2016), defines metacognition as "a construct that provides insights into awareness and executive control of knowledge construction". Similarly, Siew, Chong and Lee (2015) defined metacognition as awareness and regulation of learning processes. Jatmiko, Widodo, Martini, Budiyanto, Wicaksono, and Pandiangan (2016) suggest that development in students' conceptions of learning, improvements in the organisation of students' learning and ability to assess own learning are aspects of metacognitive development. The concept of metacognition is too limiting because it excludes motivation and behaviour (Siew, Chong and Lee, 2015).

Self-regulated learning is more accommodating construct and is described next. Awareness of ones learning skills or strategies and their efficacy leads to self-regulation of one's learning. As Jatmiko, at al. (2016) note, self-efficacy judgements and attributions ofsuccess or failure to personal control were initially considered to be the m ain components of motivated learning. Other components of motivated learning accordi ng to Jatmiko, at al. (2016) included alertness, selectivity, connecting, planning and monitoring. Zimmernann (2010) maintains, in this connection, that a student can be described as self-regulated in as far as they are "metacognitively, motivationally, and behaviourally active participants in their own learning". Similarly, Jatmiko, at al. (2016) define self-regulation as ability and motivation to implement, monitor and evaluate various learning strategies for purposes of improving one's learning. Miller and Dumford, (2016) concur with Jatmiko, at al. (2016) when they propose four phases of self-regulated learning, namely:

- planning and goal setting;
- monitoring processes of the self, learning task and context;
- control and regulation of aspects of self, task and context; and,
- reactions and reflections on the self, learning task and learning context.

Metacognition is in the formulations of these authors a subset of the set of the set of self-regulated learning. The self-regulated learner uses metacognitive and other self-regulatory skills to improve his or her learning. The research question concerning meta-cognitive awareness and use of self-regulatory skills seeks to determine the extent to which the students can be described as self-regulated learners. The question is: What self-regulatory skills, if any, do the students use when learning physical science?

Science education in the 21st century emphasize on the acquisition of scientific knowledge and development of scientific skills through active teaching and learning approach in order to develop learners' proficiency in scientific inquiry (Fadzil and Saat, 2017). The skill to conduct hands-on practical work in science laboratory is an important scientific process skill and a common intention of science standards (Schwichow, Zimmerman, Croker and Hartig, 2016). Department of Basic Education (2015, p.8) defines Physical Sciences as a subject that "investigates physical and chemical phenomena through scientific inquiry, application of scientific models, theories and laws in order to explain and predict events in the physical environment". Jatmiko et al. (2016) further asserts that Physical Science is taught to develop the learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise. Learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise involves the "sequence of events which are engaged by researchers while taking part in a scientific research investigation and are generally related to proficiency in the doing aspects of science associated with cognitive and investigative skills" (Fadzil and Saat, 2017).

These recommendations place more emphasis on understanding and developing science inquiry skills. Learners' acquisition of scientific concepts is brought about in an effective teaching and learning environment through minds-on and hands-on activities (Elliot and Joey, 2018). These activities help learners develop the science inquiry skills that enhance understanding of concepts and content of science subjects. Scientific inquiry skills transcend the content of every science syllabus; hence their development is considered more important than the acquisition of knowledge (Astutik and Prahani, 2018). The acquisition of science process skills such as stating hypothesis, analysis, testing hypothesis, carrying out experimental procedure, problem solving (Astutik and Prahani, 2018), is vital because these skills are necessary for effective citizenry in the 4th Industrial Revolution (4IR).

2.12.2 Basic Science Process Skills

These skills "provide the intellectual groundwork in scientific enquiry, such as the ability to order and describe natural objects and events" (Schwichow, Zimmerman, Croker and Hartig, 2016). Therefore, scopes of the skills below should reflect the mentioned characteristics.

i. Observing - This involves a process whereby senses of touch, smell, sight, hearing and taste are used to describe the properties, differences and similarities of objects and events. The description is either in words (e.g. brown crystalline substance) or in numerical format (e.g. 4 cm long);

ii. Measuring - This involves the use of standard instruments (e.g. laboratory clocks, rulers) to find or make estimations to describe length, mass or time for objects or events. Measurements are recorded in units, for example, 5 meters, 10 seconds and 5 grams;

iii. Classifying - This involves organising objects, events or sequences according to characteristics, similarities or differences. Results of classifying can be in tables such as a periodic table, lists of strong/weak acids and charts of substances grouped into elements, compounds and mixtures;

iv. Communicating - Communication involves use of the spoken or written word to present and explain experiences and ideas to others. Written work can be in the form of text, pictures, graphs, charts, maps, drawings, diagrams, posters, concept maps, drama, demonstrations, tables and any other information presentations;

v. Inferring - This involves using observations and previous experiences to make conclusions about some phenomena. This may include cause and effect relationship. Results of inferring are statements showing relationships between or among variables in an investigation;

vi. Predicting - This means that observations, measurements and inferences are used to form an idea of expected results. Predictions are statements /explanations showing the relationships between variables in the event. The statements are made orally or in written form; and

vii. Using the number relationships - Numbers and their relationships are used to make decisions. One example is when a force is exerted on an object to move it some distance. Work done by the object is calculated by multiplying force applied on the object by the distance the object moves in the direction of the force.

2.12.3 Integrated Science Process Skills

These skills are hierarchically and cognitively higher than the basic skills, they "are the terminal skills for solving problems or doing science experiments" (Schwichow, Zimmerman, Croker and Hartig, 2016). The ability to carry out these skills can be ascribed to higher-level reasoning. The skills described below should display these characteristics:

i. Formulating hypotheses - This refers to stating the expected outcomes of experiments based on observations. Statements are predictions of relationships between variables in experiments that can be tested. One example is that increasing temperature or/and increasing concentration of hydrochloric acid increases the rate of reaction of hydrochloric acid and magnesium metal. This idea can be tested by conducting experiments;

ii. Identifying and controlling variables - Identifying and changing/ keeping constant conditions that can change the outcomes of an experiment. The conditions are called *variables*. For example, in an experiment to compare weights of objects, the size of force of gravity on the objects is a variable that must be controlled because it can influence the results of the experiment;

iii. Generalising - This is the process of identifying data that support conclusions and help to draw general conclusions. Generalisations can be statements of hypotheses that include interpolating / extrapolating between or beyond data points, respectively;

iv. Collecting data - This entails the gathering of qualitative (observations) data and quantitative (measurements) data from experiments and recording the data systematically in tables, lists or in other ways;

v. Interpreting data - To interpret data means to organise the data collected from experiments into tables, drawings and graphs and to identify trends or patterns in the sets of data to establish generalisations or to formulate hypotheses;

vi. Operational definition - This means describing how to measure a variable or explaining the meaning of an object or an event. It includes how an observation or a measurement can be made. Descriptions or meanings must be given in language the learners understand; and

vii. Experimenting - This entails a set of operations. Firstly, appropriate questions (stating hypotheses) to be investigated in experiments are formulated. Secondly, experiments are planned (identifying variables in the experiment). Thirdly, the procedures are carried out. This includes controlling variables alongside the use of apparatus. Lastly the collected data (observations or measurements) are recorded and interpreted to draw conclusions based on the experiment.

Such Science Process Skills form a frame of reference for assessing the identification of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise in the research tasks. The described scopes are not exhaustive because of the diversity of descriptions of the same learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise. According to the (DBE, 2015, p.8), the purpose of Physical Sciences is to "make learners aware of their environment and equip learners with investigating skills related to physical and chemical phenomena". In view of this assertion, learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise discussed above were fused into the following categories of laboratory practice in this study:

i. Identifying the variables in the problem;
ii. Establishing and defining hypothesis;
iii. Making operational predictions;
iv. Designing required analysis for the solution of the problem; and
v. Drawing and interpreting graphs (DBE, 2015).

2.13 LEARNERS' ATTITUDES TOWARDS PHYSICAL SCIENCES LABORATORY WORK

The word attitude is defined within the framework of social psychology as a subjective or mental preparation for action. A commonly used definition of attitude is a learned disposition to respond in a consistently favourable or unfavourable manner with respect to a given subject, object or event (Sunarti, Wasis, Madlazim, Suyidno, and Prahani, 2018). Ngman-Wara and Edem (2016) also described attitude as a state of readiness or a tendency of a person to respond in a certain manner when confronted with a certain stimulus. Both definitions highlight a consistent behavioural response in relation to a given attitude. Attitudes are rooted in experience and become automatic routine conduct (Sunarti, Wasis, Madlazim, Suyidno, and Prahani, 2018). Therefore, science learners' actions in science classrooms might be based on their ideas and beliefs manifested in their attitudes towards science teaching and learning.

The study of attitude towards science has become an important concept for a number of reasons. First, attitudes toward science are taught to fulfil basic psychological needs, such as the need to know and the need to succeed. Second, attitudes toward science are taught to influence future behaviours, such as interest in working on a science project and scientific activities (Ngman-Wara and Edem, 2016). The quality of science instruction and teachers' attitudes toward science have been shown to positively influence learners' attitude and achievement in science as well as their decision to enrol in science courses and pursue science and technology-related careers (Miller and Dumford, 2016).

Developing favourable attitudes towards science has often been listed as one of the important goals of science teaching.

The relationship between level of science knowledge, beliefs and attitude toward science teaching has been shown to be positive in some studies. Ngman-Wara and Edem (2016) stated that attitudinal construct has an influence on learners' learning as well as cognitive factors. Sunarti, Wasis, Madlazim, Suyidno, and Prahani (2018) have suggested that the laboratory, as a unique social setting, has (when activities are organized effectively) great potential in enhancing social interactions that can contribute positively to developing attitudes and cognitive growth.

Enrolment in Physical Sciences at senior secondary school is low in many African countries. Many learners consider Physical Sciences as difficult, abstract and theoretical (Fadzil and Saat, 2017). Many learners find the subject boring, unenjoyable (Hirschfeld, 2012). Interest in senior secondary school Physical Sciences is decreasing, learning motivation is declining, and the examination results are getting worse (Sunarti, Wasis, Madlazim, Suyidno, and Prahani, 2018). In many school settings, little time is allotted towards discipline compared to language and mathematics, which are other important subjects (Tesfaye and White, 2012).

According to the study of Ngman-Wara and Edem (2016), Turkish learners' attitudes toward science lessons significantly decreased from Grade 5 through grade 11. In his study, it was also found that attitude scores of mathematics and science courses had significant relations with scores of subtests of mathematics and science tests in ÖSS (student selection examination for university registration). Moreover, Tesfaye and White (2012) examined secondary school learners' attitudes toward science in Northern Ireland. They also examined the significance of gender and grade in respect of three sub-dimensions of the attitude scale, which are importance of science, science as a career and science in the school curriculum. The sample was 838 male and 711 female secondary school learners, with a total number of 1549 from 24 schools. Statistical analyses showed that in the level of importance of science, there was no significant difference among grades. However, learners in higher grades had less positive attitudes than in lower grades to the career in science and to the place of science in the school curriculum. Furthermore, there was no significant difference in the level of importance of science between males and females. Nevertheless, males had more positive attitudes than females to the career in science and to the place of science in the school curriculum.

One of the key factors that has an effect on learners' understanding of chemistry is attitudes toward chemistry (Tesfaye and White, 2012). Sunarti, Wasis, Madlazim, Suyidno, and Prahani (2018) made a study on the relationship between attitudinal factors and learners' academic achievement in the first year chemistry courses. They found a substantial relationship between attitudes toward chemistry and chemistry achievement and found that achievement in chemistry is more dependent on attitudes than aptitudes of the learners.

Schwichow, Zimmerman, Croker and Hartig (2016) made an investigation of attitudes toward chemistry and science among upper secondary chemistry learners (Grade 11 and Grade 12) in the United States of America. In the study, an attitude questionnaire was used to reveal learners' attitudes toward science and chemistry. The questionnaire was composed of 28 items, including four sub-scales, namely, "attitudes toward school", "importance", "careers in science", and "science in school". The overall reliability coefficient (KR-20) was calculated as 0.82, indicating a high reliability. The sample upon which the study was conducted included 2804 grade 11 learners and 656 grade 12 learners from 156 schools across the United States of America. The findings of the study state that grade 12 learners have more positive attitudes toward chemistry and science than grade 11 learners in all attitudinal subscales. Generally, most learners expressed that they have positive attitudes toward the importance of chemistry and believe that science and chemistry are very important areas in modern times.

In another study by (Schwichow, Zimmerman, Croker and Hartig, 2016), it is reported that from 1970s to 1980s, there was a sharp decrease in selection of chemistry lessons among high school learners in Israel. Thus, the purpose of this study was to examine the attitudes toward chemistry among high school learners, aged 15, who had the chance to choose chemistry in the university entrance examinations in Israel. A chemistry attitude questionnaire including 20 items in a five-point Likert scale was used to assess learners' attitudes toward chemistry. The sub-scales of the questionnaire were: interest and fascination in chemistry, use of chemistry, enjoyment of chemistry and importance of chemistry. The sample of the study was 211 high school learners (85 males and 127 females) at the age of 15 from three schools considered as upper and upper-middle classes. A modern chemistry curriculum was operationalized, and the chemistry program was based on innovative teaching principles in those schools. In the study, it was concluded that there is a significant difference between male and female learners in all attitudinal sub-scales. Male learners showed more positive attitudes toward chemistry lessons than female learners. Moreover, it was found that school differences do not have an effect in attitudes toward chemistry. The study concluded that it is very important to develop positive attitudes toward chemistry, and teachers should try to improve learners' positive attitudes toward chemistry by several means such as fostering curiosity and interest of learners, encouraging learners in participating laboratory activities and providing opportunities for self-examination.

Sunarti, Wasis, Madlazim, Suyidno, and Prahani (2018) investigated grade 11 learners' attitudes toward chemistry. By conducting a pilot study with 70 learners doing grade 11 from a public high school in Athens, the instrument was formed. It included 30 items with a five-point Likert scale ranging from "strongly disagree" to strongly agree. In the main study, the participants were 576 learners in grade 11, (16-17 years old). These learners were selected from seven schools in four towns in Greece. The internal reliability coefficient of this scale (Cronbach alpha) was calculated as 0.89 in the pilot study and 0.91 in the main study.

The analysis of data showed that learners show neutral attitudes regarding interest and difficulty in chemistry course. On the other hand, they have negative attitudes in the usefulness of chemistry course in that chemistry lessons are not useful for their future career, and they have positive attitudes regarding the importance of chemistry in their daily lives. Moreover, there was no significant difference between boys and girls in the three subscales: interest, usefulness, and importance related with chemistry. However, boys had more positive attitudes than girls with regard to the difficulty of chemistry lessons. Some of the results of the study concurred with the findings by Schwichow, Zimmerman, Croker and Hartig (2016). In a study on learners' attitudes by Schwichow, Zimmerman, Croker and Hartig (2016) in Israel, revealed learners were a more positive towards Chemistry. On the other hand, some results were different from Schwichow, Zimmerman, Croker and Hartig' (2016) in gender differences. Boys showed more positive attitude toward chemistry than girls regarding interest, use, and the importance of chemistry in Israel, and there is no significant difference in Greece.

In another study, Astutik and Prahani (2018) investigated secondary school learners' attitudes toward chemistry. The interaction effect between grade level and gender was the focus of this research. The sample of the study was 954 secondary school learners, aged 16 to 19, who took chemistry courses in Hong Kong. Learners' attitudes were assessed based on an attitude toward chemistry lessons scale, which has four subscales: liking for chemistry theory lessons, liking for chemistry laboratory work, evaluative beliefs about school chemistry and behavioural tendencies to learn chemistry. The instrument had 12 items with a seven-point Likert scale and Cronbach's alpha values for each sub-dimension ranging from 0.76 to 0.86.

The findings of the study were as follows: First, by using the statistical analysis, two-way MANOVA, it was concluded that there was a significant main effect for gender, a significant main effect for grade level and a significant interaction effect between grade level and gender found to be statistically significant. Secondly, males liked chemistry theory lessons more than females in the first two years of secondary school. Statistically significant differences were limited to first two grades of secondary school and the theory lessons subscale. Another finding of the study was that male learners' attitudes to chemistry lessons, as expressed by liking chemistry laboratory work showed a significant decline as grade level increased, but there was no such significant change in female learners' attitudes. Finally, for the evaluative beliefs subscale and behavioural tendencies subscale, there was no significant change across grade level and between genders (Astutik and Prahani, 2018).

Trivedi and Sharma (2013) explored the relationships between attitude and achievement performed through a meta-analysis. The results revealed that attitude and achievement had a significant and positive relationship. It was shown that the association between attitude and achievement score was high from grades 7 to 11 and small at elementary level.

The correlation of attitude in the direction of science, with the achievement score in science, were explored by Astutik and Prahani (2018). Twenty physical science classes were used to collect data, and the results revealed a positive relationship of attitude with the achievement score. Achievement in science was influenced by means of attitude in the direction of science. Attitude and achievement score were found to positive and in strong association with each other. Among centre schools in South Florida, the connection among attitude and achievement score was investigated by Faour and Ayoubi (2018). To measure the attitude towards science, TOSRA by Fraser (2012) was used. The Attitude of learners in the direction of science subjects was positively significant and their achievement scores were higher.

2.14 THEORETICAL FRAMEWORK

This section presents the theoretical framework of this study. The overarching theoretical framework for this study is constructivism. The central concepts of the theoretical framework of this study are individual and social constructivism theories of learning, self-regulated learning and disadvantaged learners.

2.14.1 Constructivism

Learners subjected to constructivist learning theory-based laboratory instruction exhibit higher achievement scores, deeper attention, and a more frequent participation in chemistry course (Seery, Agustian and Zhang, 2019). It is also obvious that learning environments adopting and applying the constructivist learning theory should be supported with activities facilitating cooperation and interaction (Griffin and Care, 2015) which require more time. Learners cannot simply memorize, absorb or copy pre-packaged ideas but must construct their own versions through actively engaging in personal experimentation. Two major schools of thought have appeared in constructivist thinking. Cognitive constructivism, which is based on the work of Piaget (1970), emphasizes the mental processes involved in the individuals' construction of knowledge. Social constructivism, on the other hand, according to the theories of Vygotsky (1978), concentrates on the social and historical contexts responsible for the construction and creation of knowledge. Vygotsky highlights that individuals cannot detach themselves from the socio-political contexts in which they live, and that language and culture are extricable bound together and inevitably construct their interpretation of reality. Slavin (2011) recommends that both the cognitive and social aspects of constructivist should receive parallel and equal importance. Knowledge is constructed individually but mediated socially Slavin, 2011, p. 86).

Constructivist learning theory purports that knowledge is actively constructed by the learner through hands-on, active experience. However, these active experiences can be mediated through technology, offering an alternative to traditional hands-on methodologies. Technology-based theories such as anchored-instruction promoted by Griffin and Care (2015) work can be helpful when considering use of multi-media environments. Research surrounding these theories has demonstrated that technology-mediated learning environments can present learners with complex, real-world problem-solving opportunities that can support and promote higher order thinking for knowledge construction and transfer. For example, Slavin (2011) examined current learning models in learning sciences, thus systematically presenting how technology-mediated laboratories can promote learning and support conceptual change.

Virtual laboratories are one example of technology-mediated learning environments. Laboratories can take the form of imitations of real experiments or computer simulations designed to provide learners with a comparable learning experience to traditional laboratories. Virtual laboratories allow learners to "stop the world" and "step outside" of the simulation allowing them to better understand the underpinning concepts, an ability not likely feasible in most wet laboratories experiments. Several other researchers have demonstrated the effectiveness of virtual laboratories in the sciences. For example, Astutik and Prahani (2018) found that virtual laboratories in chemical engineering "help learners to understand the fundamentals of unit operations…" and had other learning benefits. The authors note, "It is also expected to contribute to increasing learners' adaptability by working in real world process plants after graduating."
The principal aim of this study was to determine the impact of a virtual laboratory delivery environment (VLDE) on grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland. This research aim guided the research design, implementation, and data analysis of this study.

Radical constructivism is a theory of learning that supports the notion that knowledge development is an adaptive process, resulting from the individual learner's interaction or experimentation with the world. To facilitate achievement and science process skills, learners should be allowed to create their own model (Von Glasersfeld, 1995) of variables, formulating hypothesis, designing experiments, and interpreting data during an experiment. Learners need to be exposed to an environment such as the virtual laboratory delivery environment in which they become active participants. According to the CAPS, learners are required to conduct experiments and submit written reports. Observations and written reports are assessed to determine the level at which the science process skills have been developed. Based on the notion of radical constructivism, learners were involved in individual experimental activities, after which their competence in conceptual knowledge and science process skills were measured to determine the effectiveness of the virtual laboratory delivery environment intervention in enhancing learner conceptual development and acquisition of science process skills.

In this study, individualized experimentation as a learning strategy to facilitate conceptual development and acquisition of science process skills was explored. Radical constructivism theoretical framework was found to be suitable for this study because it helped the researcher to answer the following sub-research questions:

i. What is the impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners?

ii. What is the impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise?

2.14.2 Social Cognitive Theory of Learning

Social Cognitive Theory was first proposed by Bandura (1977). Self-efficacy, learners' beliefs concerning their capabilities to accomplish academic-related tasks and activities, lies at the centre of the Social Cognitive Theory as it affects what we do and how we perceive the environment (Slavin, 2011). Recent Social Cognitive models of academic outcomes (Slavin, 2011) propose that motivational constructs such as attitudes, interest and value beliefs are key factors that affect learners' self-efficacy and pursuit of Science, Technology, Engineering and Mathematics (STEM) courses and careers.

Although there are differences in terminology in how some constructs are defined, Social Cognitive Theory (e.g., Bandura et al., 2001) and the Expectancy Value Model (Eccles, Midgle and Adler, 1984) propose similar models for academic and influence learning and achievement in school, which, in turn, affect a number of social cognitive factors such as self-efficacy, perceived ability and outcome expectations. These factors are proposed to be causally related to later academic behaviours in achievement models or to interest in and intention to pursue specific careers in occupation choice models. Furthermore, research has shown that self-efficacy beliefs largely influence individuals' attitudes and interest and various behaviours such as goal setting, strategy execution and persistence in academic or career pursuits (Schwichow, Zimmerman, Croker and Hartig, 2016).

Social cognitive models posit that support from parent, peers and educators affects academic performance and career choices by influencing learners' self-perceptions and interests (Trivedi and Sharma, 2013). Previous research has primarily focused on parent support but some research suggests that teachers and friends also have an impact on learners' attitudes toward academic subjects and career aspirations (Elliot and Joey, 2016).

Jatmiko et al. (2016) found that learners' perceptions of positive instructional approaches, including teacher support and use of engaging instruction, were associated with better attitudes and higher self-efficacy for math and science during the transition to middle school or high school. More recently, Rice, Barth, Guadagno, Smith, McCallum and ASERT (2012) found that social support from parents, teachers and friends was positively related to math and science efficacy and interest.

In this study, interviews were adopted to assess learners' attitude change towards Physical Sciences. Social cognitivist theoretical framework was found to be suitable for this study because it helped the researcher to answer the following sub-research question:

iv. To what extent does VLDE influence the participants' attitude change towards Physical Sciences?

2.15 SUMMARY OF CHAPTER TWO

This chapter has provided an overview of the literature research pertinent to this study. The chapter began with explaining the role of Physical Science to human kind, Physical Science and Active Learning, Practical work and its role in science education, and perspectives on Practical work. Moreover, the chapter presents the perspectives of VLDE, including Alternative Laboratory Delivery Methods, literature on research findings on virtual laboratories in other parts of the world, the potential of virtual laboratories in science education, and strengths and weaknesses of the virtual laboratories in science education. Secondly, the chapter presented literature on Learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise. Thirdly, a literature on attitudes towards science was discussed. Fourthly, a theoretical framework that underpinned this study was also presented. The next chapter presents research methodology that focuses on a research paradigm and research design that best suit this study, population and sampling techniques, data collection instruments, data collection techniques and ethical considerations.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In the previous chapter, literature review was presented, situating the study in context of what is already known about the topic. Chapter three presents the research paradigm and the overall research methodologies employed in the present study to answer the main research question: What is the impact of Virtual Laboratory Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences*?* Furthermore, the chapter provides a detailed account of the implementation of the instruments including the process of establishing their validity and reliability and selection of the participants for the interviews. Moreover, included in this chapter is the process of data gathering, presentation, analysis and reporting. The research sites where data were from collected are also described in detail.

3.2 RESEARCH PARADIGM

In this section, different types of paradigms are discussed. The paradigm deemed appropriate to this study and how it suits this study is then discussed further. A research paradigm is defined by Creswell and Poth (2018) as beliefs and actions that guide a field of the study. It may be viewed as a set of basic beliefs that deal with first principles. It represents a world view that defines, for its holder, the nature of the "world", the individual's place in it, and the range of possible relationships to that world and its parts. Beliefs are basics in the sense that they must be accepted simply on faith; as there is no way to establish their ultimate trustfulness (Okeke, 2015). Additionally, Goduka (2012, p.126) discloses a paradigm as "the entire constellation of beliefs, values and techniques shared by members of a research community".

3.2.1 The Interpretivist Paradigm

Interpretivist might be simply characterized as the belief that “facts” are not things out in some objective world waiting to be discovered, but, rather, are the social constructions of humans who apprehend the world through interpretive activity (Makombe, 2017). All those involved in the research (whether participants and/or researcher) bring their own personal meanings to the situations they encounter and each individual is constructing meanings out of whatever he or she encounters and experiences during the research process (Hammersley, 2018). Additionally, Hammersley, (2018) further observe that researchers cannot fully grasp why situations exist or people do what they do if they do not know how people involved in these situations understand and make sense of their personal world. Hammersley, (2018) points out that interpretivist research focuses closely on each of the participants in their natural contexts or habitats and observes how each individual constructs unique meanings in situations in which they find themselves. An interpretivist researcher is, therefore, always closely and personally involved with the participants and their life-worlds and the manner in which they understand, interpret and cope with everything that they encounter in their lives (Hammersley, 2018). This kind of close personal involvement and engagement stands in strict contrast to disengagement, absence of personal emotions and involvement and the impartiality characteristic of an empirical scientist.

An interpretivist researcher needs to be able to accommodate the multiple realities of subjects who are the focus of his or her research’. These types of realities that the researcher needs to understand include both the external circumstances in which participants find themselves as well as inner realities and methods of meaning-construction that participants use to make sense of their lives and circumstances (Makombe, 2017 and Hammersley, 2018). An interpretive paradigm endeavours to understand phenomena through the meanings attributed to the situation through people’s experiences and perceptions. In other words, an interpretive paradigm relies on the participants’ views of the situation being studied (Mertens, 2014). Thus, for qualitative research, interpretivism was employed.

2.2 Positivist Paradigm

The term positivism refers to a branch of philosophy that rose to prominence during the early nineteenth century because of the works of the French philosopher Auguste Comte (Rehman and Alharthi, 2016). In terms of the four foundational elements or assumptions of a paradigm, for the Positivist paradigm, its epistemology is said to be objectivist, its ontology realism, its methodology experimental, and its axiology beneficence. The objectivist epistemology holds that human understanding is gained through the application of reason (Putnam, 2012). This implies that through research we can acquire knowledge which increasingly approximates the real nature of what it is that we investigate (Searle, 2015). The experimental methodology element means that the research will involve manipulation of one variable to determine whether changes in that variable cause changes in another variable (Riyami, 2015). This methodology can only apply if we are able to control what happens to the variables or subjects we study. Such control enables the researcher to test and to accept or reject hypotheses. The beneficence axiology refers to the requirement that all research should aim at maximizing good outcomes for the research project, for humanity in general, and for the research participants (Martens, 2015).

Positivists strive to understand the social world like the natural world. In nature, there is a cause-effect relationship between phenomena, and once established, they can be predicted with certainty in the future. The epistemological position of positivists is that of objectivism. Researchers come in as objective observers to study phenomena that exist independently of them and they do not affect or disturb what is being observed. They will use language and symbols to describe phenomena in their real form, as they exist, without any interference whatsoever. Positivists believe that there are laws governing social phenomena, and by applying scientific methods, it is possible to formulate these laws and present them through factual statements.

The Positivist paradigm defines a worldview to research, which is grounded in what is known in research methods as the scientific method of investigation. In a positivist universe of assumptions, the only way to arrive at some truth is through empirical procedures that rely on strict definitions of evidence, criteria and what constitutes truth in a positivist framework (Makombe, 2017). Comte (1856) postulated that experimentation, observation and reason based on experience ought to be the basis for understanding human behaviour, and therefore, the only legitimate means of extending knowledge and human understanding. It is used to search for cause-and-effect relationships in nature. The quantitative data that positivist researchers use to answer research questions and formulate theories can be collected through true experiments or less rigorous quasi-experiments, standardized tests and large- or small-scale surveys using closed ended questionnaires. The numeric data that are generated through these methods are subjected to descriptive or inferential statistical analysis (Kivunja and Kuyini, 2017). Hypotheses are put forward in propositional or question form about the causal relation between phenomena. Research located in this paradigm relies on deductive logic, formulation of hypotheses, testing those hypotheses, offering operational definitions and mathematical equations, calculations, extrapolations and expressions, to derive conclusions. It aims to provide explanations and to make predictions based on measurable outcomes (Blaikie, 2018). The purpose is to measure, control, predict, construct laws and ascribe causality (Creswell and Creswell, 2018). To make sure no other variables caused the effect, positivist researchers try to control extraneous variables, with two or more groups being subjected to the same conditions with the only difference being the independent variable. Establishing causal relation between phenomena without any interference from extraneous variables means that the experiment has internal validity.

Research located in this paradigm relies on deductive logic, formulation of hypotheses, testing those hypotheses, offering operational definitions and mathematical equations, calculations, extrapolations and expressions, to derive conclusions. It aims to provide explanations and to make predictions based on measurable outcomes. Those measurable outcomes are undergirded by four assumptions that Cohen, Manion and Morrison (2018), explain are determinism, empiricism, parsimony and generalizability. An unpacking of each of these assumptions helps researchers understand better the meaning and expectations of research conducted within this paradigm. Briefly, the assumption of determinism means that the events we observe are caused by other factors. Therefore, if we are to understand casual relationships among factors, we need to be able to make predictions and to control the potential impacts of the explanatory factors on the dependent factors. The assumption of empiricism means that for us to be able to investigate a research problem, we need to be able to collect verifiable empirical data, which support the theoretical framework chosen for your research and enable you to test the hypotheses you formulated. In assuming parsimony, the Positivist paradigm refers to the researcher's attempts to explain the phenomena they study in the most economical way possible. Finally, the generalizability assumption tells us that the results obtained from a research project conducted within the Positivist paradigm, in one context, should be applicable to other situations by inductive inferences. This means that the positivist researcher should be able to observe occurrences in the particular phenomenon they have studied, and be able to generalise about what can be expected elsewhere in the world. In respect of these assumptions, the Positivist paradigm advocates the use of quantitative research methods as the bedrock for the researcher's ability to be precise in the description of the parameters and coefficients in the data that are gathered, analysed and interpreted, so as to understand relationships embedded in the data analysed.

The following is summary of basic characteristics of research that is normally located within the Positivist paradigm (Johnson, 2014 and Riyami, 2015):

o A belief that theory is universal and law-like generalisations can be made across contexts.

o The assumption that context is not important

o The belief that truth or knowledge is 'out there to be discovered' by research.

o The belief that cause and effect are distinguishable and analytically separable.

o The belief that results of inquiry can be quantified.

o The belief that theory can be used to predict and to control outcomes

o The belief that research should follow the Scientific Method of investigation

o Rests on formulation and testing of hypotheses

o Employs empirical or analytical approaches

o Pursues an objective search for facts

o Believes in ability to observe knowledge.

o The researcher's ultimate aim is to establish a comprehensive universal theory, to account for human and social behaviour.

o Application of the scientific method (Kivunja and Kuyini, 2017)

According to the positivist approach, research is deemed to be of good quality if it has a) internal validity b) external validity c) reliability d) objectivity (Rehman and Alharthi, 2016). If the researcher proves that it is the independent variable (and not other variables) that had an effect on the dependent variable, the study is considered to have internal validity. If the results thus arrived at are generalizable, it has external validity. If different researchers conduct the study in different times, places and contexts and arrive at the same results, it has reliability. If researchers study phenomena without contaminating their apprehension, they are considered to be objective (Blaikie, 2018). In the quantitative section of this study, the researcher used positivist paradigm to provide a more inclusive picture of the effectiveness of VLDE on achievement and attitude towards Physical Sciences among the Grade 11 learners.

3.3 RESEARCH APPROACH

Cresswell (2013) assert that what is most fundamental in the choice of research approaches is the research question, and the research approaches should follow research questions in a way that offers the best chance to obtain useful answers. Many research questions and combinations of questions are best and most fully answered through mixed research solutions. The quantitative approach takes precedence over the qualitative approach in the process of answering the first and second sub-research questions. On the other hand, the qualitative approach becomes complementary to the quantitative approach in the process of determining learners' attitude changes towards the notion that Physical Sciences is a difficult subject. Therefore, a mixed research approach was chosen for this study. This approach is apt for the research since it concerns both the statistical data and descriptions of thinking exhibited by the participants' answers to specific questions (Denzin and Lincoln, 2011; Creswell, 2013; Creswell and Poth, 2018).

Mixed methods research is a research approach with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and mixture of quantitative and qualitative approaches in many phases in the research process (Maree, 2017). McMillan and Schumacher (2012)) define a mixed method study as, research in which an investigator collects and analyses data, integrates findings, and draws inferences using both quantitative and qualitative approaches or methods in a single study or program of inquiry. As a method, it focuses on collecting, analysing and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone (Denzin and Lincoln, 2011; Creswell, 2013; Creswell and Poth, 2018).

Cresswell (2013) attest that mixed methods research provides strengths that offset the weaknesses of both quantitative and qualitative research. For example, quantitative research is weak in understanding the context or setting in which people talk, and the voices of participants are not directly heard. Moreover, quantitative researchers are in the background, and their personal biases and interpretations are seldom discussed. Creswell (2013) maintain that qualitative research makes up for these weaknesses. Qualitative research is seen as deficient because of personal interpretations made by the researcher, the ensuing bias created by this and the difficulty in generalizing findings to a large group because of the limited number of participants studied. Mixed methods research provides more comprehensive evidence for studying a research problem than either qualitative or quantitative research alone. Maree (2017) adds that researchers are given permission to use all tools of data collection available rather than being restricted to types of data collection typically associated with qualitative research or quantitative research. Mixed methods research helps to answer questions that cannot be answered by quantitative or qualitative approaches alone. Mixed methods encourage researchers to collaborate across the sometimes-adversarial relationship between quantitative and qualitative researchers. Mixed methods research encourages use of multiple worldviews or participants.

According to Creswell and Poth (2018, p.8), mixed method study increases the breadth and depth of the research findings. Using more than one research method can also help corroborate the study findings, ensuring that findings have a stronger validity. To use a mixed method design, Creswell (2013) suggests that the research questions must include both quantitative and qualitative elements. It is important that the formulated questions address both the needs for a quantitative and a qualitative study design. In mixed methods research, the researcher constructs knowledge about real world issues based on pragmatism, which places more emphasis on finding answers to research questions than on the method used (Maree, 2017). Mixed methods research approach allows for contextual interpretations, use of multiple methods and flexibility in choosing the best strategies to address the research question. According to McMillan and Schumacher (2012) a mixed method approach combines characteristics of both quantitative and qualitative approaches to research. Mixed methods research is defined as a procedure for collecting, analysing and mixing both quantitative and qualitative data at some stage of the research process within a single study to understand a research problem more completely (Maree, 2017). Mixed method researchers combine quantitative and qualitative strategies within a single study, collect both numeric data and text (words) data concurrently or one after the other, choose variables and units of analysis which are most appropriate for addressing the study's purpose and find answers to the research questions (Maree, 2017).

The complexity of using mixed methods requires that researchers carefully consider the planning of such studies. One popular mixed-methods approach is the sequential explanatory strategy. The primary purpose of explanatory research is to explain why phenomena occur and to predict future occurrences. Explanatory studies are characterized by research hypotheses that specify the nature and direction of the relationships between or among variables being studied. Probability sampling is normally a requirement in explanatory research because the goal is often to generalize the results to the population from which the sample is selected. The data are quantitative and almost always require the use of a statistical test to establish the validity of the relationships. In this approach, quantitative data are collected and analysed first and the results used to inform the subsequent qualitative phase. Often the qualitative phase is useful in helping to understand unexpected results that arise in the initial quantitative phase. This approach is commonly employed by researchers who are more comfortable with quantitative research and weight is given primarily to the quantitative findings, which explains why this strategy is considered explanatory.

In contrast, the sequential exploratory strategy places greater emphasis on an initial qualitative phase which is used to gain insight into an understudied phenomenon (hence the exploratory nature). Qualitative research is employed to develop knowledge and testable hypotheses, and the secondary quantitative phase is used to examine the phenomenon in a more generalizable fashion. A common application of this strategy is to conduct qualitative research on a particular phenomenon or with a special population, and then use this information to develop an appropriate survey instrument to collect quantitative data. In this study, the researcher used the sequential explanatory strategy to address the following main research question, 'What is the impact of Virtual Laboratory Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland?'

In order to inquire into the research problems, a mixed methods research approach was used, in which both quantitative and qualitative research are integrated. These will provide a better understanding of the problem than either quantitative or qualitative data in isolation, by means of alternative perspectives and condensed as well as detailed description (Creswell, 2012). Accordingly, Creswell (2012) argue that a mixed method provides a sound platform for:

• triangulation, whereby validity is increased and bias minimised;

• complementarity, whereby the strength and weakness of individual methods complement each other;

• development, whereby the results of one method are used to enhance another;

• initiation, whereby data analysis provides avenues for different perspectives;

and

• expansion, whereby the scope of research is increased.

In a mixed methods paradigm, different priorities can be weighed between an emphasis on quantitative data or qualitative (Molina-Azorin, 2016). Correspondingly, the implementation of data collection can also follow a particular sequence.

In this study, the quantitative element was emphasised, on the rationale of research questions and the issues investigated. Learners' learning experience, as opposed to other terminologies such learning outcomes or learning results, is a concept that is arguably better quantified than verbalized. Likewise, learners' views and understanding of the nature of science lend itself to a qualitative substantiation, rather than numerical data.

In the following sections, relevant methodological issues will be discussed, the context of the study will be described, and research instruments and analyses will be elaborated.

3.4 RESEARCH DESIGNS

The research design selected for the study was quasi-experimental in that two treatment conditions were established to compare the effectiveness of instruction with and without virtual laboratories. Its principal method of data collection was the use of Pre-Test and Post-Test to assess learner outcomes (achievement and science process skills). However, qualitative data, through semi-structured interviews, were added to embellish the quantitative results. This chapter describes and justifies the methodological aspects of this study in terms of the research questions guiding the methods, the sample selection, the materials used to include assessment instruments and other resources, the procedures followed, data collection, entry, and analysis, and limitations of the study. To have an in-depth understanding of the problem under research, the researcher felt that it was best to combine the following research designs:

3.4.1 Quasi-experimental

Among the different types of quasi-experimental designs, the researcher adopted the pre-test-post-test non-equivalent group design (Cohen, Manion and Morrison, 2011) or more simply, non-equivalent comparison group design (John, 2014, p.94) as shown in Figure 3.1.

Non-equivalent comparison group design

Experimental	O_1	X	O_2
Control	O_1		O_2

Figure 3.1: Non-equivalent comparison group design, (John, 2014, p.94.)

In Figure 3.1, the dashed line indicates that experimental and comparison groups have not been equated by randomization, hence the term 'non-equivalent'. John (2014, p.94) further explicates the different symbols used in the Figure 3.1 as follows:

- X represents the exposure of a group to an experimental variable or event, the effect of which are measurable; and
- O refers to the process of observation or measurement.

Maree (2017) posits that as in all quasi-experimental designs the sample in this study was divided amongst two treatment conditions. The two treatment groups were 'naturally occurring' in that they were already organized into classes in their respective schools. The researcher implemented this study with one class from research site A that used virtual laboratories and one class from research site B that did not, thus maintaining consistent instruction from the same teacher between the experimental and control group, except for the intervention. Thus, one intact class of learners from one research site was chosen as the experimental group (EG) and another intact class from the other research site was chosen as the comparison group (CG); both groups are grade 11. A pre-test (PrT) was administered to both groups to establish a baseline to inform the intervention strategies for the EG. Furthermore, the information obtained from the analysis of the PrT was used as a guide for designing a teaching module to enhance the conceptual understanding of Stoichiometry and the acquisition of techniques and practical expertise in Physical Sciences. Therefore, while learners were subjected to different treatment groups, other variables, such as the teacher, the physical classrooms, the content delivered, and the level of ability of the learners, were controlled for in that they were present in both the experimental and control groups. This design allowed for more accurate results because the effects of confounding variables were equally distributed throughout the study's sample.

3.4.2 Case Study

McMillan and Schumacher (2014) define a case study as "an in depth study of interactions of a single instance in an enclosed system." Opie goes on to indicate that the focus of the case study is on real situations with real people. Cohen, Manion, and Morrison (2011) share this view, stating that case study is "a research design that provides a closer look at reality and as a result provides detailed explanations of the phenomenon being investigated by focusing on specific instances in a bounded system." Trochim, Donnelly and Arora (2015) state that in a case study, the insight-stimulating cases should be selected for special study. For particular problems, certain cases may be found more appropriate than others. The aim of the case study is to know precisely the factors and causes which plain the complete behavioural patterns of unit and the place of the unit in its surrounding social miller. It gives enough information about a person or a group or a unit the case study technique, generally, studies the subject-matter qualitatively and covers all aspects of a single entity (Trochim, Donnelly and Arora, 2015). In order to explore the impact of Virtual Laboratory Delivery Environments on Grade 11 learners' learning outcomes in Physical Sciences, a case study research design seemed appropriate. This study can be categorised as an educational case study as it explores an educational issue with Grade 11 Physical Sciences learners. Moreover, the aim of this study was to draw attention and make recommendations as to what impact innovative science classrooms can contribute to Physical Sciences learners to enhance conceptual development, acquisition of techniques and practical expertise.

A case study focuses strongly on reality by looking at the social truths that may represent discrepancies between the viewpoints held by the participants. A single researcher may also conduct a case study. However, the case study is susceptible to bias, subjectivity and a lack of generalisation. A case study offers the opportunity to explain why results happened rather than just finding out what the results are, and the researcher took on the responsibility of ensuring that the case provided answers to the research questions (McMillan and Schumacher, 2014). One of the characteristics of a case study is that it concentrates on a particular incident and attempts to locate the story of a certain aspect of behaviour in a particular setting and factors influencing the situation (Trochim, Donnelly and Arora, 2015). In this study, employing a case study research design included looking in-depth at how Grade 11 Physical Sciences learners develop scientific concepts, acquire scientific techniques and expertise as well as the change their attitude towards Physical Sciences. Using a case study allowed the researcher to get rich data because methods used within a case study allowed the researcher to get close to the participants, thus giving opportunities to access subjective factors such as the thoughts, feelings and desires of the participants.

The advantage of a case study is that it provides "an audit trail by which other researchers may validate or challenge the findings, or construct alternative arguments' (McMillan and Schumacher, 2014). The case study is more appropriate as data from research questions can provide an insight into other similar situations. The findings on the case could evoke further research and debates and also recommendations about the inclusion of Virtual Laboratory Delivery Environments in science education within National Curriculum Statement. McMillan and Schumacher (2014) add that another advantage of a case study is its uniqueness, as well as its capacity for understanding complexity in particular contexts. This case study provided the understanding of how VLDE impacted learners' learning outcomes in Physical Sciences. Since the researcher's third objective focused on learners' attitudes towards Physical Sciences, part of the data was collected qualitatively. To triangulate the findings, a focus group interview with selected learners from the EG were conducted to address the third sub-research question.

Table 3.1 Summary of the phases for research sites A

Participants	Phase one			Phase two			Phase three
	Pre-test	Treatment	Post-test	Pre-test	Treatment	Post-test	Interviews
	PSATCU	VLDE	PSATCU	PSPST	VLDE	PSPST	
EG (N= 39)	All			All			All

Table 3.2 Summary of the Phases for research site B

Participants	Phase one			Phase two			Phase three
	Pre-test	No Treatment	Post-test	Pre-test	No Treatment	Post-test	Interviews
	PSATCU	CTEM	PSATCU	PSPST	CTEM	PSPST	
CG (N= 44)	All			All			0

3.5 POPULATION FOR THIS STUDY

Simon and Goes (2012) define population as the entire group of individuals or items that share one or more characteristics from which data can be gathered and analysed. Additionally, Alvi (2016) states that population refers to all the members who meet the particular criterion specified for a research investigation. The population of this study comprised all Grade 11 Physical Sciences learners from all Senior Secondary Schools in OR Tambo Inland, in the Eastern Cape Province, South Africa. The sample in this study consisted of eighty-three (83) learners who were doing Physical Sciences in Grade 11. The sample was composed of one Grade 11 intact class from each research site. Research site A was the Experimental Group (EG) while research site B was the Control Group (CG) throughout this study. In each phase, the EG were exposed to the VLDE while the CG were exposed to the Conventional Teacher Expository Method (CTEM).

3.6 SAMPLING PROCEDURES AND TECHNIQUES

A sample is defined by Simon and Goes (2012) as a subset of the population. To add on, Alvi (2016) states that the process through which a sample is extracted from a population is called sampling. Creswell et al. (2018, p.158) orate that in purposive sampling, the inquirer selects individuals and sites for study because they can purposely inform an understanding of the research problem and central phenomenon in the study. Additionally, Maree (2017) explains that purposive sampling is used in special situations where the sampling is done with a specific purpose in mind. Purposive sampling was adopted to select the two senior secondary schools in the in OR Tambo Inland. In consideration of the defining characteristics that made the subjects holders of the data needed for the study, not all schools possessed the required characteristics. Furthermore, the sampling frame comprised schools from the same geographic setting and learner composition, with enrolments of between thirty and forty-five learners in Grade 11 Physical Sciences classes.

Table 3.3: Some demographic characteristics of learner participants

Demographic Characteristics	**Sampled Physical Science Learners (Learner quantitative study: n= 83; learner interviews: n = 39)**				
	School A		**School B**		**Total**
Gender	Male	Female	Male	Female	
Sample: quantitative study	18	21	15	29	83
Sample: learner focus group interviews	18	21	0	0	39

Age (years)	15-19	15-19	15-19	15-19	
Subjects	Science stream (Mathematics + Physical Sciences + Geography + other subjects)		Science stream (Mathematics+ Physical Sciences + Geography + other subjects)		
Socio-economic category	Low income category School		Low income category school		

3.7 A DESCRIPTION OF THE RESEARCH SITE

The researcher chose the research sites using convenient sampling, this made the accessibility of the research sites easy for the researcher, who is a full–time educator in the neighbouring school. This allowed the researcher to spend more time with the participants without compromising his obligations as an educator and without disrupting the participants' school routine. The research sites were purposefully sampled from historically disadvantaged public senior secondary schools in OR Tambo Inland under the Eastern Cape Province Department of Basic Education. The research sites catered for learners in Grades 8 to 12 as learners are admitted in Grades 8, 9 and 10. School A has an enrolment number of about 1 200 learners while school B has an enrolment number of 1 130, with staff of 65 and 55 respectively. Both sites share learners from the surrounding feeder primary schools, and the learners are from a similar socio-economic background.

Both schools have excellent infra-structural facilities. All learners' mother tongue in research site B is isiXhosa, whereas, in research site A, eighty percent of learners are isiXhosa speaking. In research site B, IsiXhosa is taught as a First Language whilst English is taught to all learners as a Second Language. However, in research site A, some classes take English as First Language and Afrikaans as Second Language while other classes take isiXhosa as First Language and English as the second Language. In both sites, English is the language of teaching and learning or the language of instruction.

Learners in Grade 10 have the option to choose one stream from the following four streams (Mathematics with Accounting, Mathematics with Physical Sciences, Mathematical Literacy with Tourism or Mathematical Literacy with History) but have to continue with the subjects until Grade 12. Learners are randomly assigned to different classes, depending on whether they are doing Mathematics with Accounting, Mathematics with Physical Sciences, Mathematical Literacy with Tourism or Mathematical Literacy with History.

3.8 DATA COLLECTION INSTRUMENTS

This section discusses the research instruments used to collect data for this study. Maree (2017) asserts that Hesse-Biber and Leavy (2011) argue that methods are tools that researchers use to collect data. These tools enable us to gather data about social reality from individuals, groups, artefacts and texts in any medium Maree (2017). For real collection of data, the researcher must have to in his real research field, and it is collected in a selected step at the time of data collection reality is necessary for investigation (Trochim, Donnelly and Arora, 2015).

Maree (2017) list the following ways of collecting data: surveys, questionnaires, tests, simulations, interviews, focus groups, direct observation, performance monitoring, actions plans and performance contracts. Creswell and Poth (2018, p. 8) have added the following methods of collecting data to this list: documentation, verbal protocol (thinking aloud sessions or conversation analysis), and diaries. Creswell and Poth, 2018, p. 8) note that 'data can be evaluated by using a variety of data collection methods and analysis'. In addition to this, 'the method known as data crystallization can also be used'. This would involve, for example, having another expert with a different point of view to attend the discussion group Creswell and Poth, 2018).

The focus group interviews were undertaken among Grade 11 learners in one senior secondary school in OR Tambo Inland. In total, the researcher conducted four focus group interviews with a total of 39 learners, in groups ranging from 8 to 10, at research site A. The group interview is considered a better strategy than a one-to-one interview as it promotes self-disclosure for the participant (Maree, 2017). This means that participants likely felt freer to contribute when they were in groups than they would have in one-to-one conversations, which could create fear and tension for the learners. To ensure a friendly relationship with learners, the researcher conducted group interviews only after several visits to the schools. The interview questions were prepared following the procedure suggested by Maree (2017), which requires that questions be easy, clear, and short. Further, questions were structured in such a way that the interview started with an opening question aimed to make learners comfortable in talking. The actual questions, focusing on the research question, were critical thinking questions that required learners to think and provide suggestions (see focus group interview schedule protocol Appendix L). The interviews were audio recorded with the permission of participants and the participants' responses were transcribed for analysis. As the research design adopted a mixed approach, the instruments used served the purpose of capturing statistical and qualitative data. This research study therefore used:

i. Physical Sciences Achievement Test on Conceptual Understanding (PSATCU);
ii. Physical Sciences Practical Skills Test (PSPST); and
iii. Physical Sciences Attitudes Interview Schedule (PSAIS).

Table 3.4 below is visual representation of the data collection instruments and how each relates to the research question of this study.

Table 3.4 Data collection methods and instruments related to the subsidiary research questions.

Data collection method	**Data collection instruments**	**Subsidiary research question**
Quasi-experimental pre-test post-test	PSATCU	What is the impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners?

Quasi-experimental pre-test post-test	PSPST	What is the impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise?
Focus group interviews	PSAIS	To what extent does VLDE influence the participants' attitude change towards Physical Sciences?

3.8.1 Physical Sciences Achievement Test on Conceptual Understanding (PSATCU)

The Physical Sciences Achievement Test on Conceptual Understanding (PSATCU) was used to assess the learners' conceptual understanding of the stoichiometry topic. An achievement test is an examination that generates information which can be utilized to recognize and group learners (Coe, Waring, Hedges and Arthur, 2017). In this study, an achievement test was used because the scores obtained from it were used to categorize learners according to their problem-solving proficiency and to describe the learners' problem solving proficiency after they were exposed to stoichiometry problem solving in Grades 10 and 11. The other reason for using an achievement test was that the scores from an achievement test were used to assess the ability of learners to solve problems accurately, understand and use chemical symbols, communicate using chemical vocabulary, recognise stoichiometric relationships, identify and execute appropriate problem-solving strategies as well as to analyse the data. The instrument comprised short answer questions and was structured on stoichiometry. These questions tested knowledge, comprehension and application of learned materials.

3.8.2 Physical Sciences Practical Skills Test (PSPST)

To determine learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise scientific process skills, Scientific Process Skill Test (SPST) developed by Okey, Wise and Burns (1982) was used. The test was adapted by (Trochim, Donnelly and Arora, 2015). In this study, it was further adapted to consist of a 5-option multiple choice of 19 questions for which a table of specifications was constructed to ensure content validity. It involves questions assessing skills to define variables in a problem, establish and define hypotheses, make operational explanations, design required analysis on the solution of problems, draw and interpret graphs.

The instrument covered the content of practical aspects of the Grade 11 Physical Sciences curriculum as stated in South African Curriculum and Assessment Policy Statement (CAPS). The units evaluated the performance of process skills by the learners. The instrument was pilot-tested by two other Physical Sciences classes not partaking in the study from the two research sites. The PSPST was pre-tested and post-tested with the Experimental group and Control group at each research site. The treatment group was taught with more emphasis on the extent and degree of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise.

3.8.3 Interviews

Johnson and Burke (2017); Johnson, Burke and Christensen (2017) define interviews as 'purposive interaction between two or more persons, where one obtains information from the other'. However, it has been concluded by researchers that the interviews permit researchers to obtain information that cannot be obtained from observations alone. The researcher interviews the participants and records their responses at the same time, which later provides the researcher with a *verbatim* account of the interview (Johnson and Burke, 2017; Johnson, Burke and Christensen, 2017). The interviews have a number of unique advantages and disadvantages, but Gay (2008, p. 231) points out that when well conducted, these can produce in-depth information that are not conceivable with any other type of instrument. In this study, to gain a clear understanding of how the participants experienced all the activities in the classroom (especially those involving learning of Physical Sciences), as well as any particular problems they encountered, semi-structured interviews were conducted with both groups.

The advantage of interviews is that they provide access to a subject's thinking, what he or she likes or dislikes (values and preferences) and thinks (attitudes and beliefs) or information concerning a particular issue (Creswell and Poth, 2018). Interviews remain a good way of accessing people's meanings, definitions of situations and constructions of reality (Maree, 2017). The interviews were used to obtain feedback about attitudes towards learning Physical Sciences at senior secondary school level. Trochim, Donnelly and Arora (2015) explains that interviews offer an apparently deeper picture than the variable-based correlations of quantitative studies. An interview is a data collection method in which the interviewer asks questions to the interviewee or participant while aiming at entering the inner world of the respondent and gaining an understanding of that participant's perspectives.

In this study, the researcher adopted semi-structured interviews to collect data. A semi-structured interview which is flexible, allowing new questions to be brought up during the interview based on what the interviewee says. The interviewer in a semi-structured interview generally has a framework of themes to be explored, and the interview progresses in a way that tackles the identified themes. A semi-structured interview involves a set of open-ended questions that allow for spontaneous and in-depth responses (Trochim, Donnelly and Arora, 2015). Amidst the current notion among most learners that Physical Sciences is "a killer subject", the use of semi-structured interviews also enabled learners to describe their experiences and attitudes towards the integration of practical work in Physical Sciences education in greater detail. The interview schedule consisted of a core set of ten guiding questions on limits. The researcher used focus group interviews with learners as explained below

Focus group interviews were carried out in data collection to address the third sub-research question: To what extent does VLDE influence the participant' attitude change towards Physical Sciences?

3.8.3.1 Advantages of an interview

The researcher decided to use an interview as a data collection gathering technique because of the following reasons mentioned by Creswell and Poth (2018):

- The interview is most appropriate for asking questions that cannot effectively be structured into a multiple-choice format, such as questions dealing with personal phenomena;
- An interview is flexible; hence, questions can be adjusted to suit the situation of the interviewer; and
- The interviewer establishes rapport and trust relationships with the participants. By so doing, the researcher can often obtain information that participants would not provide on other data collection instruments (Creswell and Poth, 2018).

3.8.3.2. Disadvantages

However, Trochim, Donnelly and Arora (2015) points out that the interview can have the following disadvantages:

- Interviews can be extremely costly;
- Interviews are lengthy and time consuming;
- Participants are not easily accessible; and
- If the respondents are busy, it will not be easy to access them for interviews.

3.9 EXPERIMENTAL INTERVENTION

This section explains how the researcher selected the virtual laboratories for use in this study. Virtual laboratory delivery environments are facilitated by technology-enhanced classrooms which integrate technology in day to day classroom teaching and learning activities. In designing the intervention, the researcher conscientiously considered issues around inclusivity. According to the Education White Paper 6 (South Africa, 2011), inclusivity is about accommodating the needs of all learners, irrespective of disability, cultural and socio-economic background. Additionally, it refers to a change in attitude, behaviour, teaching methods, assessment methods, curricula, teaching and learning environments to accommodate all learners. It also speaks to maximizing the participation of all learners and particularly the needs of those learners who experience barriers to learning. Figures 3.2 depict the technology-enhanced classroom used in the administration of the intervention to the Experimental group in this study.

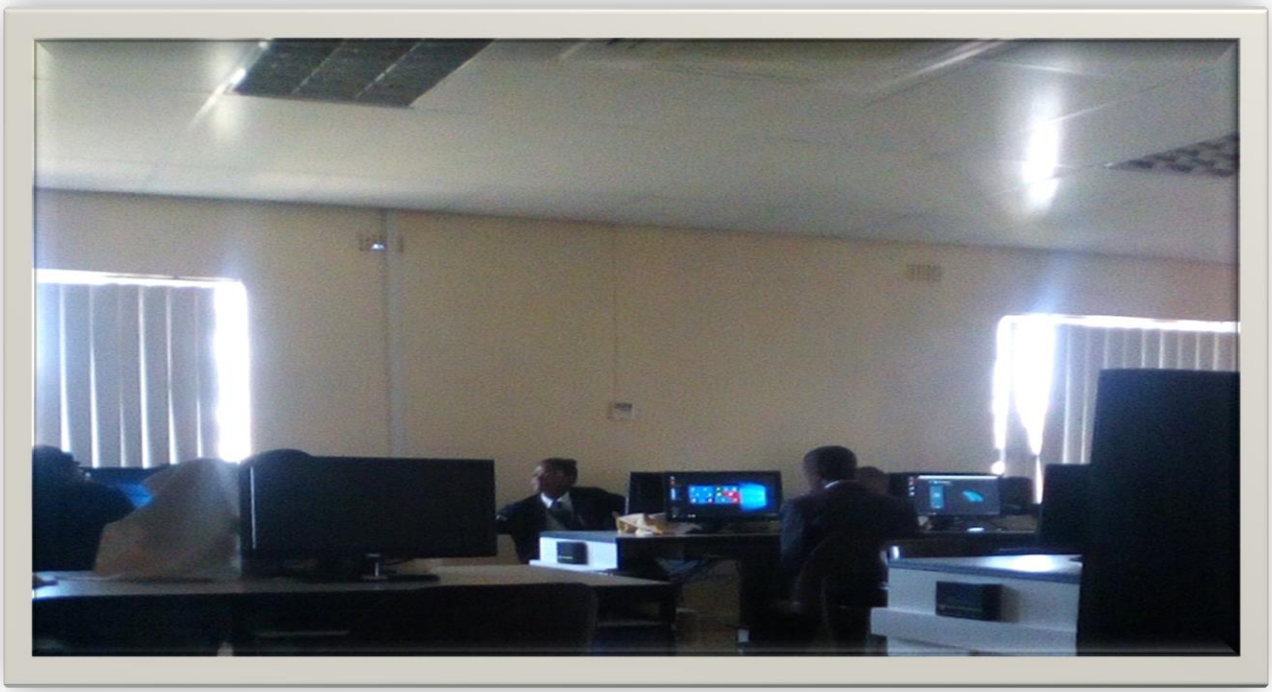


Figure 3.2: Learners doing Physical Sciences experiments through virtual laboratory delivery environments in a technology-enhanced classroom

For each experiment, a suite of printed pre-laboratory resources in the form of laboratory manuals was made available. The manuals consisted of background theory experimental skills, and post-laboratory data analysis). Thus the laboratory manuals contained relevant information about the experiment and, to some extent, some background theory.

Essentially, the printed manual was learners' point of reference as they proceeded through the experiment.

In the study, lesson plans were prepared for both the experimental and control groups. Participants were taught three times a week. One session was a sixty (60) minute period while the other was a one-hundred-and-twenty-minute double period per week. The essence of lesson plans was to guide the researcher on the steps and procedures to follow during the treatment. The EG was randomly exposed to five dimensions of VLDE, namely:

1. **Material Environment**

   Features of materials of VLDE were:

   - Well-furnished virtual chemistry laboratory room with storage and preparatory facilities; and
   - Enough computer gadgets for all participants.

2. **Integration**

   Features of the VLDE in this regard were:

   - Learners had an opportunity to compare theoretical with practical knowledge;
   - Learners were made to relate observations made in the laboratory to what had been taught in the classroom lessons;
   - Learners related observations made to knowledge of other related subjects; and
   - Learners related observations made to the natural environment

3. **Open-endedness**

   VLDE features were:

   - Learners were frequently asked questions to guide them to the solution to the problem;
   - Learners were provided opportunities to discuss their results to the rest of the class at the end of the experiments;

- Exchange of ideas among learners was encouraged; and
- Learners were allowed different patterns of interaction.

4. **Learner cohesiveness**

   Features of VLDE were:

   - Participants were free to discuss with mates when doing the practical;
   - Learners were allowed to assist one another during the activities; and
   - Participants had an opportunity to work together without being put in groups.

5. **Rule clarity**

   VLDE features were:

   - Learner attendance was very strict;
   - Discipline among learners was encouraged; and
   - Interactions among learners were expected to be restrictive under such a structured environment.

3.10. DEVELOPMENT AND USE OF TEACHING MODULE

The content used during instruction was developed and based on the Curriculum and Assessment Policy Statement (CAPS), learners' textbooks and other relevant materials. Educators' manuals include the content to be covered and lesson plans to be used in teaching stoichiometry during the study period. Learners had manual worksheets comprising guidelines and procedures to be followed when performing the Virtual Chemistry laboratory work. These manuals were used by the experimental group.

The user-friendliness of the Virtual Chemistry Laboratory to instructors

The following are benefits of the Virtual Chemistry Laboratories:

- Allows learners to learn and discover in a manner that was not available before the advent of Virtual Chemistry Laboratories;

- ❖ Provides a method to perform classic experiments quickly and easily with more efficient learning outcomes;
- ❖ Can conform to any pedagogical style and learning environment;
- ❖ Is the ultimate inquiry-based learning tool;
- ❖ Is easy for learners to install and use; and
- ❖ Provides a host of experiments not normally accessible to learners in wet laboratories.

Experiment 1 (Chemistry - Chemical Change: Chemical Equilibrium)

Aim: To determine the effect of a change in concentration and temperature on chemical equilibrium

Apparatus: test tubes, tongs, ice-bath, water bath, Bunsen burner.

Chemicals: 0,2 mol.dm^{-3} Cobalt Chloride ($CoCl_2$) in ethanol solution, Concentrated Hydrochloric acid (HCl), water,

Method:

1. Heat the water bath.
2. Put 4 to 5 drops of the $CoCl_2$ solution into a test tube, add 10 drops of water and add 20 drops of HCl.
3. Use the tongs to place the test tube in the hot water-bath, leave for 120 seconds. Record your observations.
4. Use the tongs to place the test tube in the ice-bath, leave for 120 seconds. Record your observations.

Experiment 2 (Chemistry- Chemical Change: Titration)

Part 1

Aim: To prepare a standard oxalic acid solution for volumetric analysis

Apparatus: 25 ml volumetric flask, mass meter, spatula, funnel

Chemicals: oxalic acid, water

Method:

1. Accurately weigh the amount of solute
2. Use a funnel to transfer this to a volumetric flask
3. Add water and swirl gently to dissolve the solute
4. Add water up to the volume mark
5. Calculate the concentration of the solution using the equation:

   $c = \frac{m}{MV}$

Part 2

Aim: To use the titration of oxalic acid against sodium hydroxide to determine the concentration of the sodium hydroxide

Apparatus: Erlenmeyer/ conical flask, burette, pipette, retort stand and clamp

Chemicals: water, sodium hydroxide solution, phenolphthalein indicator

Method:

1. Fill the burette with the stand solution, and use the tap to let some of it off until the solution is at the zero mark
2. Measure an accurate amount of the sodium hydroxide solution using a pipette and pour this into the conical flask
3. Add a few drops of the phenolphthalein indicator
4. Slowly open the tap of the burette to allow the acid standard solution to flow into the base solution in the flask until the end point is reached (The point where the indicator just starts to change colour)
5. The chemical equation for this reaction is:

   $2NaOH_{(aq)} + H_2C_2O_{4(aq)} \longrightarrow 2H_2O_{(aq)} + Na_2C_2O_{4(aq)}$
6. Calculate the concentration of the NaOH solution using the equation:

   $$\frac{n_a}{n_b} = \frac{c_aV_a}{c_bV_b}$$

3.11 VALIDITY AND RELIABILITY OF INSTRUMENT

3.11.1 Validity

Babbie and Mouton (2014) contends that validity means that "it measures what it purports to measure." McMillan and Schumacher (2014) suggest that internal validity focuses on the viability of causal links between the independent and dependent variables. Internal validity is, therefore, the degree to which the design of an experiment controls extraneous variables. McMillan and Schumacher (2014) also suggest that external validity refers to the generalizability of the results and conclusions to other people or locations. External validity concerns whether the results of the research can be generalized to another situation such as population, different subjects, settings, times and occasions.
The content of the test was derived from the Curriculum and Assessment Policy Statement Grade 10-12, and questions were selected and set using (Trochim, Donnelly and Arora, 2015) framework as cited in (Trochim, Donnelly and Arora, 2015). The test was sent to two Physical Sciences educators, who are teaching Physical Science at FET phase to determine whether the items in the test were representative of all the parts of the concepts covered during learners' engagement with the VLDEs. The instrument was then adjusted in line with their recommendations. Thus, content validity was used.

3.11.1.1 Pilot study

To ensure that learners in grade 11 could easily read and comprehend each item on the instruments used in this study, a pilot study was conducted. Original forms of the instruments were administered to a grade 11 class taking Physical Sciences in the same grade during the year preceding to the implementation of this study. This sample was from one non-participating school in the OR Tambo Inland district and its population was quite diverse and representative of the larger sample used for the current study. After choosing the participants, the researcher explained the importance of the test to the learners, informed them of their right to withdraw from the test at any moment. The researcher added that the tests results would be used for the purpose of the research only and that participants did not have to write their names on the answer scripts but only their age and gender.

The test was administered by their Physical Sciences teacher at their school. This was done to minimize reactive effects. The purpose of piloting the instruments was to pre-test their success. This was achieved by allowing learners to check the clarity of the items, instructions and layout, and to check the time taken to complete the tasks. Learners were instructed to highlight words and questions that they did not understand and comment on the clarity of items. Some learners thought that the original instruments were too lengthy and some did not understand certain terms as they were intended by the researcher. Based on learners' comments and patterns in item responses, the researcher modified some of the wording, eliminated the use of reverse items, and narrowed down the scales.

3.11.2 Reliability

According to Babbie and Mouton (2014), to be reliable means that if we measure the same thing again on another day, we obtain the same result. Creswell et al. (2018, p.264) define reliability as the stability of responses to multiple codes of data sets. Maree (2014, p.215) refers to reliability as the extent to which a measuring instrument is repeatable and consistent. The purpose of establishing the reliability of the achievement test was to determine whether the same results would be attained if the measuring device is administered more than once under similar situations and to establish the extent to which items assessing the same concept in a test concur (Vogt, Garden and Haeffele, 2012; Creswell et al. (2018, p.264)). Other reasons for using split-half reliability in this study were because it was not possible to test and re-test the same learners because the subjects of the pilot project were not available, and splitting the test items into two equal halves minimized the effects of fatigue and test anxiety Creswell et al. (2018).

3.11.3 Triangulation

Triangulation seeks convergence, corroboration, correspondence of results from different methods (Trochim, Donnelly and Arora, 2015). Additionally, triangulation or greater validity refers to the traditional view that quantitative and qualitative research might be combined to triangulate findings in order that they may be mutually corroborated. If the term was used as a synonym for integrating quantitative and qualitative. When quantitative and qualitative methods are used together, they both contribute to a common understanding of the research phenomenon. The findings from one method can aid in the development of another. Triangulation may involve the use of different methods, especially observation, focus groups and individual interviews, which form the major data collection strategies for much qualitative research (Johnson and Burke, 2017; Johnson, Burke and Christensen, 2017). For this study, data triangulation was in the form of achievement test, laboratory equipment test and interviews.

3.12 DATA COLLECTION PROCEDURES

The procedure for collection of data was in three main phases and lasted for eight weeks. The Phases were:

- A diagnostic pre-test (PrT) for the first week;
- The VLDE Treatment (EG) and CTEM (CG) for the next six weeks; and
- Post-test (PoT) for the last week of the eight weeks.

Both the Experimental and Control groups from the research sites were subjected to a diagnostic test (pre-test) to measure the learners' entry behaviour before treatment is administered to the Experimental group, while the control group was taught using the Conventional Teacher Expository Method (CTEM). At the end of the treatment period, post-tests (PSATCU and PSPST) were again administered to both groups using the same instruments. The PSATCU and PSPST were used to measure learners' achievement and proficiency in the acquisition of Physical Sciences techniques and practical expertise, respectively. The researcher supervised the teaching and scored both the pre-tests and post-tests. Interviews were conducted with all the participants in School A to assess their attitudes towards learning of Physical Sciences using a researcher designed interview data collection instrument.

3.13 DATA ANALYSES

After the collection of data, the researcher makes the conclusion of the whole research or investigation for conclusion coding, tabulating and graph representation is used for data analysis purposes (Trochim, Donnelly and Arora, 2015). In this study, Microsoft Excel and Statistical Package for Social Sciences (SPSS) were used to analyse quantitative data collected from the interviews. Descriptive statistics such as frequencies, mean and standard deviation were used to analyse the collected data. The T-tests were also used, and content analysis in the form of coding, forming categories and themes, was used to analyse qualitative data.

3.14 ETHICAL CONSIDERATIONS

Ethics are defined as the standards or norms that distinguish between right and wrong behaviour (Resnik, 2011; Creswell et. al, 2018; Leah, 2018). In research, ethical considerations are very critical. It is vital that a researcher adheres to the ethical considerations in a research study (Creswell et. al., 2018). The researcher accepts the assertion that research contributes to scientific knowledge and that human and technological advances are based on this knowledge. In particular, it is accepted that educational research should contribute to better the scholarship of teaching and the development of the learner. Prior to the collection of the data, the researcher first sought permission from the research sites and the provincial office of the Eastern Cape Department of Basic Education. The researcher contacted the principals of the two research sites and sought to be introduced to the Physical Sciences educators of the intact classes used in this study. The researcher agrees with McMillan and Schumacher

(2012) that the following should be observed: Gaining of consent from participants; No deception on the part of participants; No violation of the participants' privacy; Voluntary participation of all participants; No harm or risk to participants; Privacy of the research participants; and Release and publication of the findings in an accurate and responsible manner. In view of the above ethical considerations, the researcher observed the following:

3.14.1 Permission

Creswell et al. (2018, p.55) state that prior to conducting the study, the researcher should gain local access permission. Maree (2014, p.306) stipulates that students must obtain permission from the education department before conducting any research whatsoever. Permission to conduct research at the two Senior Secondary Schools was sought from the principals of the two selected schools (See Appendix C and Appendix D) and from the Department of Basic Education's provincial office following approval of the study by the university's ethics committee (See Appendix A and Appendix B).

3.14.2 Appointments

Letters were delivered to the principals of the participating schools, followed by appointments to administer tests and conduct interviews. Group meetings were held with the educators and learners to explain the research project and the process.

3.14.3 Confidentiality

Confidentiality refers to the protection of entrusted information. A trust relationship between researcher and participants is essential in promoting confidentiality (Maree, 2014; Creswell et al., 2018) and ensure the integrity of the research. All respondents were assured of confidentiality by means of a written notice. Participants were given pseudonyms to protect their identities and to ensure confidentiality. All participants were assured that their responses would not be disclosed to any third party without their consent except in the publication of results of this study for educational purposes.

3.14.4 No violation of the participants' privacy

Maree (2014, p.306) asserts that the right to privacy is the individual's right to decide when, where, to whom and to what extent his or her attitudes, beliefs and behaviour will be revealed. Furthermore, McMillan and Schumacher (2014) stress that research should never result in physical or mental discomfort, harm, or injury to the participants. It is fundamental that no harm must come to participants as a result of their participation in the research. This means not only that participants must not be exposed to pain or danger in the course of the research but also that there must be no adverse consequences to a person as a result of their participation. At the very least, the researcher must do their utmost to protect participants from any harm, and to ensure under the principle of informed consent that the participant is fully appraised of all possible risks from participation.

3.14.5 Voluntary participation of all participants;

"Voluntary participation means that participants cannot be compelled, coerced or required to participate" (McMillan and Schumacher, 2014, p.130). Furthermore, McMillan and Schumacher (2014), state that potential participants should not be forced to participate in a study unless they agree. Furthermore, as implied by the principle of informed consent, participation must be voluntary and not subject to any coercion or threat of harm for non-participation. In this study, assurance was given to all participants that participation in the study was voluntary and that participants were free to withdraw at any time without any negative effects.

3.14.6 Privacy of the research participants

Okeke and van Wyk (2015) state that the principle of respect for privacy has been identified as the point at which research goals and the right to privacy may come into conflict. According to Coe, Waring, Hedges and Arthur (2017), there are two ways in which issues regarding privacy arise in research. One concerns the collection of data and the other concerns what information is made public via the research process or in research reports. McMillan and Schumacher (2014) also state that the privacy of research participants means that access to participants' characteristics, responses, behaviour, and other information is restricted to the researcher. In research, privacy is the freedom a participant has to determine the following aspects about his or her identity and private information:

- Time – When, during the research process, one's identity and private information should be shared or withheld from others
- Extent – How much private information should be shared or withheld from others
- Circumstances – Conditions under which the participants' identity and private information can be shared or withheld from others (Okeke and van Wyk, 2015).

The researcher assured the participants that she will respect them at all times including their gender, religion, culture as orated by Creswell et al. (2018) who say that the researcher has to respect participants. The researcher ensures privacy by using anonymity, confidentiality and appropriate storing of data. In view of this, participants were not forced to share any information which they thought was private and not in their interest to share. Instead, the researcher negotiated on the amount of privacy to be maintained during and after data collection.

3.14.7 Post-research relationships

The research report would be made available to the Special Collection Section of Walter Sisulu University.

3.15 SUMMARY OF CHAPTER THREE

The methodology adopted for this study was outlined and justified in this chapter. The research paradigm, research approach and design were presented. Chapter three also addressed the population and sampling for the study, as well data collection and analysis procedure. Validity and reliability were also presented after ethical considerations. The next chapter deals with analysis, presentation and interpretation of data.

CHAPTER FOUR

ANALYSIS, PRESENTATION AND INTERPRETATION OF DATA

4.1 INTRODUCTION

Chapter three presented the research methodology including and explicating in detail the process, rationale and purpose of the research design. The mixed methods research approach was applied in this study to acquire an experiential overview of the extent of the effectiveness of the Virtual Laboratory Delivery Environments on Grade 11 learners' learning outcomes in Physical Sciences. Data collection instruments were discussed, and indications were highlighted of the methods of statistical analyses. To complete this study properly, it is necessary to analyse the data collected in order to answer the research questions. As already indicated in the preceding chapter, data was interpreted in a descriptive form. This chapter comprises the presentation, analysis and interpretation of the data resulting from this study. The analysis and interpretation of data is presented in two phases. The first part, which is based on the results of the Physical Sciences Achievement Test on Conceptual Understanding (PSATCU) and Physical Sciences Practical Skills Test (PSPST) instruments, deals with quantitative analyses of data. The second, which is based on the findings from the interview and focus group discussions, is a qualitative interpretation.

The effectiveness of Virtual Laboratory Delivery Environments, as the focal point of this study, is evaluated for academic effectiveness against critical elements, such as academic achievement, learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise and Attitudes towards Physical Sciences. Subsidiary research questions were crafted to answer the following main research question:

What is the impact of Virtual Laboratory Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences?

The sub-questions were:

i. What is the impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners?
ii. What is the impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise?
iii. To what extent does VLDE influence the participants' change of attitude towards Physical Sciences?

4.2 DEMOGRAPHIC RESPONSES

In this study, there were 39 learners in the experimental group and 44 learners in the control group. Figure 4.1 shows that the experimental group had 22 (56.4%) female learners and 17 (43.6%) male learners. Figure 4.2 is the control group that had 29 (65.9%) female learners and 15 (34.1%) male learners.

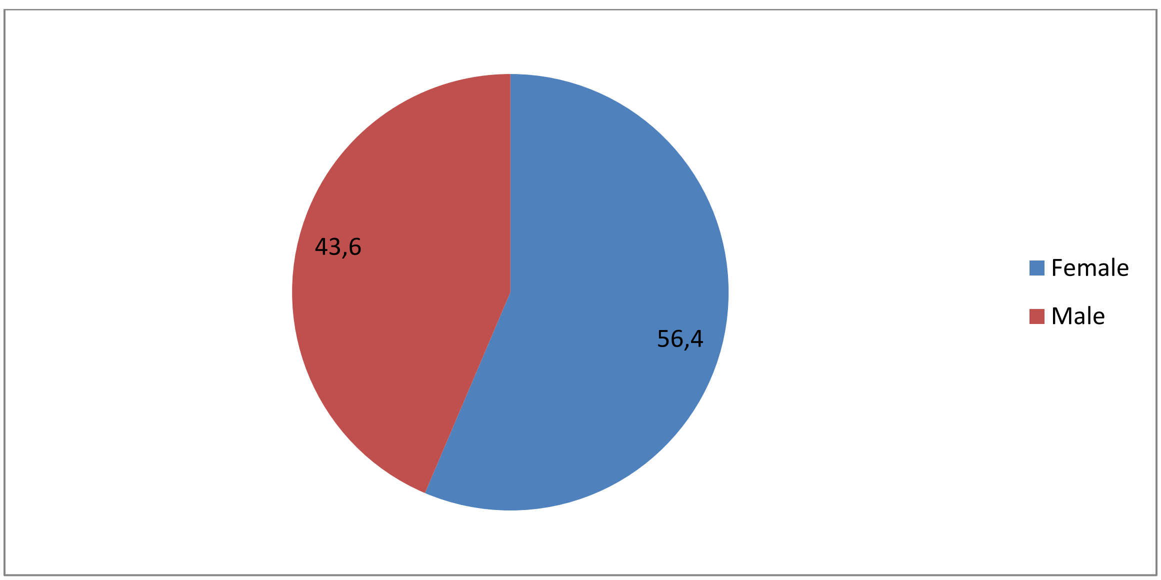


Figure 4.1: Demographic characteristics of experimental group

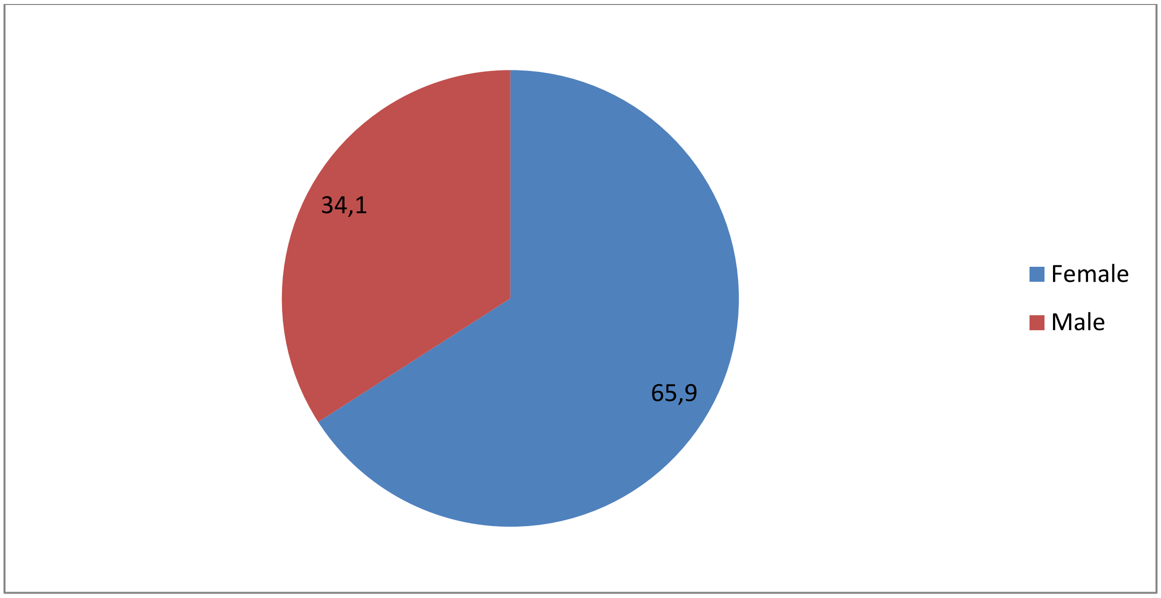


Figure 4.2: Demographic characteristics of control group

Figure 4.2 shows that there were more female participants than the male participants in this study.

4.3 RESULTS PRESENTATION

The following results were discussed

4.3.1 The impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners

To address the first sub-research question as per 4.3.1, Conceptual themes, t-tests and Hypotheses Testing for Control and Experimental Groups (N=83) are presented and analysed in the following sections**.** This study adopted itemised presentations categorised into generated conceptual themes. Table and graph headings were shortened. For complete questions, refer to Appendices 4.1 and 4.2.

4.3.1.1 Conceptual themes

Questions in Instrument 4.1 (PSATCU) were grouped into conceptual themes. Question-by-question analysis was also presented to assess learners' understanding of some concepts on stoichiometry. Furthermore, t-tests were also done to test the first hypothesis.

4.3.1.1.1 Analysis of questions on "Balancing chemical equations"

Questions 1 and 2 were meant to assess the learners' ability to apply the concept of balancing chemical equations. This section presents learners' responses during the pre and post-test as guided by the four options of the multiple-choice questions. An analysis of the correct responses (CR) and incorrect responses (ICR) are presented in Tables 4.1 and 4.2.

Table 4.1: Analysis of CR and ICR: PrT and PoT – Question 1

Choices		Responses							
		Pre-test				Post-test			
		CG		EG		CG		EG	
		N	%	N	%	N	%	N	%
A	Energy released in the reaction	14	31.8	11	28.2	10	22.7	5	12.8
B	Mechanism involved in the reaction	6	13.6	3	7.7	3	6.8	3	7.7
C	Mole ratio of any two substances in the reaction	16	36.4	14	35.9	29	65.9	30	76.9
D	Electron configuration of all elements in the reaction	8	18.2	11	28.2	2	4.5	1	2.6

Table 4.1 shows that pre-test results did not show much differences in learner performance as 16 (36.4 %) control group learners, compared to 14 (35.9 %), got the answer correct. Almost 32 % in the control group selected A, compared to 28 % in the experimental group. Post-test results show that 29 (65.9 %) from the control group compared to 30 (76.9 %) from the experimental group got the question correct. That gives a 0.5 % difference in favour of the control group, outweighed by a massive 11% difference in favour of the experimental group in the post-test.

Table 4.2 indicates that pre-test results showed much similarities in learner performance as 11 (25.0 %) control group learners compared to 10 (25.6 %) got the answer correct. However, 68 % in the control group incorrectly selected C, compared to 33 % in the experimental group. Post-test results show that 16 (36.4 %) from the control group compared to 25 (64.1 %) from the experimental group, got the question correct. In the post-test, exactly 22 (50 %) from the control group incorrectly selected C, showing a decline of 8 % from the pre-test. On average, experimental group learners performed better.

Table 4.2: Analysis of CR and ICR: PrT and PoT – Question 2

Choices		Responses							
		Pre-test				Post-test			
		CG		EG		CG		EG	
		N	%	N	%	N	%	N	%
A	Number of valence electrons involved in the reaction	2	4.5	10	25.6	6	13.6	0	0
B	Relative numbers of moles of reactants and products	11	25.0	10	25.6	16	36.4	25	64.1
C	Number of atoms in each compound in a reaction	30	68.2	13	33.3	22	50.0	12	30.8
D	Masses, in grams, of all reactants and products	1	2.3	6	15.4	0	0	2	5.1

4.3.1.1.2 Yields: Actual and theoretical

Four questions were presented under this theme. Questions 3, 4, 17 and 18 were meant to assess learners' understanding of the concept of yield (actual and theoretical) as it applies to stoichiometric calculations.

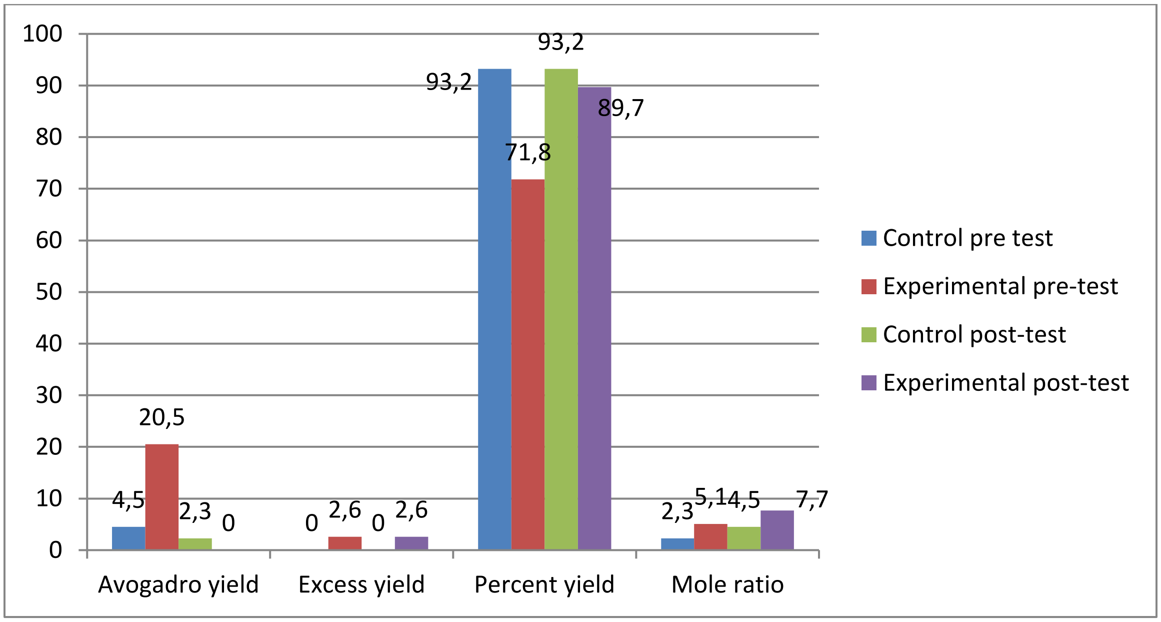


Figure. 4.3: Analysis of CR and ICR: PrT and PoT – Question 3

Figure 4.3 shows that about 20 % of learners in the experimental pre-test selected Avogadro yield. None of the control group learners ever selected excess yield. In this question, the control group remained at the same level of 93.2 % on correctly choosing percent yield. On the other hand, there was an increase in getting the correct answer in the experimental group from 71.8 % in the pre-test to 89.7 % in the post-test.

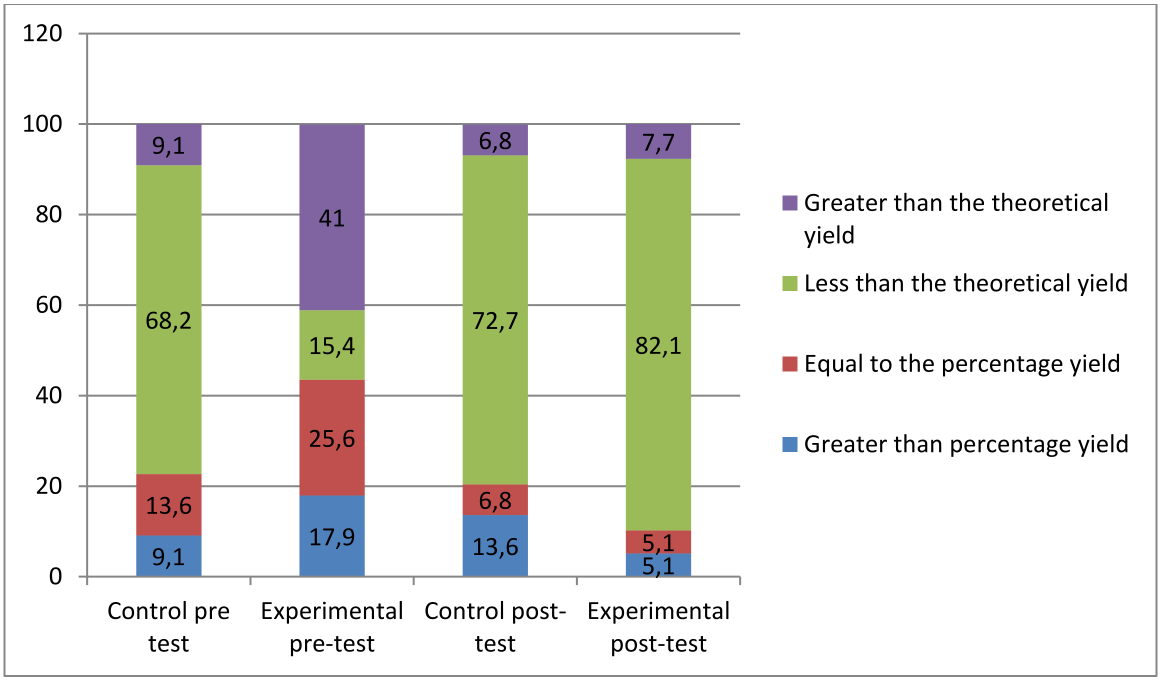


Figure 4.4: Analysis of CR and ICR: PrT and PoT – Question 4

Figure 4.4 shows that in the pre-test, 30 (68.2 %) of the control group compared to only 10 (25.6 %) got the answer correct. After the intervention, it is shown that 32 (72.7 %) of the control group learners compared to 32 (82.1 %) of the experimental group got the answer correct in the post-test. That was an increase of 4.5 % for the control group compared to 56.5 % for the experimental group.

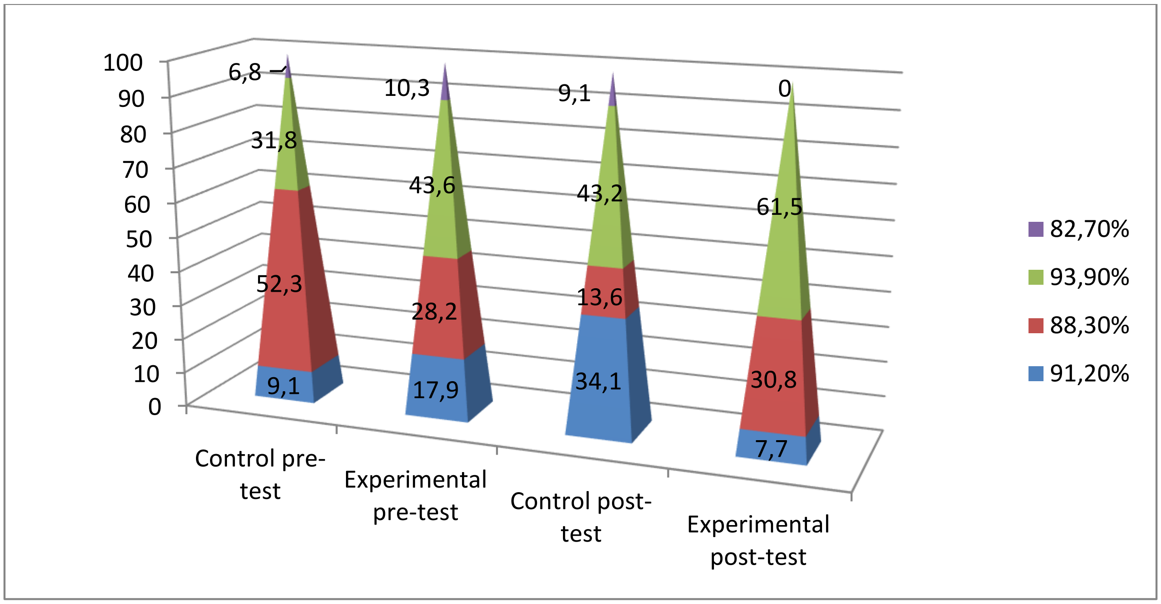


Figure 4.5: Analysis of CR and ICR: PrT and PoT – Question 17

Figure 4.5 shows that in the pre-test, 31.8 % of the control group compared to 43.6 % of the experimental group got 93.90 % as the correct answer. In the post-test, the control group increased by about 11 % to 43.2 %, compared to the experimental group that increased by almost 18 % to 61.5 %.

Table 4.3: Analysis of CR and ICR: PrT and PoT – Question 18

Choices		Responses							
		Pre-test				Post-test			
		CG		EG		CG		EG	
		N	%	N	%	N	%	N	%
A	82.10%	12	27.3	5	12.8	11	25.0	9	23.1
B	98.90%	9	20.5	19	48.7	11	25.0	2	5.1
C	73.40%	19	43.2	9	23.1	12	27.3	18	46.2
D	91.00%	4	9.1	6	15.4	10	22.7	10	25.6

Table 4.3 shows that there were no significant differences in the pre-test and post-test performances for the two groups. Only 4 (9.1 %) of the control group, compared to 6 (15.4 %), obtained the correct answer in the pre-test while 10 (22.7 %) of the control group compared to 10 (25.6 %) obtained the correct answer in the post-test.

4.3.1.1.3 Mole ratios

There were six items under this conceptual theme. Questions 6, 7, 8, 10, 14, and 20 addressed this.

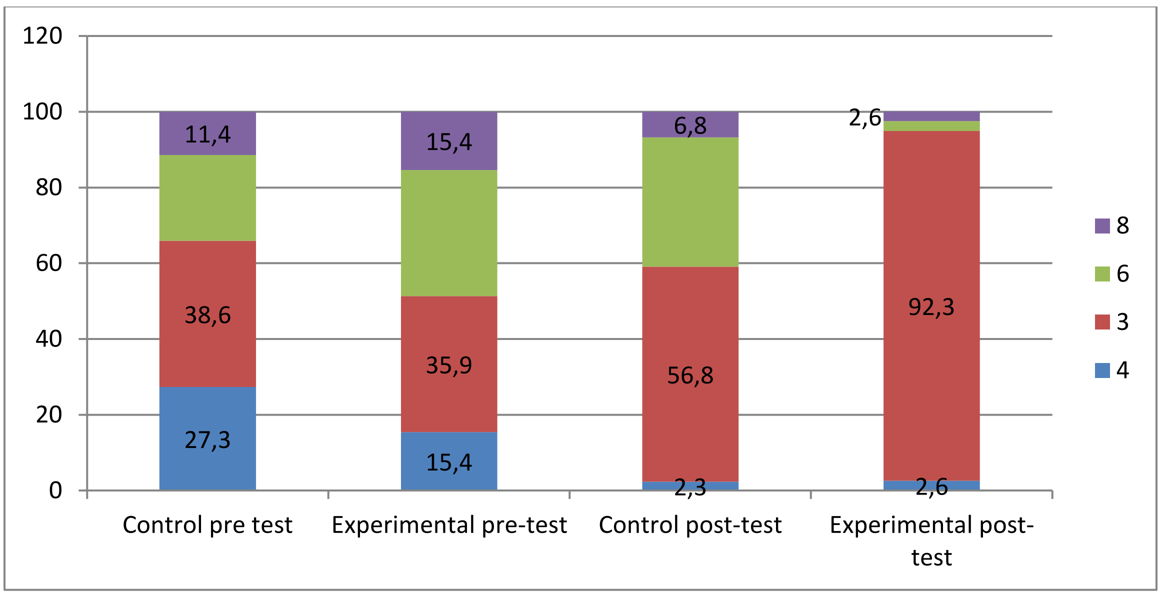


Figure 4.6: Analysis of CR and ICR: PrT and PoT – Question 6

Figure 4.6 shows very close performance characteristics between control group learners who had 17 (38.6 %) getting the correct while 14 (35.9 %) from the experimental group got the correct answer in the pre-test. In the post-test, control group learners who got the correct answer increased to 25 (56.8 %), compared to 36 (92.3 %) who got the correct answer.

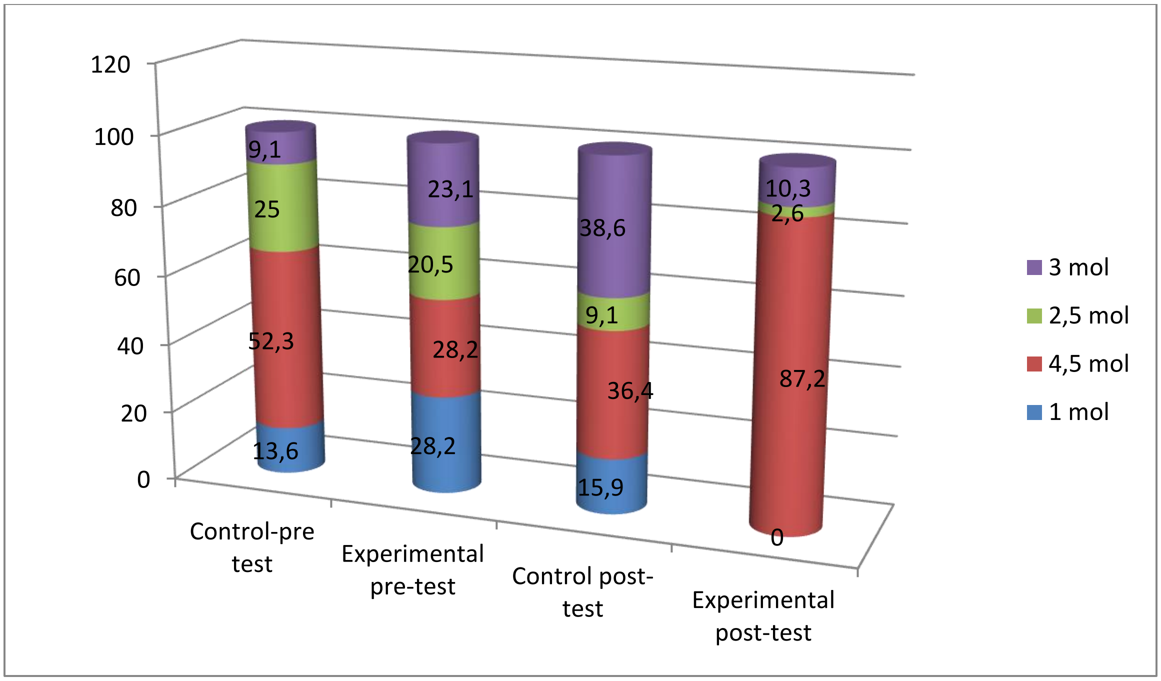


Figure 4.7: Analysis of CR and ICR: PrT and PoT – Question 7

Figure 4.7 shows that in the pre-test, the control group outweighed the experimental group by more than 20%. In the post-test, experimental learners performed so well that they outclassed their counterparts who even performed worse than in the pre-test.

Table 4.4: Analysis of CR and ICR: PrT and PoT – Question 8

Choices		Responses							
		Pre-test				Post-test			
		CG		EG		CG		EG	
		N	%	N	%	N	%	N	%
A	10:6	2	4.5	11	28.2	5	11.4	2	5.1
B	4:3	31	70.5	11	28.2	19	43.2	22	56.4
C	3:4	4	9.1	8	20.5	5	11.4	0	0
D	2:3	7	15.9	9	23.1	15	34.1	15	38.5

Table 4.4 shows great differences between pre-test results as 63.6% control group learners compared to only 10.3 % experimental group learners got D as the correct response. In the post-test, control group learners increased by 2.3 % to 65.9 % with the experimental group increasing by more than 40 % to 53.8 %. For both groups, the percentage of learners who selected C declined.

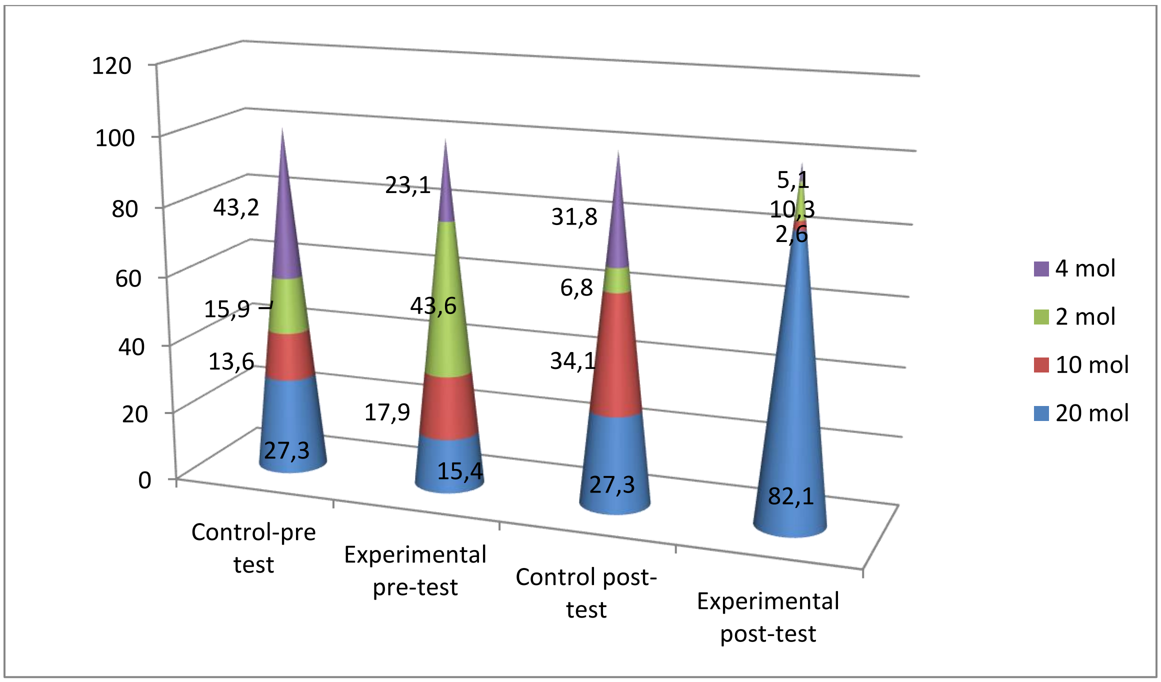


Figure 4.8: Analysis of CR and ICR: PrT and PoT – Question 10

Figure 4.8 shows that there was no difference in the control group performance during the pre-test and post-test as only 27.3 % got the answer correct. In the experimental group, however, there was a significant increase by the experimental group from a pre-test performance of 15.4 % to 82.1 % in the post-test. That was from a large number that had previously selected 2 moles, instead of 20 moles in the pre-test of the experimental group, whereas the number of incorrect choices for the control group rose from 13.6 % to 34.1 % for 10 mol.

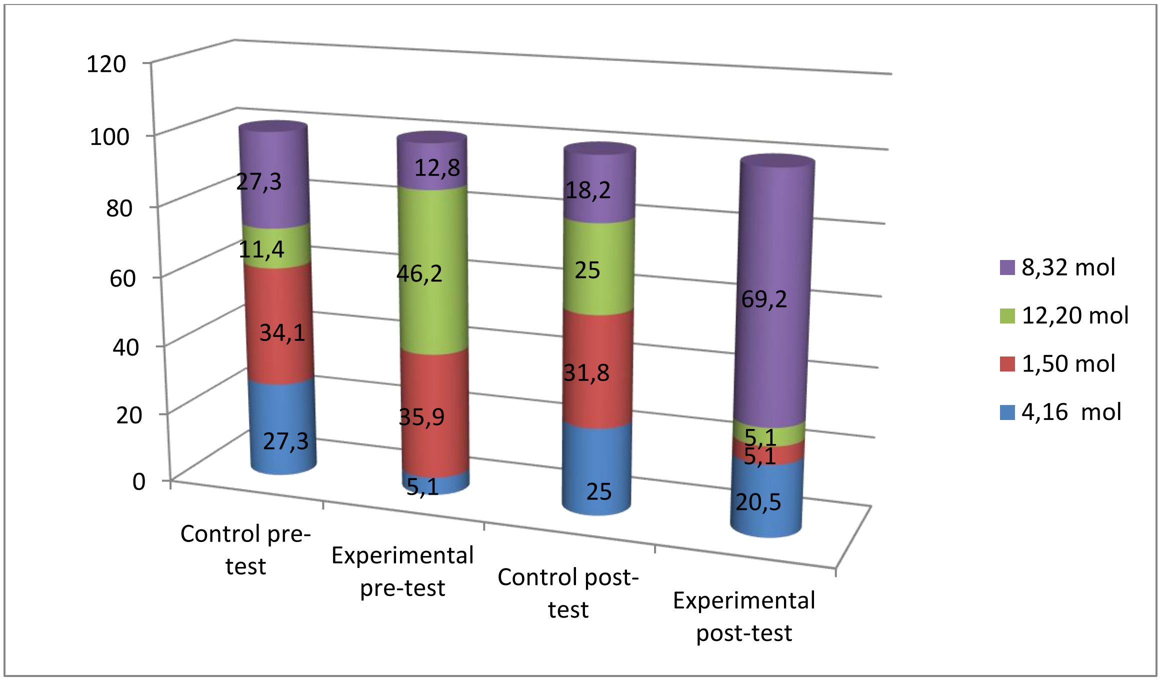


Figure 4.9: Analysis of CR and ICR: PrT and PoT – Question 14

From Figure 4.9, the pre-test had 27 % compared to 12 % who got the answer correct, whereas in the post-test, the control group dropped to 18 % compared to the experimental group who improved by 69 %.

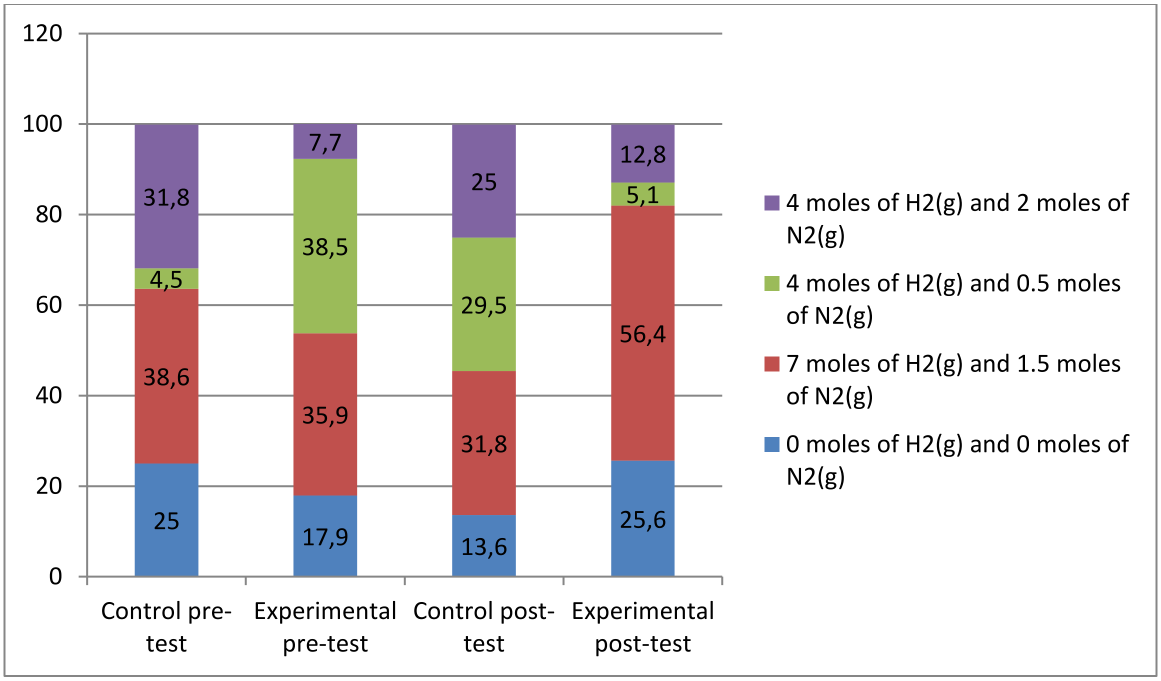


Figure 4.10: Analysis of CR and ICR: PrT and PoT – Question 20

Figure 4.10 shows a surprising performance for the experimental group. In the pre-test, 4.5 % of the control group compared to 38.5 % of the experimental group got the correct answer. However, in the post-test, 29.5 % of the control group compared to only 5.1 % of the experimental group were correct.

4.3.1.1.4 Limiting reagents

Questions 5 and 11 were meant assess learners' understanding of the concept of limiting reagent as it applies to stoichiometry.

Table 4.5: Analysis of CR and ICR: PrT and PoT – Question 5

Choices		Responses							
		Pre-test				Post-test			
		Control		Experimental		Control		Experimental	
		N	%	N	%	N	%	N	%
A	Calculating bond energies	3	6.8	8	20.5	2	4.5	1	2.6
B	Determining the masses of 100 moles of each reactant	1	2.3	7	17.9	4	9.1	0	0
C	Calculating the mass of a single product formed from each reactant	12	27.3	20	51.3	9	20.5	17	43.6
D	Determining the molar masses of the products	28	63.6	4	10.3	29	65.9	21	53.8

Table 4.5 shows great differences between pre-test results as 63.6 % control group learners compared to only 10.3 % experimental group learners got D as the correct response. In the post-test control group, learners increased by 2.3 % to 65.9 %, with the experimental group increasing by more than 40% to 53.8 %. For both groups, the percentage of learners who selected C declined.

Figure 4.11 shows the analysis of Correct Responses (CR) and Incorrect Responses (ICR) of Pre-Test(PrT) and Post Test(PoT) for Question 11 of the current study

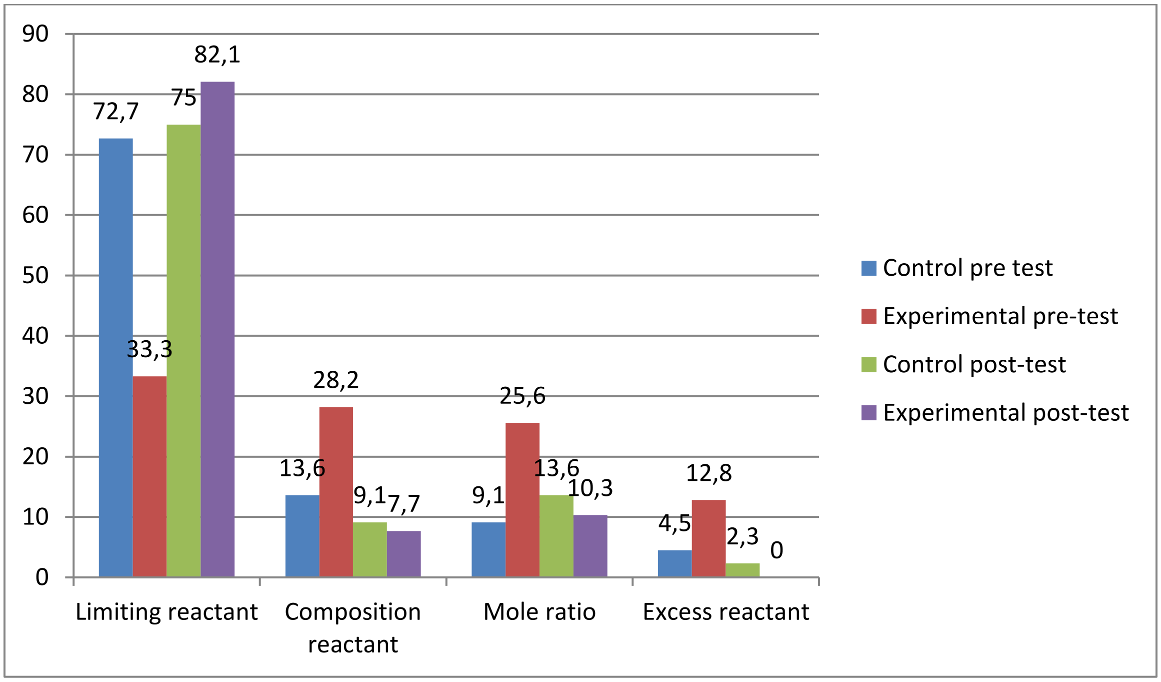


Figure. 4.11: Analysis of CR and ICR: PrT and PoT – Question 11

Figure 4.11 shows about 72 % of the control group correctly choosing limiting reactant compared to about 33 % from the experimental group in the pre-test. In terms of post-test outcomes, control group learners who obtained the correct answer increased to 75 % while the experimental group rose by about 50 % to 82,1 %.

4.3.1.1.5 Calculations

Questions 9, 12, 13, 15, 16 were meant to assess the participants' ability to deal calculations based on the stoichiometric concepts. These questions assessed learners' abilities to work between moles and masses.

Table 4.6: Analysis of CR and ICR: PrT and PoT – Question 9

Choices		Responses							
		Pre-test				Post-test			
		Control		Experimental		Control		Experimental	
		N	%	N	%	N	%	N	%
A	When the reactant is given in moles and the product is sought in moles	20	45.5	17	43.6	31	70.5	30	76.9
B	When the reaction is given in grams and the product is sought in grams	13	29.5	18	46.2	9	20.5	6	15.4
C	When the reactant is given in grams and the product is sought in litres	9	20.5	3	7.7	4	9.1	3	7.7
D	When the reactant is given in litres and the product is sought in number	2	4.5	1	2.6	0	0	0	0

Table 4.6 shows that in the pre-test control group, learners almost performed the same as the experimental group as there is percentage difference of only 1.9 %. In the experimental group, post-test results reflected a different picture as experimental group got 76.9 % compared to 70.5 %. To get the correct answer, there was little difference of about 1,9 % less for the experimental group in the pre-test compared to the control group. However, 30 (76,9 %) of the experimental group, compared to 31 (71,5 %) of the control group got the answer correct in the post test.

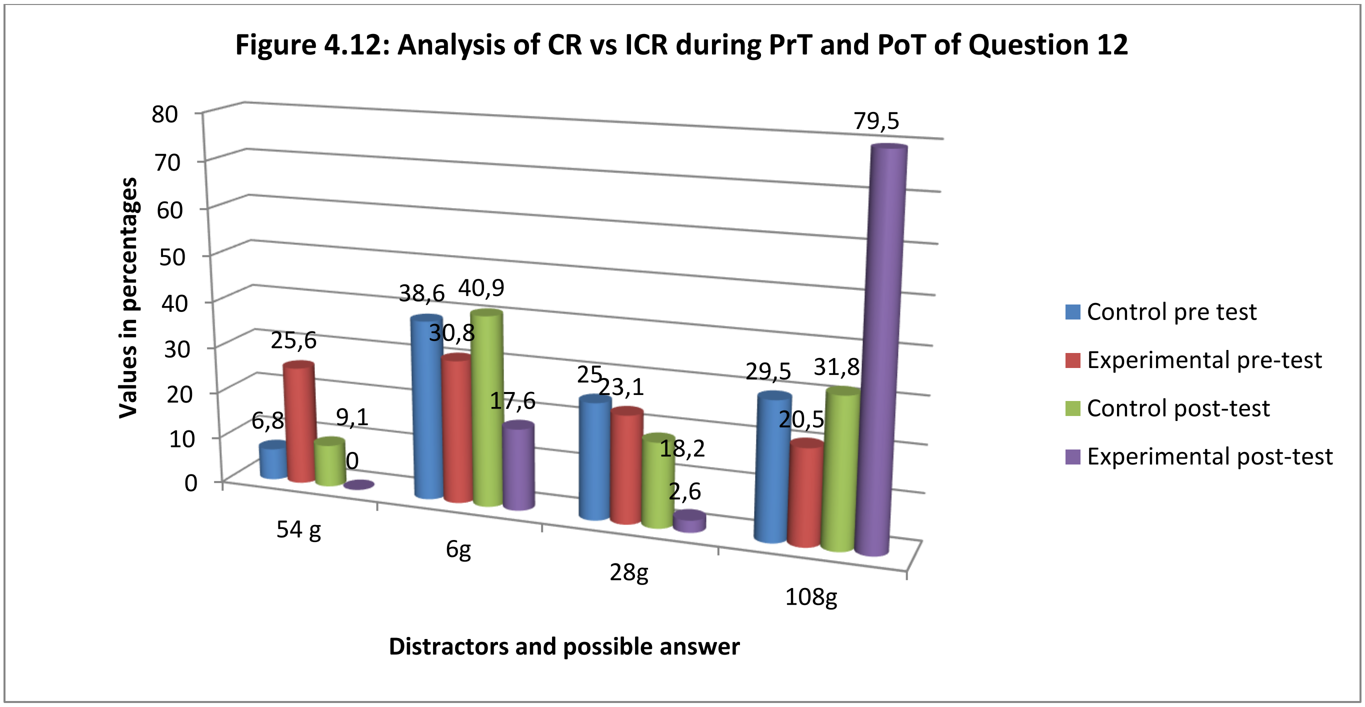


Figure 4.12: Analysis of CR and ICR: PrT and PoT – Question 12

Figure 4.12 shows about 29.5 % of the control group correctly choosing limiting reactant compared to about 20.5 % from the experimental group in the pre-test. In terms of post-test outcomes, control group learners who obtained the correct answer increased to 31.8 % while the experimental group rose to 79.5 %.

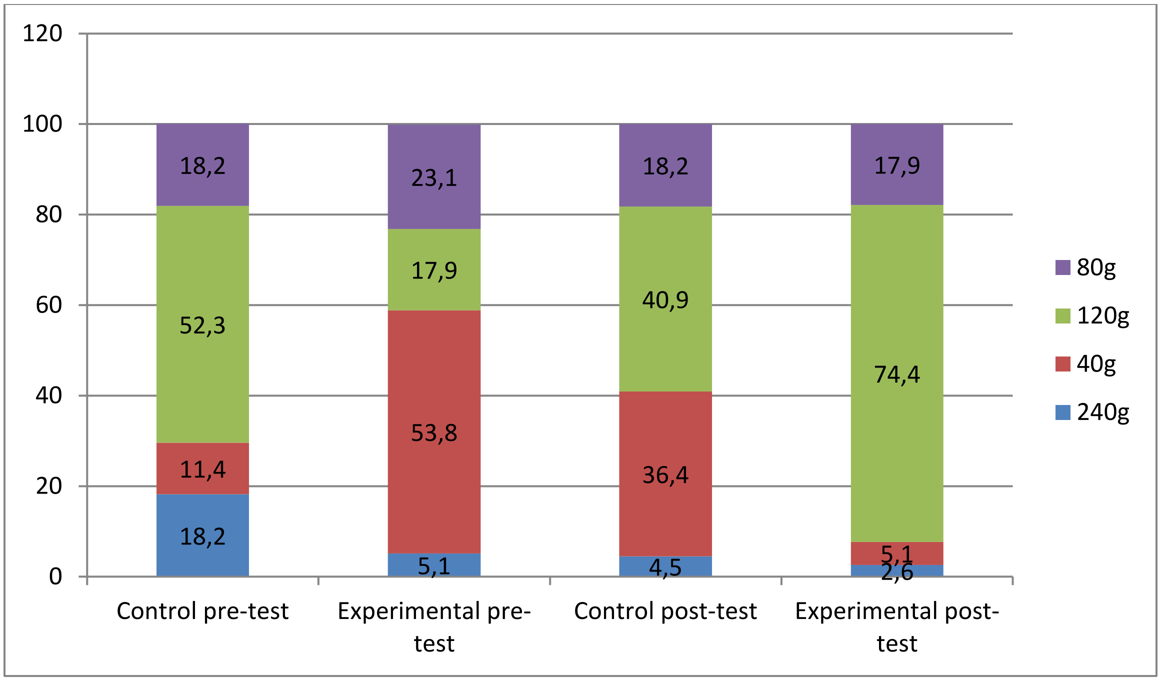


Figure. 4.13: Analysis of CR and ICR: PrT and PoT – Question 13

Figure 4.13 shows that by a wider margin, control group learners got the response correct in the pre-test compared to the experimental group. However, in the post test, the control group performed worse from 52,3 % in the pre-test to 40,9 % while the experimental group increased to 74,4 % from 17,9 %, which is at least four times better.

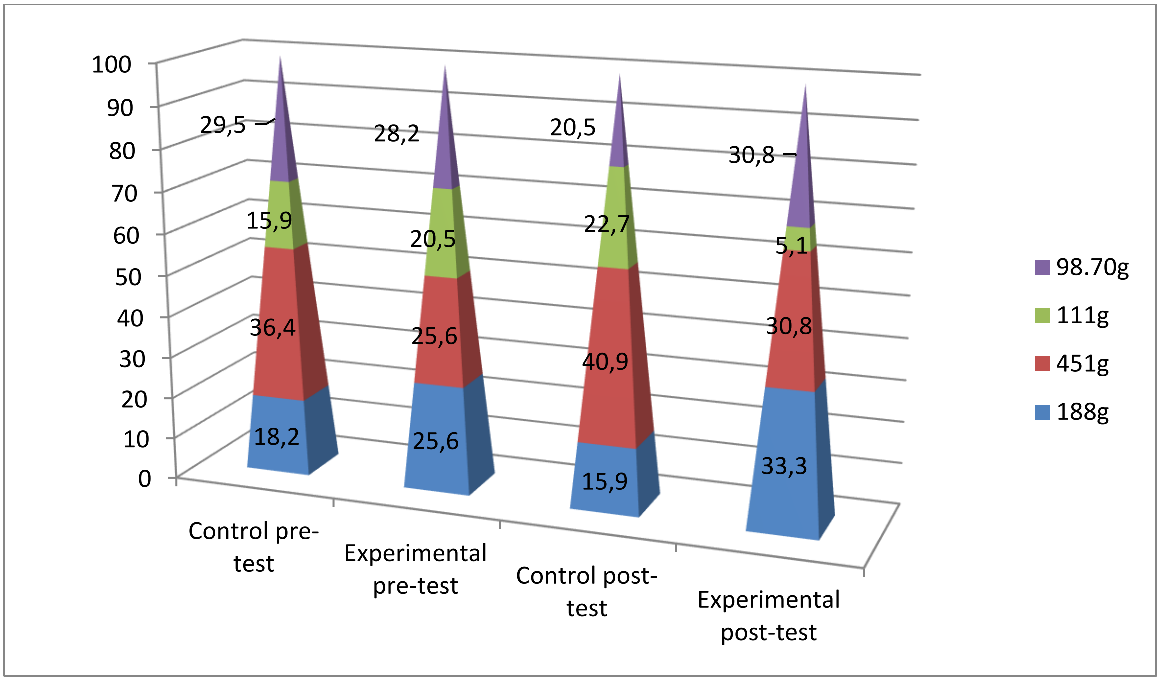


Figure 4.14: Analysis of CR and ICR: PrT and PoT – Question 15

Figure 4.14 shows a control group performance that declined from the pre-test to the post-test. However, there was a slight improvement of the post-test performance for the experimental group.

Table 4.7: Analysis of CR and ICR: PrT and PoT – Question 16

Choices		Responses							
		Pre-test				Post-test			
		CG		EG		CG		EG	
		N	%	N	%	N	%	N	%
A	825g	10	22.7	6	15.7	15	34.1	24	61.5
B	409g	11	25.0	7	17.9	6	13.6	5	12.8
C	112g	16	36.4	24	61.5	19	43.2	5	12.8
D	319g	7	15.9	2	5.1	4	9.1	5	12.8

Table 4.7 shows gradual performance of the control group from 22.7 % to 34.1 % in the pre-test and the post-test, respectively, compared to the experimental group that respectively performed from 15.7 % to 61.5 %.

The next section presents pre-test and post-test performances of participating learners in each group.

4.3.1.2 Analysis of scores obtained by CG during PrT

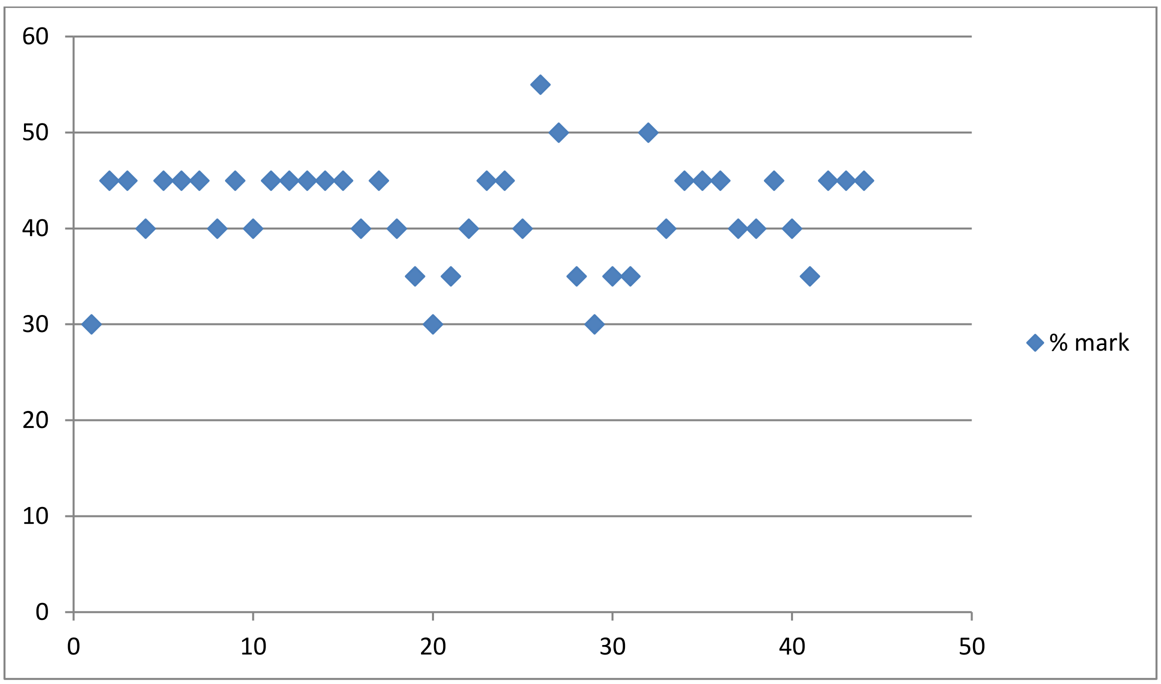


Figure 4.15: Scatter plot showing CG performance during PrT

In Figure 4.15, data shown indicates that the minimum mark was 30 % and the maximum was 55 %. The modal mark was 45 % with 20 learners, and the median was also 45 %. That made 45 % appear as the line of best fit.

4.3.1.3 Analysis of scores obtained by CG during PoT

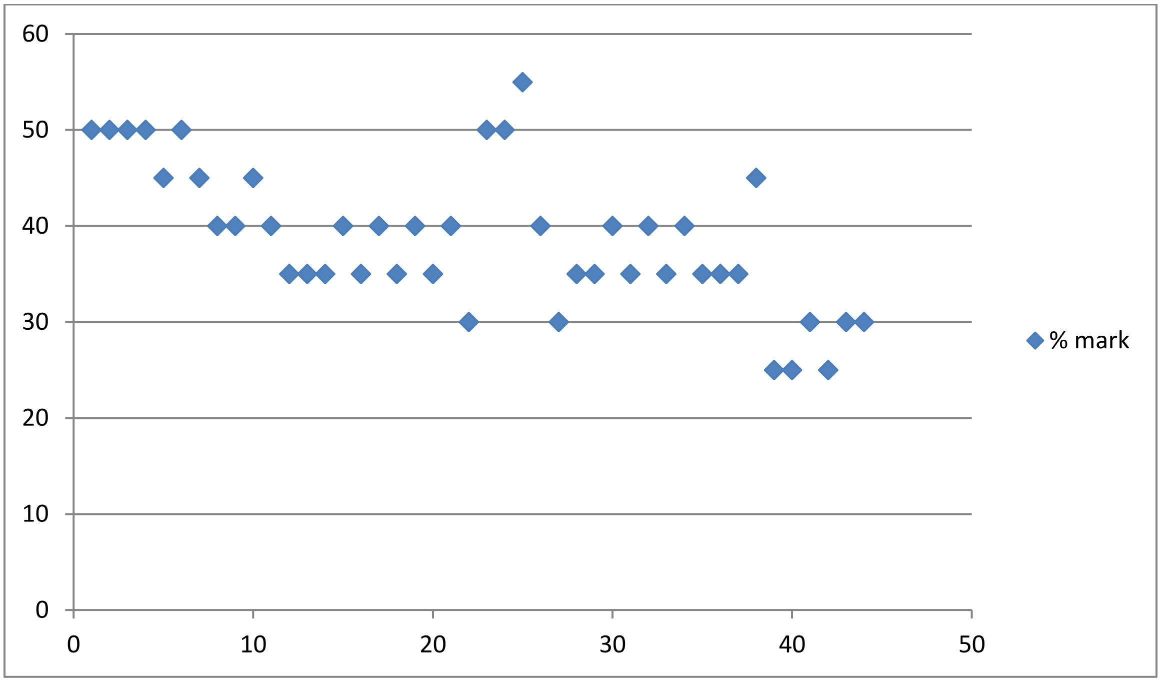


Figure 4.16: Scatter plot showing CG performance during PoT

In the post-test in Figure 4.16, the minimum mark was surprisingly 25 % and the maximum remained 55 %. The modal mark was 35 % with 13 learners, and the median was 40 %. There were generally no significance differences in learner performances from pre-test to post-test.

4.3.1.4 Analysis of scores obtained by the EG during PrT

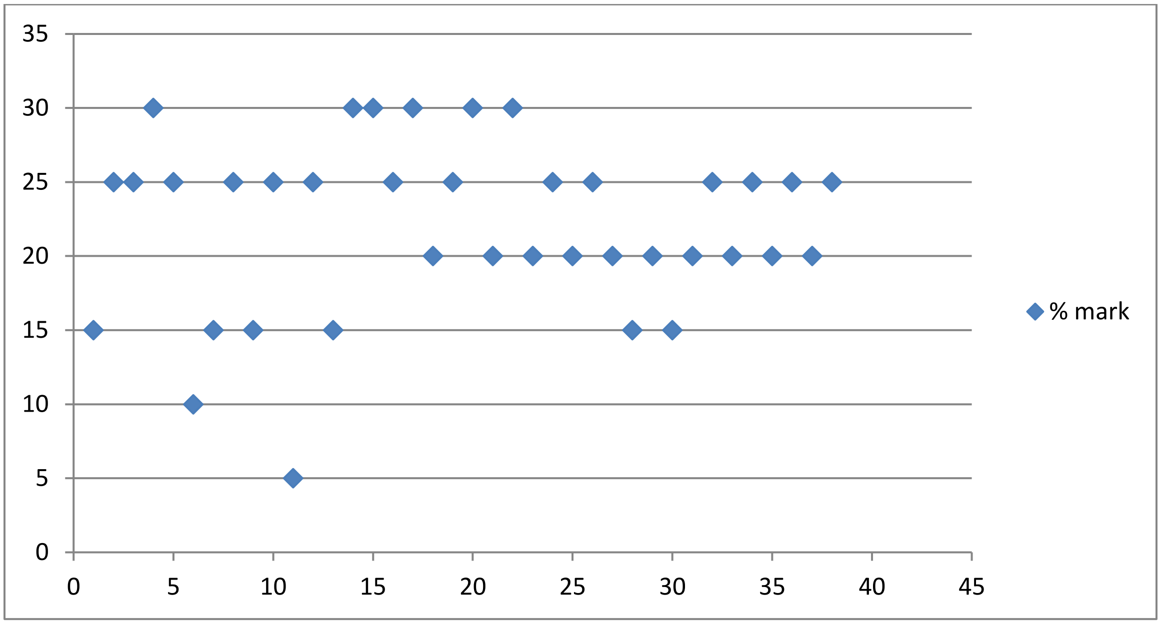


Figure 4.17: Scatter plot showing EG performance during PrT

Figure 4.17 shows that the least mark was 5 % and the highest was 30 %. The modal mark, which was also the median mark, was 25 % with 14 learners. Thus, all experimental learners underperformed in the pre-test.

4.3.1.5 Analysis of scores obtained by the EG during PoT

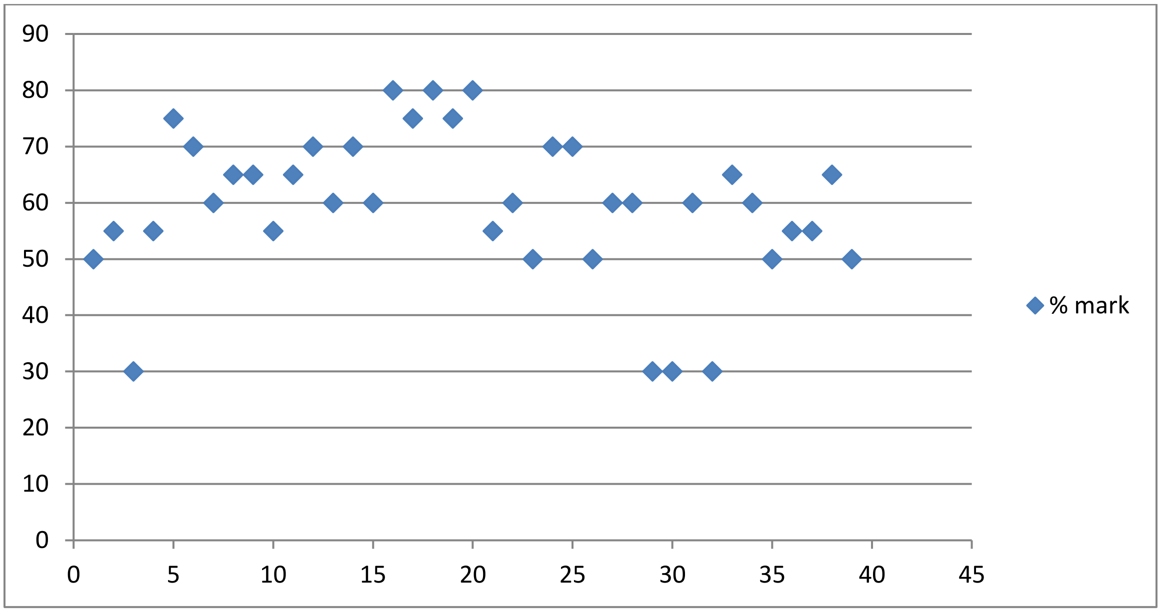


Figure 4.18: Scatter plot showing experimental group performance in post-test

Figure 4.18 shows that the least mark in the test was 30 %, and the highest was 80 %. The modal mark was 60 % when eight learners achieved 60 %. There was a notable improvement in learner performance from as only about 9 % failed with 30 %, so the pass rate rose from zero to approximately 91 % in the post-test.

4.3.1.6 Hypothesis testing for conceptual understanding

The following hypotheses were formulated by the researcher to guide the study.

1. H_1: There is significant difference between the mean response on the scientific literacy among the grade 11 Physical Science learners and matching their abilities through the VLDE experiences they are exposed to.

2. H_2: There is significant deference between the mean response on development and mastering of scientific skills as roles of the use of VLDE in teaching the Physical Science subject among the Grade 11 learners.

The following t-test results emerged as the study sought to test the hypothesis stated.

Table 4.8: t-test paired samples statistics raw mark results for experimental and control groups (N=83)

Pair	Mean	Standard deviation	Correlation	Paired Differences				
				Mean	S.D.	t	df	Sig. (2-tailed)
$Pretest^E$	4.41	1.163	0.919	– 7.385	1.801	– 25.609	38	0.000*
$Posttest^E$	11.79	2.811						
$Pre\text{-}test^E$	4.41	1.163	0.913	– 3.765	0.485	– 48.576	38	0.000*
$Pre\text{-}test^C$	8.39	0.970						
$Post\text{-}test^E$	11.79	2.811	0.930	4.359	1.678	16.224	38	0.000*
$Post\text{-}test^C$	7.75	1.294						
$Pre\text{-}test^C$	8.39	1.104	0.909	0.636	0.685	6.161	43	0.000*
$Post\text{-}test^C$	7.75	1.512						

Key: $Pre\text{-}test^E$ = pre-test experimental group and $Post\text{-}tes^{ts}$ = post-test control group
*p<0.05

The t-test results in Table 4.8 were for tests marked out of 20 and tested at 5 % significance level. For the experimental group, the mean differences in the pre-test and post-test were 7.385, representing almost 17 % overall performance improvement. There was no significant difference for the control group pre-test and post-test mean mark difference of 0.636. Pre-test control mean of 8.39 was evidently way above and almost doubled the pre-test experiment mean mark of 4.41. Across all the pairs, since $p<0.05$, H_0 is rejected, and there is strong evidence to support H_1. Firstly, it is clear that there was little difference in the performance within the control group. Across and within all pair combinations, it is also evident that the experimental group performed far much better in the post-test. Thus, it was concluded by post-tests that the impact of the VLDE intervention was 95% significant in favour of $H_{1,}$ irrespective of whether it was within or across the experimental and control group pairs. Therefore, the VLDE had a strongly positive impact in learner performance.

4.3.2 The impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise

To address the second sub-research question themes, t-tests and hypothesis testing are presented and analysed in the following sections. Results were also presented under the following different themes:

4.3.2.1 Establishing and defining hypothesis

Only one question belonged to this theme in assessing integrated skill.

Table 4.9: Analysis of CR: PrT Mode and PoT Mode- Question 1

[Key: 1=A, 2=B, 3=C, 4=D, 5=E: N=83]

Group/Group Modal Choice	PrT mode		PoT mode	
	Control	Experimental	Control	Experimental
You may do an unassigned experiment only	1	1	1	1

Table 4.9 shows that the modal learners per group during the pre-test and the post-test did not get the question correct.

4.3.2.2 Making operational predictions

A single question was presented on this basic skill.

Table 4.10: Analysis of CR: PrT Mode and PoT Mode -Question 2

Question/Group Modal Choice	Pre-test mode		Post-test mode	
	Control	Experimental	Control	Experimental
In the laboratory, you are allowed to eat and drink only	5	5	5	5

Modal learners per group had the highest frequencies in getting the question in Table 4.10 correct.

4.3.2.3 Identifying and controlling variables in a problem

There was only one question in this integrated skill category.

Table 4.11: Analysis of CR: PrT Mode and PoT Mode – Question 3

Question/Group Modal Choice	Pre-test mode		Post-test mode	
	Control	Experimental	Control	Experimental
If you notice an unexpected chemical reaction of your experiment	4	4	4	4

Assessing the integrated skill in Table 4.11 produced results that the modal learners in all groups got the response correct.

4.3.2.4 Designing required analysis for the solution of the problem

Two questions belonged to this assessment theme.

Table 4.12: Analysis of CR: PrT and PoT- Questions 4 and 5

Question/Group Modal Choice	Pre-test mode		Post-test mode	
	Control	Experimental	Control	Experimental
The following should be reported to the instructor	5	5	5	5
If you accidentally mix the wrong chemical, you must	4	4	4	4

Table 4.12 tested the theme which had the majority of learners getting the questions correct both in the pre-test and post-test.

4.3.2.5 Making operational predictions

There were four questions, including those in Table 4.2 under this theme.

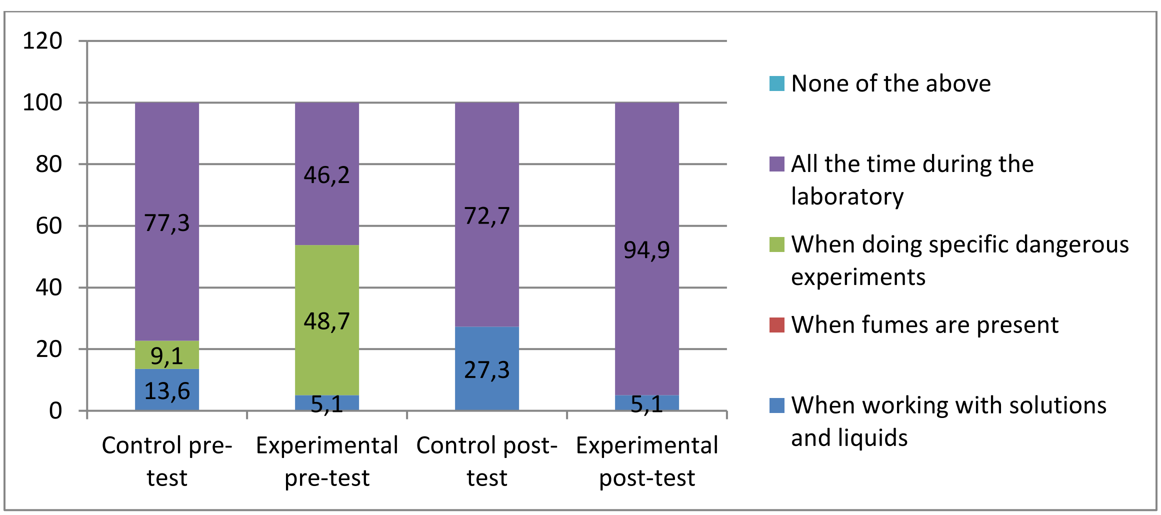


Figure 4.19: Analysis of CR and ICR on the theme: Making operational predictions

Figure 4.19 shows that there was a decrease in the control group getting the correct answer for this question from 77.3 % to 72.7 %. On the other hand, there was more than slightly a 100% increase in the experimental group, getting the question correct from 46.2 % to 94.9 %.

Table 4.13: Analysis of CR and ICR: PrT and PoT- Question 7

Choices		Responses							
		Pre-test				Post-test			
		Control		Experimental		Control		Experimental	
		N	%	N	%	N	%	N	%
A	Sandals that allow proper ventilation to the feet	4	9.1	2	5.1	0	0	2	5.1
B	A comfortable pair of slippers	2	4.5	3	7.7	5	11.4	0	0
C	Closed-toe shoes	18	40.9	19	48.7	32	72.7	24	61.5
D	Shoes with low heel	8	18.2	6	15.4	5	11.4	7	17.9
E	None of the above	12	27.3	9	23.1	2	4.5	6	15.4

Table 4.13 shows pre-test and post-test results for the control group rose from 40.9 % to 72.7 %, respectively, while that of the experimental group rose from 48.7 % to 61.5 %.

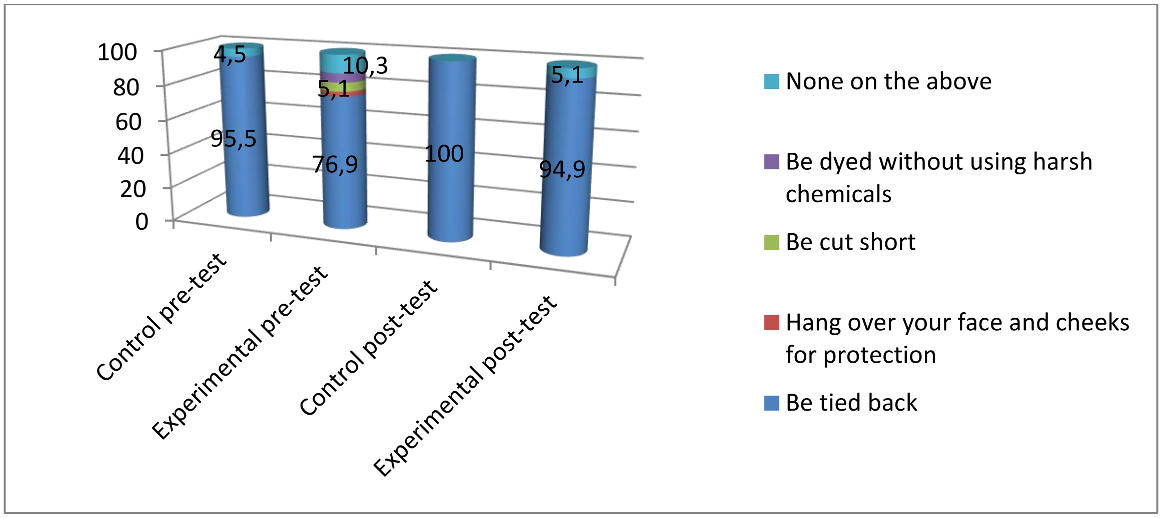


Figure 4.20: Analysis of CR and ICR on the theme: Designing required analysis for the solution of the problem

Figure 4.20 indicates that in the pre-test, 95.5 % of the control group compared to 76.9 % the experimental group got the correct answer. In the post-test, the entire control group got the answer correct, compared to 94.9 % of the experimental group.

Table 4.14: Analysis of CR and ICR: PrT and PoT- Question 10

Choices		Responses							
		Pre-test				Post-test			
		Control		Experimental		Control		Experimental	
		N	%	N	%	N	%	N	%
A	Ignore it and keep working on your experiment so you can finish on time	0	0	4	10.3	0	0	0	0
B	Walk straight over the spilled chemical to notify the instructor	4	9.1	4	10.3	0	0	0	0

B	Walk straight over the spilled chemical to notify the instructor	4	9.1	4	10.3	0	0	0	0
C	Keep it confidential and do not let the other learners around you know about it	2	4.5	0	0	0	0	0	0
D	Alert nearby learners and call the instructor for instructions about how to clean it up	36	81.8	0	0	42	95.5	39	100.0
E	None of the above	2	4.5	31	79.5	2	4.5	0	0

Table 4.14 shows interestingly that in the pre-test the range of the learners who passed between the control group, and the experimental group was 81.8 % since none of the experimental group got it right. In the post-test, however, all experimental learners got the answer correct compared to 95.5 % of the control group.

4.3.2.6 Designing required analysis for the solution of the problem

There were six questions clustered under the theme assessing integrated skills including those in Table 4.15.

Table 4.15: Analysis of PrT Mode and PoT Mode - Questions 11- 20

Question/ Item	Expected CR	Associated Science Process Skill (SPS)	Pre-test mode		Post-test mode	
			Control	Experimental	Control	Experimental
11	B	Classifying	2	2	4	2
12	C	Inferencing	1	2	1	2
13	B	Operational	3	3	3	3
14	E	Measuring	1	1	1	1
15	B	Operational	3	3	3	4
16	C	Operational	1	3	5	3
17	A	Generalising	1	1	1	1
18	D	Classifying	1	3	4	3
19	A	Operational	1	2	1	1
20	E	Operational	1	1	2	1

According to Table 4.15, using modal responses to interpret the results shows that in all the cases except the few highlighted below, the majority of learners did not correctly get the answers both in the pre-test and in the post-test. However, the question, *"After dispensing a chemical from a container"* which assessed integrated operational skill, had the majority of the experimental group getting it correct in the two test phases unlike the control group. The integrated skill on generalising "*You should always hold containers* *that have chemicals"* was correctly answered in both phases by both groups. The basic skill theme, 'classifying' assessed on, *"Before using the contents of a bottle, check*" was scored correctly by the majority of the control group in the post-test.

Lastly, "*To remove solid chemicals from a bottle"* which assessed integrated skill had the majority of the experimental group failing it in the pre-test. However, the majority from both groups got it correct in the post-test.

4.3.2.7 Comparison of responses by CG and EG during the PrT and PoT on Science process skills

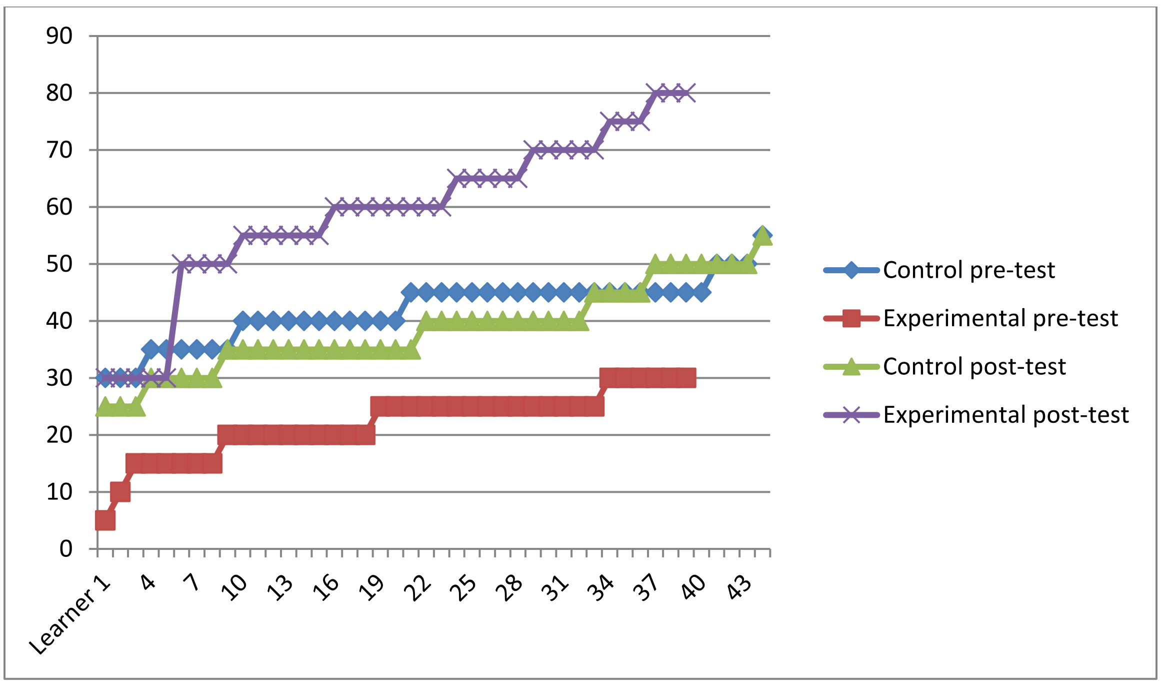


Figure 4.21: Comparison of responses by the CG and EG during the PrT and PoT.

Figure 4.21 shows an interesting picture regarding the impact of the intervention. Experimental pre-test marks were the lowest of the four sets of marks. There were no significant differences between pre- and post-test control group learner performances, especially when it is shown within the control group class that the minimum mark of 25 % came from three post group learners yet they shared the highest of 55 %. On the other hand, the least mark of 5 % was a pre-test mark result which came from the experimental group whose highest was 30 %, and the modal mark was 25 %. The highest mark of 80 % was unsurprisingly obtained by the experimental group. That proved the worthiness of the study.

4.3.2.8 Hypothesis testing for learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise

Table 4.16 represents t-test results that emerged for the hypothesis stated.

Table 4.16: T-test paired samples statistics raw mark results for experimental and control groups (N=83)

Pair	Mean	Standard deviation	Correlation	Paired Differences				
				Mean	S.D.	t	df	Sig. (2-tailed)
Pre-test^E	6.79	1.105	0.913	– 5.179	0.451	– 71.654	38	0.000*
Post-test^E	11.97	1.013						
Pre-test^E	6.79	1.105	0.640	– 1.641	0.873	– 11.736	38	0.000*
Pre-test^C	8.44	0.502						
Post-test^E	11.97	1.013	0.858	1.821	0.644	17.663	38	0.000*
Post-test^C	10.15	0.489						
Pre-test^C	8.50	0.506	0.646	–1.750	0.438	–26.502	43	0.000*
Post-test^C	10.25	0.534						

Key: Post-test^E = post-test experimental group and Pre-test^C = pre-test control group.
*$p<0.05$

Table 4.16 shows t-test statistics for the tests that were marked out of 20 and tested at 5 % significance level. The experimental group mean differences in the pre-test and post-test was 5.79 compared to 0.646 control group's pre-test and post-test mean mark difference. Pre-test experimental mean of 6.79 was slightly below the overall control group mean of 8.50, indicating that the control group was fairly better in the pre-test. However, since $p<0.05$ in all cases, H_0 is rejected in acceptance of H_2. It was, therefore, evident that for all pair combinations, through the post-test, the impact of the VLDE intervention was strong against H_0 at 95% significance level, irrespective of whether it was within or across group pair assessment. The next section presents qualitative data for the next research question.

4.3.3 The extent to which VLDE influence the participants' change of attitude towards Physical Sciences

To address the third sub-research question, interviews were conducted and responses were themed and presented in the following sections. The following section presents themes from qualitative findings on learners' opinions on what can be done to improve learner performance in Physical Sciences and how VLDE influenced their change in attitude towards learning of Physical Sciences.

4.3.3.1 Physically do experiments

The issue of doing practical activities was the most dominant among all the other suggestions thought to improve learning attitude towards Physical Sciences. The following responses came from the majority of the respondents:

A: "*Allow learners to do experiments physically because that will help them to develop more interest for physical sciences* "(Respondent 1). B: "*Physical sciences must be brought into life experiments; experiments must be done to prove the laws"* (Respondent 2). C: "*Learners must get a chance to experiment on their own, whilst the teacher is watching them"* (Respondent 3). D: "*More practical activities should be done"*

(Respondents 5; 25; 26; 27). E "*Have a teacher who is willing to do practical on the topics"* (Respondent 6). F: "*Conduct practical science activities and teachers to explain concepts instead of just reading them out"* (Respondent 11). G: "*Science should be practical-oriented so that learners' interests maybe improved too"* (Respondent 16). H: "*We must practice Physical Sciences daily"* (Respondent 15). I: "*Practical should be conducted frequently"* (Respondents 17; 19). J: "*Learners to be allowed to fully participate during physical sciences lessons"* (Respondents 20; 21). K: "*Conduct experiments during physical science lessons instead of verbalising them"* (Respondent 28).

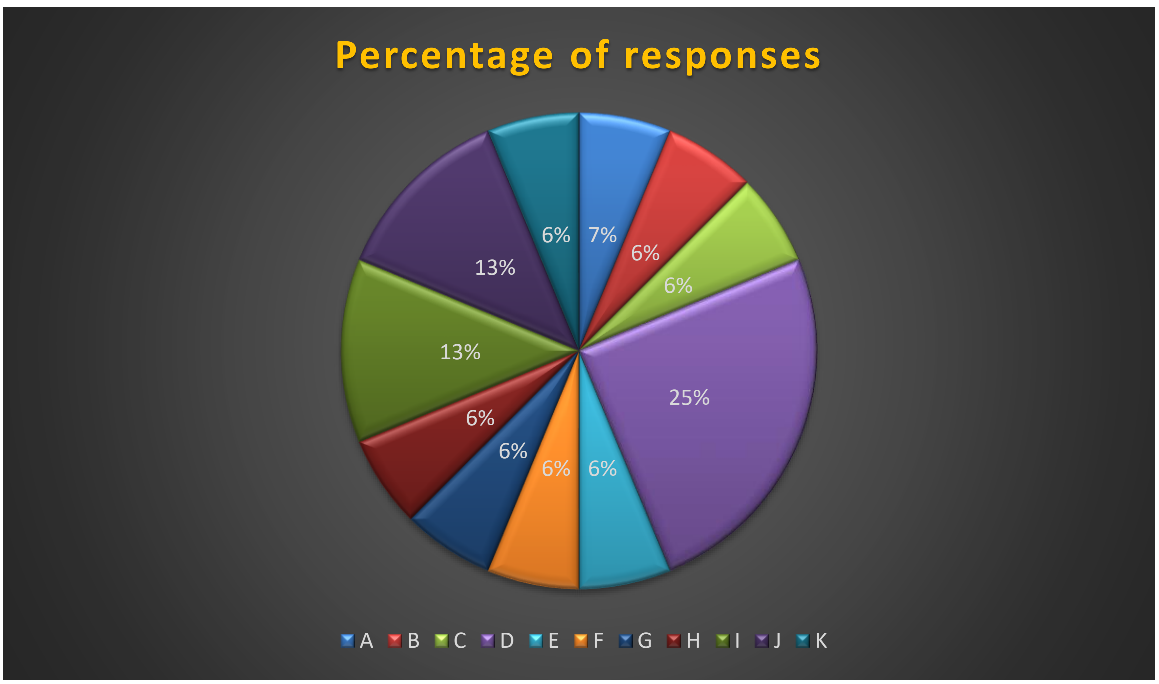


Figure 4.22: Percentage of learners' responses to doing experiments physically

Emerging from Figure 4.22, 25 % of the respondents advocated for more Physical Sciences experiments to be done during Physical Sciences classes. Other findings to take note of were learners' strong support for doing experiments frequently (13 %) and learners' active participation during Physical sciences experiments.

4.3.3.1.2 Encourage teamwork

Learners viewed working in teams and collaboratively as critical to improve attitude towards learning Physical Sciences. Some of them said:

"Teamwork should be improved. Group work should be fun and interesting" (Respondent 4). [We should] "*Be allowed to do tasks on our own or in groups* "(Respondent 12). "*Have study groups"* (Respondents 14; 35). It was clear that learners viewed working together as necessary in improving understanding of physical sciences.

4.3.3.1.3 Have extra classes

Interviews also revealed that learners were positive about the need for extra classes as they indicated that they should:

A: *"Have extra classes"* (Respondents 8; 12; 13). B: "*Practise every day and must attend extra lessons with different teachers"* (Respondent 9). C: "*Take extra lessons from other teachers and practise every day"* (Respondent 10). D: "*Introduce extra classes and workbooks for physical science learners"* (Respondent 18). E: "*Learners should be given extra physical sciences work"* (Respondent 22).

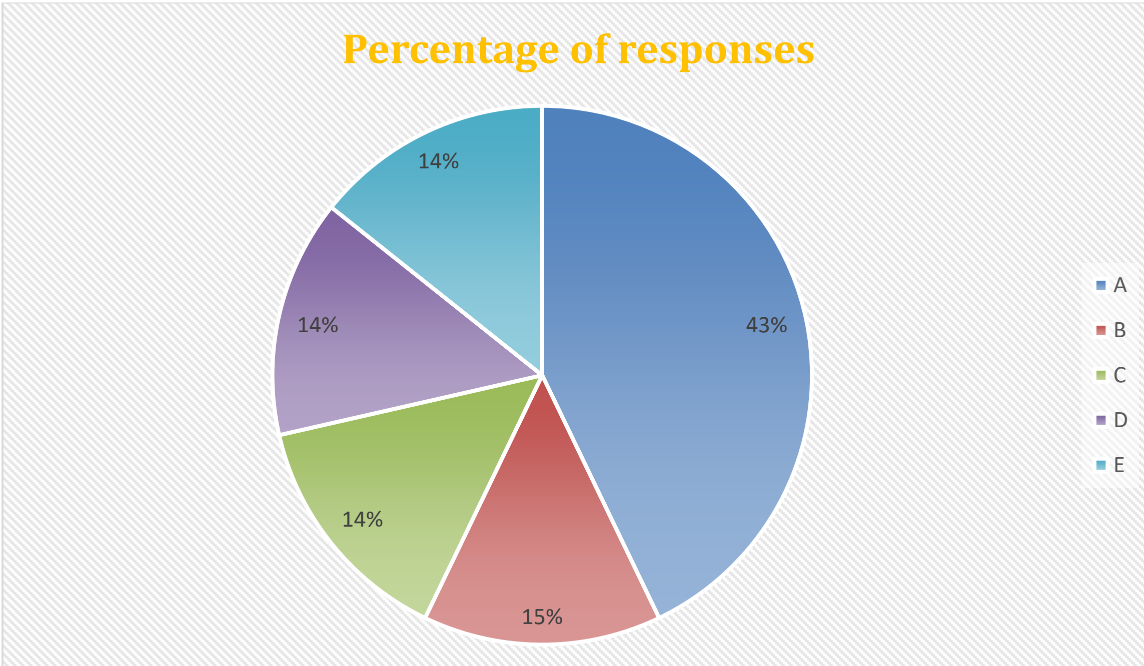


Figure 4.23: Percentage of learners' responses to extra Physical Sciences classes

Figure 4.23 show that 43 % of the respondents strongly felt that extra Physical Sciences classes would improve their performances in the subject, while 15 % were of the view that practising Physical Sciences daily and attending extra classes would improve their performance in the subject. Another 14 % 0f the respondents were of the view that their performance would improve if they are given homework every day. The remaining percentages also indicated that having extra classes with different teachers would help them improve in the subject (14 %) and having extra classes as well as workbooks would also help them improve (14 %).

4.3.3.1.4 Having knowledgeable teachers

Interviews showed that respondents were positive about being taught by knowledge teachers.

"Being taught by teachers whose approach is grounded on differentiated learning" (Respondent 13). "*Teachers should make notes for learners and allow learners to co*

conduct practical; Introduce weekly tests to assess learners' understanding" (Respondent 32). "*Teachers need to make follow up on tasks given to learners"* (Respondent 35). *"Teachers need to improve their support for learners doing Physical Sciences and check their work"* (Respondent 39).

From the responses above, there was a strong suggestion that if teachers improve their approaches to teaching Physical sciences, learners' performance would also improve. Some respondents were of the view that teachers needed to use approaches such as differentiated learning approach, while other learners strongly felt that frequent assessment and feedback would help them improve. Others advocated for teacher follow up and support.

4.3.3.1.5 Introduce Physical Science in Grade 8

Physical Science should be introduced in Grade 8 so that learners are familiar with some of the concepts. "*It should not be Natural Science"* (Respondent 31). Other participants decided not to respond.

4.3.3.1.6 Teach Physical science via the VLDE

Taking a cue from their experiences, most learners suggested that if there are challenges to providing physical laboratories in schools, then physical science should be taught through VLDE. They responded:

"VLDE practical activities helped us to develop scientific skills and develop knowledge" (Respondent 1). "*They helped us to consolidate what we do in theory"* (Respondent 2; 37). "*I developed scientific skills* "(Respondents 3; 34; 35). "*It helped me understand Physical science better* "(Respondents 4; 6; 9; 14). "*Doing experiments motivated us to like Physical Sciences"* (Respondents 5; 22). "*It improved our understanding of the science concepts"* (Respondents 8; 19; 24; 38). "*Every school should have a Virtual Laboratory so that learners get the opportunity to conduct experiments"* (Respondent 29). "*Experiments improved our marks during assessments"* (Respondent 15). "*It helped us improve our understanding"* (Respondents 21; 23).

The responses show that most participants strongly felt that VLDE helped them “develop scientific skills”, “improved their understanding of the science concepts” and “helped them understand Physical Sciences” as a subject.

4.3.3.1.7 Doing lots of problem-solving during learning Physical Sciences

Learners felt the need to do lots of Physical Sciences problem-solving during learning and argued that through this:

"You get to understand concepts better" (Respondents 2; 6) “*and improve your marks"* (Respondent 2). “*You get to know ways in which to answer similar questions"* (Respondent 3). “*I find relationships among questions and that boost my marks during examinations"* (Respondent 8). "*It will expose learners to as many questions as possible"* (Respondent 18). [It helps learners to be] “*Familiar with various questioning techniques"* (Respondent 19). “*I get familiar with the questions for examination purposes"* (Respondents 14; 20; 21; 26; 27; 34; 35). “*Train me on speed and familiarize myself with various questions"* (Respondent 29). “*This can boost my confidence during examinations"* (Respondent 38).

The respondents indicated that the majority suggested that by doing lots of problem solving during Physical Sciences classes, they familiarize themselves questions for examination purposes.

4.4 SUMMARY OF CHAPTER FOUR

This chapter presented in detail the findings of the study. It started by presenting quantitative results from the first two research questions and closed with qualitative results from the data for the third question. In each case, data were also analysed. The next chapter presents a discussion of findings, summary, recommendations and conclusion.

CHAPTER FIVE

DISCUSSION OF FINDINGS, SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.1 INTRODUCTION

In the previous chapter, the researcher presented and analysed the results. This chapter presents a discussion of the research study findings. It focuses on the evaluation of the relative impact of virtual laboratory delivery environments versus the Conventional Teacher Expository Method in the development of concepts, acquisition of Physical Sciences techniques and practical expertise and nurturing of positive attitudes towards physical sciences. The evaluation is based on results of learners' performance in the achievement test, science skills process test and their interview responses. This chapter will also present the summary of the study, recommendations and conclusion of the study.

5.2 DISCUSSION OF FINDINGS

The principal aim of this study was to determine the impact of a virtual laboratory delivery environment (VLDE) on grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland. This research aim guided the research design, implementation and data analysis of this study. Radical constructivism is a theory of learning that supports the notion that knowledge development is an adaptive process, resulting from the individual learner's interaction or experimentation with the world. In this study, individualized experimentation as a learning strategy to facilitate conceptual development and acquisition of science process skills was explored. Radical constructivism theoretical framework was found to be suitable for this study because it helped the researcher to answer the following sub-research questions:

i. What is the impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners?

ii. What is the impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise?

5.2.1 The impact of teaching Physical Sciences in Virtual Laboratory Delivery Environments to enhance scientific literacy among Grade 11 learners

In the first question, post-test results showed that 65.9 % from the control group compared to 76.9 % from the experimental group got the question correct. That meant a 0.5 % difference in favour of the control group was outweighed by a massive 11 % difference in favour of the experimental group in the post-test. This is consistent with Dadach (2013); Nadelson et al. (2015) and van de Heyde and Siebrits (2019) who opined that science is known to be a way of doing certain things by the observation of natural phenomena, quantifying the observed thing, integration of such quantities and interpretation of the results to make useful meaning out of the exercise.

Regarding responses on the actual yield of a chemical reaction, it emerged that in the pre-test, 68.2 % of the control group, compared to only 25.6 %, got the answer correct. After the intervention, 72.7 % of the control group learners compared to 82.1 % of the experimental group got the answer correct in the post-test. That was an increase of 4.5 % for the control group compared to 56.5 % for the experimental group. Consistently, Wicaksono et al. (2017) explicate that laboratory learning environments allow learners to interact physically and intellectually with instructional materials through hands-on experience and through minds-on and inquiry-oriented activities. Various laboratory environments afford learners the opportunity to develop and practice the process of science such as observation, experimentation, communication of thoughts, formulation of hypotheses and classification.

The finding is also consistent with the radical constructivism is a theory of learning that supports the notion that knowledge development is an adaptive process, resulting from the individual learner's interaction or experimentation with the world. To facilitate achievement and science process skills, learners should be allowed to create their own model (Von Glasersfeld, 1995) of variables, formulating hypothesis, designing experiments, and interpreting data during an experiment. Learners need to be exposed to an environment such as the virtual laboratory delivery environment in which they become active participants.

The finding that post-test results for the experimental group outweighed that of the control group showed the positive effects of exposing learners to the practical side of learning. This result is in conformity with the similar study by Garrett (2015) the study investigates the ways in which the unique perceptual-motor features of science laboratory environments can affect students" learning. The result was statistically significant, this indicated that the perceptual-motor features of science laboratory environments did indeed shape learners" understanding of the underlying science concepts. The significant differences observed could be attributed to the uniqueness and practical nature of VLDEs. Furthermore, this is in line with Hampden-Thompson and Bennett's (2013) view that quality practical experiments are designed on the premise that they promote the engagement and interest of learners as well as developing a range of skills, science knowledge and conceptual understanding. Learners benefit through engagement with concepts in practical work through, interactions, hands-on activities and application in science. However, the result of this study in contrast with the study of Sundra (2014). The results of the experiment indicated there was no significant difference in learning outcomes with VLDE instruction.

The study also found that either for individual question performances or learner performance in the pre-test and post-test, the experimental group did generally better than the control group. For instance, one scatter plot showed that the least mark in the test was 30 % and the highest was 80 %. The modal mark was 60 % when eight learners achieved 60 %. Thus, there was a notable improvement in experimental learner performance from zero in the pre-test to approximately 91 % in the post-test. Thus, technology-based theories such as anchored-instruction promoted by Griffin and Care (2015); Elliot and Joey (2018) work can be helpful when considering the use of multi-media environments. Research surrounding these theories has demonstrated that technology-mediated learning environments can present learners with complex, real-world problem-solving opportunities that can support and promote higher order thinking for knowledge construction and transfer. For example, Astutik and Prahani (2018) examining current learning models in learning sciences, systematically present how technology-mediated laboratories can promote learner learning and support conceptual change.

5.2.2 The impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise

In one question, there was a decrease in the control group getting the correct answer from 77.3 % to 72.7 %. On the other hand, there was more than slightly a 100 % increase in the experimental group getting the question correct from 46.2 % to 94.9 %. This could be attributed to active learning theory, which depends on studies by De Korver and Towns (2015); Bretz (2019) who emphasized the importance of learners' being active in the learning process, and Piaget, who perceives intelligence not only as characteristics at birth but also as a conclusion of the interaction between the individuals and their environments as well (De Korver and Towns, 2015; Bretz, 2019).

It also emerged using modal responses that in all the cases except a couple highlighted below, the majority of learners did not correctly get the answers both in the pre-test and in the post-test. However, the question, *"After dispensing a chemical from a container"* had the majority of the experimental group getting it correct in the two test phases unlike the control group. "*To remove solid chemicals from a bottle"* had the majority of the experimental group failing it in the pre-test. However, the majority from both groups got it correct in the post-test. As learning is a lifelong process and individuals need to learn, interpret or judge situations, they experience under various conditions, scientific process skills are very important for significant learning (Tatli and Ayas, 2013; Kumar, 2014). Scientific process skills are tools for learning science and understanding scientific studies while setting an essential goal of learning (Elliot and Joey, 2018).

Aggregate results showed that experimental pre-test marks were the lowest of the four sets of marks. There were no significant differences between pre- and post-test control group learner performances, especially when it was shown within the control group class that the minimum mark of 25 % came from three post group learners who obtained a highest of 55 %. On the other hand, the least mark of 5 % was a pre-test mark, which came from the experimental group whose highest was 30 % and the modal mark was 25 %. The highest mark of 80 % was, unsurprisingly, obtained by the experimental group in the post-test. That proved the worthiness of the study. Along these lines, Wicaksono et al. (2017) found that virtual laboratories in chemical engineering help learners to understand the fundamentals of unit operations and had other learning benefits. The authors note that it is also expected to contribute to increasing learners' adaptability by working in real world process plants after graduating.

5.2.3 The extent to which VLDE influence the participants' change of attitude towards Physical Sciences

Interviews were adopted to assess learners' attitude change towards Physical Sciences. Social cognitivist theoretical framework was found to be suitable for this study because it helped the researcher to answer the following sub-research question:

iii. To what extent does VLDE influence the participants' attitude change towards Physical Sciences?

It emerged from the study that the need to physically do experiments was the most dominant among all the other suggestions thought to improve learning attitude towards Physical Sciences. This is consistent with findings by Chan, Lai and Tsai (2014) who argued that in the laboratory with equipment learners do the experiments themselves and interact with each other. The purpose of "laboratory practices" is to enable learners to develop a high capability to observe when the experiments are conducted. The finding is in line with Social Cognitive Theory was first proposed by Bandura (1977) in that self-efficacy, learners' beliefs concerning their capabilities to accomplish academic-related tasks and activities.

Respondents also viewed team work and collaborative working as critical to positively change attitude towards learning Physical Sciences. Focus group interviews also revealed that learners were positive about the need for extra classes as they indicated that they should. This corroborates findings by Ojediran, Oludipe and Ehindero (2014) that laboratory work encourages learners to approach problems and solve them, find facts and new principles, develop ability to cooperate and develop critical attitude towards the subject.

It also emerged that teachers should have competent subject knowledge to, for example, understand and use differentiated teaching approach. Respondents further argued that Physical Science should be introduced in early grades, for instance, in Grade 8 so that learners are familiar with some of the concepts. This is line with the view that the idea of teaching the subject using inquiry-based practical work is new to the majority of Physical Sciences teachers (Palmero et al. 2016). According to Palmero et al. (2016), practical work is still regarded as one of the most challenging tasks for many science teachers, and is practiced infrequently or inefficiently in many science classrooms. This lies at the centre of the Social Cognitive Theory as it affects what we do and how we perceive the environment (Slavin, 2011).

The findings of this study are consistent with studies that discuss difficulties of teaching Physical Sciences without using inquiry-based practical work (Siew et al. 2014; Miller and Dumford, 2016). Miller (2014) reported that teachers themselves emerged from an education system that did not groom them to do experiments or practical work. Lecturers in pre-service training lacked knowledge and experience in conducting practical work. Schools were also found to lack equipment and laboratories (Bretz, 2019) and laboratory technicians to support teachers. Muwanga-Zake (2020) further established that even headmasters kept science equipment for display in their offices and never used them in the science classrooms. This further confirms that principals lack understanding of the purpose of practical work and its role in the CAPS science curriculum. According to the CAPS, learners are required to conduct experiments and submit written reports. Observations and written reports are assessed to determine the level at which the science process skills have been developed. Based on the notion of radical constructivism, learners were involved in individual experimental activities, after which their competence in conceptual knowledge and science process skills were measured to determine the effectiveness of the virtual laboratory delivery environment intervention in enhancing learner conceptual development and acquisition of science process skills.

Taking a cue from their experiences, most learners suggested that if there are challenges to providing physical laboratories in schools, then physical science should be taught through VLDE. This is consistent with the view that researchers and policymakers recommend that a modern learning environment should incorporate media and technology, including virtual experiences (Jatmiko et al., 2016). However, this environment must be characterized by understanding the relationship between tasks and resources, integration, establishing and maintaining good study habits, building confidence, including enrichment, annotation, tracking and feedback (Fadzil and Saat, 2017). It is further argued that Virtual Laboratories are quickly replacing hands-on laboratory activities as the norm for teaching and learning science in the high school setting (van de Heyde and Siebrits, 2019). Schwicho et al. (2016); Fadzil and Saat (2017) describe three main reasons for this shift. First, materials for hands-on laboratory activities are very expensive. Second, use of chemicals in the classroom could potentially lead to lawsuits if chemicals are not properly handled by either the teacher or student. Third, virtual labs can provide quality experience for learners, especially if the teacher lacks in-depth knowledge of the subject being taught. Furthermore, Kolloffel and Jong (2013) found virtual laboratories to be an easy and effective means to present the laboratory experience. Virtual laboratories provide the learners' learning environment as well as their laboratory environment and are located on a website that usually contains a main page with links to activities, achievements and laboratory evaluation.

It was found that learners felt the need to solve many Physical Sciences problems during learning and argued that there are many benefits that improve understanding and chances of passing. Some learners indicated the need for extra time to learn the subject. This is in line with Social Cognitive models of academic outcomes (Slavin, 2011) which propose that motivational constructs such as attitudes, interest and value beliefs are key factors that affect learners' self-efficacy and pursuit of Science, Technology, Engineering and Mathematics (STEM) courses and careers. Elliot and Joey (2016) indicate that many learners consider Physical Sciences as difficult, abstract and theoretical. Many learners find the subject boring and unenjoyable (Hirschfeld, 2012). Interest in senior secondary school Physical Sciences is decreasing, learning motivation is declining, and examination results are getting worse (Sunarti, et al., 2018). In many school settings, little time is allotted for the discipline compared to language and mathematics, the other important subjects (Tesfaye and White, 2012; Fadzil and Saat, 2017).

5.3 SUMMARY OF KEY FINDINDS

The main aim that guided the research design, implementation and data analysis of this study was "to determine the impact of a virtual laboratory delivery environment (VLDE) on grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland". The main research question of the study was:

"What is the impact of Virtual Laboratory Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences?" The active learning conceptual framework underpinned this study as it guided the research path used in delivering the virtual laboratory environment to Grade 11 learners. In addition, radical constructivism and social cognitive theoretical frameworks were found to be suitable for this study because they helped the researcher to answer the main and sub-research questions.

5.3.1 Theoretical Frameworks

Two theoretical frameworks identified and reviewed to guide the study were:

5.3.1.1 Radical Constructivism

Constructivist learning theory purports that knowledge is actively constructed by the learner through hands-on, active experience. However, these active experiences can be mediated through technology, offering an alternative to traditional hands-on methodologies. Technology-based theories such as anchored-instruction promoted by Griffin and Care (2015) work can be helpful when considering use of multi-media environments. Research surrounding these theories has demonstrated that technology-mediated learning environments can present learners with complex, real-world problem-solving opportunities that can support and promote higher order thinking for knowledge construction and transfer. Based on the notion of radical constructivism, learners were involved in individual experimental activities, after which their competence in conceptual knowledge and science process skills were measured to determine the effectiveness of the virtual laboratory delivery environment intervention in enhancing learner conceptual development and acquisition of science process skills. Conceptual understanding was one of the key focus areas in this study. The study revealed that on the question to assess what a balanced chemical equation allows one to determine, it emerged that pre-test results did not show much differences in learner performance for control and experimental group learners. Small differences in favour of the control group in the pre-tests were outweighed by large differences in favour of the experimental group in the post-test. To determine the meaning of the coefficient in a chemical equation, results indicated that pre-test results showed similarities in learner performances for both groups. In the post-test, on average, experimental group learners performed better.

When assessing the ratio of the actual yield to the theoretical yield multiplied by 100 %, the control group remained at the same level of 93.2 % on correctly choosing percent yield. On the other hand, there was an increase in getting the correct answer in the experimental group from 71.8 % in the pre-test to 89.7 % in the post-test. Throughout the study, it emerged that the VLDE intervention had a positive impact and sometimes massive positive effects on learner performance in the post-test, compared to the pre-test. For example, in one question, there was great difference between pre-test results as 63.6 % control group learners compared to only 10.3 % experimental group learners got the correct pre-test response. In the post-test control group, learners increased by 2.3 % to 65.9 %, with the experimental group increasing by more than 40% to 53.8 %.

Raw control group data based on aggregate individual test performances indicated that there were generally no significant differences in learner performance from pre-test to post-test. In the experimental group, there was a notable improvement in learner performance as the pass rate rose from zero in the pre-test to approximately 91 % in the post-test.

Relating to the impact of VLDE on Grade 11 learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise, the study revealed that:

- There was an improvement, especially in the experimental group of understanding laboratory skills required for safety. For example, there was a decrease in the control group getting the correct answer for the question asking 'when should goggles be worn' from 77.3 % to 72.7 %. On the other hand, there was more than slightly a 100 % increase in the experimental group getting the question correct from 46.2 % to 94.9 %.

- Respondents showed differences in understanding handling of chemicals with the experimental group getting it better than the control group.
- Regarding working with chemicals, the experimental group also edged the control group in a number of ways for the assessment given. Analysis of control and experimental pre-test and post-test achievement in skills confirmed an interesting picture regarding the impact of the intervention. While experimental pre-test marks were the lowest of the four sets of marks, the post-test marks told a different story, yet there were no significant differences between pre- and post-test control group learner performances. That proved the worth of the study.

5.3.1.2 Social Cognitive Theory of Learning

Recent Social Cognitive models of academic outcomes (Slavin, 2011) propose that motivational constructs such as attitudes, interest and value beliefs are key factors that affect learners' self-efficacy and pursuit of Science, Technology, Engineering and Mathematics (STEM) courses and careers. Social cognitive models posit that support from parent, peers and educators affects academic performance and career choices by influencing learners' self-perceptions and interests (Trivedi and Sharma, 2013). Relating to the extent to which VLDE influences participants' attitude change towards Physical Sciences, the study revealed that there was need for learners to physically do experiments; encourage team work; conduct extra classes; have knowledgeable teachers; introduce virtual laboratory delivery environments to not only the FET phase but to intermediate and senior phase learners, and do lots of problems during learning Physical Sciences.

5.4 SUMMARY OF THE STUDY

The aim of the current study was to investigate the impact of Virtual Laboratory Delivery Environment (VLDE) on Grade 11 learners' learning outcomes in Physical Sciences in two schools in OR Tambo Inland. The study differentially evaluated the impact of virtual laboratory delivery environments, an educational innovation, in terms of learners' academic achievement in science, their acquisition of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise when using the learning environment. The impact of such virtual laboratories was also explored in terms of the learners' attitudes towards Physical Sciences.

This study was first conceptualized based upon the researcher's anecdotal observation that the levels of achievement, acquisition of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise and interest of learners not normally engaged in Physical Sciences classes was piqued by the use of virtual laboratory delivery environments. Therefore, the researcher set out to test this initial observation methodically to determine if virtual laboratory delivery environments were indeed effective in increasing the identified outcomes among grade 11 learners.

The rationale for this study was based on a combination of improved standards in science education, particularly for the topic of Stoichiometry, and the lack of improvement in the resources necessary to enable learners to attain those higher standards. Virtual laboratory delivery environments represent a possible method to narrow the gap between lack of resources and higher standards in science education in that they allow learners to experience laboratory environments and experiments that would not otherwise be possible in a high school classroom but with which learners are required to be familiar. Furthermore, the role of learners' attitudes towards science was explored by defining the term 'attitude', explaining the assessment of attitudes, and reviewing the effect of various educational interventions on students' attitudes. Attitudes constituted another criterion of effectiveness for virtual laboratories.

In the current study, concepts on virtual laboratories were addressed within the context of dynamic educational technology. Virtual laboratories were defined as electronic workspaces that are based on interactive simulations of scientific experiments. Benefits included the increased emphasis on conceptual understanding and reduced reliance on constraints, such as time, safety hazards, geographic distance, and cost. While technological interventions in the classroom were predicted to be more useful than studies have shown they were not generally detrimental to learners' learning and they were therefore considered to be effective alternatives for certain educational experiences.

Chapter two presented literature on the role of Active Learning Strategies in science education, practical work, wet laboratories, alternative laboratory delivery methods, virtual laboratories, potentials and impact of virtual laboratories in Physical Sciences education, strengths and weakness of virtual laboratories in science education, best practices for virtual science laboratories and Virtual ChemLab application, all in line with research objectives.

The study was prompted by the emphasis on the promotion of learners' conceptual understanding, acquisition of learners' proficiency in the acquisition of Physical Sciences techniques and practical expertise and nurturing of positive attitudes towards Physical Sciences through but not limited to the prescribed and recommended experiments in the Curriculum and Assessment Policy Statement (CAPS) document. The experimental group (EG) of leaners conducted experiments using the Virtual Laboratory Delivery Environment (VLDE) and the control group (CG) of learners used the traditional instruction of the Conventional Teacher Expository Method (CTEM). Through SPSS, the EG and CG were differentially compared to find out if there were statistical significant differences in the identified outcomes. In addition, the study explored if conducting experiments through virtual laboratory delivery environment could nurture positive attitudes towards Physical Sciences among Grade 11 learners.

A mixed research approach was used in this study. Quasi-experimental non-equivalent and case study research designs were adopted to collect data from two senior secondary schools and involved 83 learners. Purposive sampling was adopted to select the two senior secondary schools in the OR Tambo Inland. This ensured that the sampling frame comprised schools from the same geographic setting and learner composition, with enrolments of between thirty and forty-five learners in Grade 11 Physical Sciences classes. The instruments used to collect data were Physical Sciences Achievement Test on Conceptual Understanding (PSATCU), Physical Sciences Practical Achievement Test (PSPAT), and Interview Schedule on Attitudes towards Learning of Physical Sciences (ISALPS). The PSATCU and PSPAT were used in conjunction with the SPSS for statistical values during the pre and post-tests. The interview schedule on the other hand was used after the intervention to the EG. The statistical scores in the pre and post-tests for the experimental group and control group were compared to determine the statistical significances between the two groups. Interview responses were used qualitatively to assess the experimental group's attitudes towards Physical Sciences.

Quantitative results revealed that:

- Test comparisons between control and experimental groups revealed that across all questions, it was generally evident that control group outclassed experimental group in the pre-test.
- On average, however, there was a significant reverse trend of a wider margin in the post-test outcomes for generally all questions whereby experimental group outperformed control group.
- There was a positive impact of VLDE on learning outcomes for the experimental group, as evident in Physical Sciences post-test.
- There was also a marked positive impact on learner performances in Laboratory Skills test as experimental group performed much better as compared to the control group.

The views and opinions of learners from the experimental group provided qualitative data for the third research question, which explored the extent to which VLDE influence the participants' attitude change towards Physical Sciences. Results collected and analysed qualitatively revealed that the experimental group was of the view that utilising virtual laboratory delivery environments experiences can be effective to help change and promote positive attitude towards Physical Sciences among high schools' learners.

5.5 CONCLUSSION THE STUDY

With reference to the main research question investigated in this study, it was concluded that integration and learner cohesiveness dimensions of Virtual Laboratory Delivery Environments could be relied upon. It appeared that the virtual laboratory environments could be relied on in enhancing learners' academic achievement, proficiency in the acquisition of techniques and practical expertise and nurturing positive attitude in Physical Sciences. Thus from the study it could be concluded that, the main research question and subsidiary questions were answered. Also the aim and the objectives of the study were explored and achieved.

5.6 RECOMMENDATIONS

The Curriculum and Assessment Policy Statement (CAPS) advocates for the development of scientific literacy, which includes conceptual understanding, acquisition and nurturing of positive attitudes in the General (GET) and Further Education Training (FET) bands in natural sciences subjects in South African schools. Based on the findings of this study and in line with this advocacy, these recommendations are advanced:

5.6.1 Recommendations for practice:

The following recommendations for practice were as folows

5.6.1.1 Adoption of the Virtual Laboratory Delivery Environments

i. It is recommended that Physical Science learners should be exposed to VLDE to promote and encourage social interaction, active learning, motivation, learning by doing and learning by experience.

ii. Virtual laboratory should be used to complement physical laboratory as a mutually beneficial interface between both (laboratories) could impact positively on the learners.

iii. The use of the package will enhance the achievement of learners in science irrespective of their gender.

v. Curriculum developers should embrace and include VLDE in order to bring about improvement in learning, acquisition of critical thinking, social interaction, problem solving and performance skills in students.

5.6.1.2 To implement the use of Virtual Laboratory Delivery Environments in stages.

i. The concepts and principles of Virtual Laboratory Delivery Environments, which are not yet in practice in South Africa, should be adopted. This is to allow effective measurement of both the teachers and learners' performance as a strategy to improve teaching and learning of sciences subjects in South Africa.

ii. The implementation of advanced technology across an entire enterprise with no additional technical support can be a challenge. In order to ensure that the Virtual Laboratory Delivery Environments are implemented successfully, a narrow focus is recommended. Focusing implementation efforts narrowly will allow the DBE to concentrate on the resources necessary to support a successful implementation. The researcher recommends starting with grade 10 to 12 curricula because learners require less teacher support than lower grades. This would allow laboratory work to be the focus, rather than how to use a computer. As soon as learners are confident in the implementation's success, additional grade level curricula may be considered to include Virtual Science Laboratory Delivery Environments.

iii. The adoption of the concept of the Virtual Laboratory Delivery Environments will require sensitization in the form of workshops, seminars and training of various stakeholders in the educational system. As laboratory work is a unique teaching strategy in South Africa, Science teachers should be provided with training. To achieve this, the Department of Basic Education and other educational agencies such as NGOs, UNICET, UNESCO and other education stakeholders should organize workshops on the use of laboratory to enhance better performance of learners.

iv. Virtual Laboratory Delivery Environments should be used to determine the actual situation of the Physical Sciences Virtual Laboratory Delivery Environments. This would enable the Physical Sciences teachers to know what particular environment variables need improvement. This could facilitate improvement in the Physical Sciences laboratory lessons.

v. Emerging from the findings of this study, the researcher recommends that the government and other stakeholders in the education system make positive improvement on the Virtual Laboratory Delivery Environments of learners and motivate teachers who are curriculum implementers, it is most likely that learners' performance in Physical Sciences will be highly enhanced.

vi. The researcher recommends that Virtual Laboratory Delivery Environments should be used to determine the actual situation of the Virtual Laboratory Delivery Environments. This would enable Physical Science teachers to know particular environment variable(s) that would enhance teaching and learning of the subject.

5.6.1.3 To develop Virtual Laboratory Delivery Environments that are in-line with the current National Curriculum Statement.

For Software developers to apply their minds to the Virtual Laboratory Delivery Environments concept and develop software that is in line with the South African Science Curriculum. This software should be compatible with Personal Computer (PCs) tablets and android cell phones. This will allow learners to engage in practical activities in and out of the school (anytime and anywhere). Incorporate free, quality virtual laboratory located on the internet into the current science national curriculum statement. The DBE should take success factors for course quality, student services/technology infrastructure, and training into consideration when choosing online virtual laboratory sites.

Quality: There are a large number of virtual science laboratory available on the internet, both for free and for a charge. The quality of laboratories was of high importance in the review process. The researcher validated that the virtual laboratory met the current educational standards as set forth by Quality Assurance Bodies as Umalusi, National Research Council and the Partnership for 4^{th} Industrial Revolution (4IR) Skills.

Training: Training to support the educators and learners is another success factor for the implementation. The researcher assessed some of the recommended virtual laboratories for the amount and type of educator training available. This recommendation also suggests frequent meetings to monitor progress.

Because of the size and intimate nature of the learners doing Physical Sciences, Virtual Laboratory Delivery Environments should have little trouble with communication during the implementation; however, regularly scheduled meetings, as part of a formal process, will ensure that communication is not overlooked. Formal communication is necessary in any implementation plan to discuss successes and failures along the way. Issues must be addressed immediately to develop changes in strategy and keep the program moving forward.

5.6.1.3 To market the implementation of the virtual laboratories in schools.

Marketing the program is also noted as a success factor. The Virtual Laboratory Delivery Environment Onsite Administrator should choose at least two school events where the educators can showcase successes, demonstrating to parents, teachers, and other administrators how much richer and valuable the children’s learning experiences are at the Virtual Laboratory Delivery Environments. Parental support in program advance is always welcomed when it comes to budget discussions, raising funds for future enhancements, and increasing overall enrolment. Showcasing the program’s success to the other teachers can inspire other implementation efforts going forward.

5.6.2 Recommendations for further research

This research forms a baseline for future research. Review of related literature and findings of this study indicated that the Virtual Laboratory Delivery Environment exerts a great influence on learners’ academic performance, acquisition of techniques and practical expertise and their attitudes towards Physical Sciences. The findings of this study also revealed that the Virtual Laboratory Delivery Environment is a significant factor in determining learners’ achievements, acquisition of techniques and practical expertise and nurturing positive attitude in Physical Sciences. Consequently, a desirable direction for future research in the Virtual Laboratory Delivery Environment would be to:

i. determine the relationship between learning environments and learners’ learning outcomes at the secondary school level in science subjects. Further research can be done using a larger sample of schools and participants. The different activities enhanced by the Virtual Laboratory Delivery Environments during teaching and learning, for example, lesson delivery, manipulation of apparatus during experiments, discipline of learners and assessment of learners to enhance quality have not been addressed in full. Therefore, it is suggested that further research should entail in-depth practical work observations to reveal if Virtual Laboratory Delivery Environments influence positively learners' learning outcomes in Physical Sciences.

ii. to investigate teachers' and learners' perceptions on their actual and preferred Virtual Laboratory Delivery Environment since it will make a positive contribution to the academic performance and development of positive attitude toward the learning of Physical Sciences.

iii. Establish financial resources and planning as a success factor for implementation of the Virtual Laboratory Delivery Environments. Financial constraint makes it challenging but not impossible to locate resources. To grow the program, the Virtual Laboratory Delivery Environments administrator should look to include additional monitors and computers for the virtual laboratory in each classroom in upcoming budgets. It will not take long for teachers to locate additional internet resources to add to the program, so software costs should be added to the budget over time.

REFERENCES

Abdulwahed, M., and Nagy, Z. K., 2011. The trilab, a novel ict-based triple access mode laboratory education model. Computer & Education, 56, pp. 262-274.

Abdulwahed, M. and Nagy, Z.K., 2013. Developing the TriLab, a triple access mode (hands-on, virtual, remote) laboratory, of a process control rig using LabVIEW and Joomla. *Computer Applications in Engineering Education*, 21(4), pp.614-626.

Adom, D., Hussein, E.K. and Agyem, J.A., 2018. Theoretical and Conceptual Framework: Mandatory Ingredients of a Quality Research. [pdf] Available at:< http://www.researchdate.net/publication/32220458.pdf> [Accessed October 20, 2019].

Agustian, H. Y., and Seery, M. K., 2017. Reasserting the role of pre-laboratory activities in chemistry education: A proposed framework for their design. Chemistry Education Research and Practice, 18, pp. 518-532.

Akpan, U.O., 2012. Learning environment as correlates of chemistry students' achievement in secondary schools in Akwa Ibom State of Nigeria. African research review. *An international multidisciplinary journal, Ethiopia*, 6(3), pp. 208-217.

Alameh, S.K., 2013. *The impact of using computers as cognitive tools on grade 10 Lebanese students' attitudes and conceptual understanding in physics*. Unpublished Master's thesis. American university of Beirut. Lebanon: Beirut.

Alammary, A., Sheard, J. and Carbone, A., 2014. Blended learning in higher education: Three different design approaches. *Australasian Journal of Educational Technology*, 30(4), pp.440-454.

Alkan, F., 2016. Experiential Learning: Its Effects on Achievement and Scientific Process Skills Journal of Turkish Science Education [online] 13(2), pp.15-26 Available at<http://www.tused.org> [Retrieved June 3, 2018].

Aliyu, F. and Talib, C.A., 2019. Virtual Chemistry Laboratory: A Panacea to Problems of Conducting Chemistry Practical at Science Secondary Schools in Nigeria*. International Journal of Engineering and Advanced Technology (IJEAT*), 8(5C), pp.544-549.

Alvi, M.H., 2016. A Manual for Selecting SamplingTechniques in Research. MPRA: 01 UT. Available at>https://mpra.ub.unimuenchen.de/70218/>[Accessed 29 November 2019].

American Chemical Society. 2011. Importance of hands-on laboratory activities. American Chemical Society Public Policy Statement. [pdf] Available at: < https://www.acs.org/content/dam/acsorg/policy/publicpolicies/invest/computersimulations/hands-on-science.pdf> [Retrieved June 16, 2019].

Amin, A. and Hafiz, M., 2012. Virtual Laboratory experiments of Physics and Chemistry and its impact on the development of the Observation for the Intermediate school learners and their Academic Achievement. *Journal of International educational specialized,* 1(8), pp.459-478.

Anderson, L. W., and Krathwohl, D., 2018. A taxonomy for learning, teaching, and assessing. New York: Longman.

Arabacioglu, S. and Unver, A.O., 2016. Supporting inquiry based laboratory practices with mobile learning to enhance students' process skills in science education. *Journal of Baltic Science Education*, 15(2), pp.216-230.

Arends, F., Reddy, V., Prinsloo, C., Visser, M., Winnaar, L., Feza, N., Rogers, S., Janse van Rensburg, D., Juan, A., Mthethwa, M., Ngema, M. and Maja, M., 2012. Highlights from TIMMS 2011: The South African perspective. Cape Town: Human Science Research Council.

Arif, M., Ameen, K., 2011. Library Electronic Resources' Use–Students Attitude: Technology Acceptance Model. *Pakistan Library and Information Science Journal,* 42(2), pp.3-12.

Astutik, S., and Prahani, B. K., 2018. The Practicality and Effectiveness of Collaborative Creativity Learning (CCL) Model by Using PhET Simulation to Increase Students' Scientific Creativity. *International Journal of Instruction*, 11(4), pp.409-424.

Ay, Ö. S., and Yilmaz, S., 2015. Effects of Virtual Experiments Oriented Science Instruction on Students' Achievement and Attitude. *Elementary Education Online*, 14, pp. 609-620

Babateen, H.M., 2011. The role of Virtual Laboratories in Science Education*.* In: *International Conference on Distance Learning and Education IPCSIT*, 12(8), pp.100-104, Singapore: IACSIT Press.

Babbie, E. and Mouton, J., 2014. The practice of social research. Cape Town: Wadsworth.

Baeten, M., Dochy, F. and Struyven, K., 2013. The effects of different learning environments on students' motivation for learning and their achievement*. British Journal of Educational Psychology,* 8(3), pp.484–501.

Baird, A. C., 2012. *Teacher shortage areas: Nationwide listing 1990-1991 through 2012-2013*. Washington, DC: US Department of Education.

Balce, M.E., 2010. Teaching quality science education in Filipino. Presentation at the *First Philippine Conference-Workshop on Mother Tongue-based Multilingual Education*. Capitol University, Philippines.

Bandura, A., 1977. Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review*, 84 (2), pp.191-215.

Bandura, A., 1997. *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Bandura, A., 2001. Social cognitive theory: An argentic perspective. *Annual Review of Psychology*, 52(1), pp.1-26.

Bandura, A., Barbaranelli, C., Caprara, G.V. and Pastorelli, C., 2001. Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development*, 72(1), pp.187-206.

Barnes, B., 2011. *Teacher perception and understandings of diversity and Inclusive Education.* Unpublished MEd Dissertation. Cape Town, University of Stellenbosch, RSA.

Barth, J.M., Todd, B., McCallum, D.M., Goldston, M., Guadagno, R.E., Roskos, B. and Burkhalter, C., 2011. Effects of Engaging Classroom Strategies and Teacher support on Student Outcomes Over School Transitions. *Proceedings of the American Society for Engineering Education*, 2011.

Bell, J., 2012. *Doing your research project: A guide for first-time researchers in education, health and Social Sciences. Fifth Edition*. New York: McGraw-Hill.

Bellanca, J. A., 2011. 21st-century skills: Rethinking how students learn. Indiana: Solution Tree Press.

Benner, S., 2011. What Scientists do The BIOLOGOS? [online] Available athttp://biologus.org online> [Retrieved May 26, 2017].

Bennett, J., Hogarth, S., Lubben, F., Campbell, B. and Robinson, A., 2009. Talking science: The research evidence on the use of small group discussions in science. *International Journal of Science education*, 32(1), pp.69-95.

Bigelow, M., 2012. From cookbook to inquiry. [online] Available at:< http://nstacommunities. org/blog /2012/06/ 24/from-cookbook-to-inquiry online> [Retrieved May 27, 2018].

Bigelow, M., 2012. From cookbook to inquiry. [online] Available at:< http://nstacommunities. org/blog /2012/06/ 24/from-cookbook-to-inquiry online> [Retrieved May 27, 2018].

Blaikie, N., 2018. Designing Social Research. Cambridge, England: Polity Press.

Bloom, B.S.; Engelhard, M.D.; Furst, E.J.; Hill, W.H. and Krathwohl, D.R., 1956. Taxonomy of education objectives: Handbook I, Cognitive Domain. New York: McKay.

Bose, R., 2013. Virtual Labs Project: A Paradigm Shift in Internet-Based Remote Experimentation. IEEE. 1 [pdf] Available at:< http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6637004.pdf> [Retrieved July 12, 2018].

Bretz, S. L., 2019. Evidence for the importance of laboratory courses. *Journal of Chemical Education,* 96(2), pp.193-195.

Bretz, S.L., Fay, M., Bruck L.B. and Towns M.H., 2013. What Faculty Interviews Reveal about Meaningful Learning in the Undergraduate Chemistry Laboratory. *Journal of. Chemical. Education*., 90(3), pp. 281–288.

Bruner, J.S., 1971. The relevance of Education. New York: Norton. In Mwamwenda, S. T. (2004). Education Psychology. African Perspective, Third edition, Heinemann.

Bulent, A., Mehment, E., and Nuran, E., 2014. The investigation of science process skills of elementary school teachers in terms of some variables: Perspectives from Turkey. *Asia-Pacific Forum on Science Learning and Teaching*, 15(1), pp.1-12.

Buthelezi, N., 2012. Inside efforts to turn the tide on South Africa's poor maths and science performance. Creamer Media's Engineering News. [online] Available at< http://www. engineeringnews.co.za online> [Retrieved February 23, 2018].

Campbell, H., 2012. Why science test scores being 'stagnant' is a good thing. [online] Available at: <http://www.science20.com/science_20/why_science_test_scores_being_stagnant_good_thing-90396 online> [Retrieved May 24, 2018].

Carnoy, M. and Arends, F., 2012. Explaining mathematics achievement gains in Botswana and South Africa*. Prospects*, 42(4), pp.453.

Centre for Educational Research and Development (CERD). 2015. New Lebanese educational ladder. Lebanon, Beirut: CERD.

Chang, M.Y., and Davis, A.S., 2011. *Achievement Testing. In: Goldstein S., Naglieri J. (eds) Encyclopedia of child behavior and development*. New York: Springer.

Chen, S., Chang, W.H., Lai, C.H. and Tsai, C.Y., 2014. A Comparison of Students' Approaches to Inquiry, Conceptual Learning, and Attitudes in Simulation-Based and Microcomputer-Based Laboratories*. Science Education*, 98(5), pp.905–935.

Clark, A., 2014. What we can learn from performance data: Lecture given at the University of the Free State. 3(5), pp.1-103.

Coe, R., Waring, M., Hedges, L.V. and Arthur, J., 2017. *Research methods and methodologies in education. 2nd ed*. London: SAGE.

Cohen, L., Manion, L. and Morrison, K., 2011. Research Methods in Education. 6th ed. New York: Routledge Taylor and Francis.

Collins *English Dictionary - Complete and Unabridged*. 2012. Digital Edition © William Collins Sons and Co. Ltd.

Comte, A., 1856. A general view of positivism. London: Smith Elder & Co.

Creswell, J. W., 2012. Educational research: Planning, conducting, and evaluating quantitative and qualitative research. Upper Saddle River: Pearson.

Creswell, J.W., 2013. Qualitative Inquiry and Research Design: Choosing among Five Approaches. 3rd edition, Thousand Oaks, CA: SAGE.

Creswell, J. W., 2014. Qualitative Inquiry and Research Design: Choosing among the Five Approaches. 4th Edition. Los Angeles: Sage.

Creswell, J.W. and Plano Clark, V.L., 2011. *Designing and Conducting Mixed Methods Research. 2nd ed.* Los Angeles: SAGE.

Creswell, J. W. and Poth, C.N., 2018. Qualitative Inquiry and Research Design: Choosing Among Five Approaches. 4th Ed. New Delhi: SAGE.

Dadach, Z.E., 2013. Quantifying the Effects of an Active Learning Strategy on the Motivation of Students. *International Journal of Engineering Education*, 29(4), pp. 904–913.

Darrah, M., Humbert, R., Finstein, J., Simon, M., and Hopkins, J., 2014. Are virtual labs as effective as hands-on labs for undergraduate physics? A comparative study at two major universities. *Journal of Science Education and Technology*, 23 (6), pp.803-814.

Department of Basic Education (DBE). 2012. *Curriculum News: Improving the quality of learning and teaching. Strengthening Curriculum implementation from 2010 and beyond*. Pretoria: Government Printers.

Department of Basic Education (DBE). 2012. *Curriculum and Assessment Policy Statement Grade 10-12*. Pretoria: Government Printers.

Department of Basic Education (DBE). 2015. *National Diagnostic Report*. Pretoria: Department of Basic Education.

Department of Basic Education (DBE). 2015. Curriculum and Assessment Policy Statement Grade 10-12. Pritoria: Government Printing Works.

Department of Basic Education (DBE). 2018. *National Diagnostic Report*. Pretoria: Government Printers.

DeKorver, B. K., and Towns, M. H., 2015. General chemistry students' goals for chemistry laboratory coursework. Journal of Chemical Education, 92(12), pp.2031-2037.

DeKorver, B. K., and Towns, M. H., 2016. Upper-level undergraduate chemistry students' goals for their laboratory coursework. *Journal of research in science teaching*, 53(8), pp.1198-1215.

Dhurumraj, T., 2013. *Contributory Factors to Poor Learner Performance in Physical Sciences in KwaZulu-Natal Province with Special Reference to Schools in the Pinetown District.* M.ED dissertation. Pretoria, University of South Africa, RSA.

Donnelly, D., O'Reilly, J., and McGarr, O., 2013. Enhancing the student experiment experience: Visible scientific inquiry through a virtual chemistry laboratory Research in Science Education, 43, pp. 1571-1592.

Elliot, H.A. and Joey, J.L., 2018. Virtual reality in education: a tool for learning in the experience age. *International Journal of Innovation in Education* 4(4), pp.216-226.

Erdmann, M., Fischer, R., Glaser, C., Klingebiel, D., Krause, R., Kuempel, D., Muller, G., Rieger, Steggemann, M.J., Urban, M., Walz, D., Weidenhaupt, K., Winchen,T., and Weltermann, B., 2014. A field study of data analysis exercises in a bachelor physics course using the internet platform VISPA. *European Journal of Physics*, 35 (2014), pp.1-14.

Fadzil, H.M. and Saat, R.M., 2014. Enhancing STEM education during school transition: Bridging the gap in science manipulative skills*. Eurasia Journal of Mathematics, Science and Technology Education*, 10(3), pp.209-218.

Fadzil, H.M. and Saat, R.M., 2017. Exploring students' acquisition of manipulative skills during science practical work*. Eurasia Journal of Mathematics, Science and Technology Education*, 13(8), pp.4591-4607.

Falode, O. C., 2014. A BATES" ACTIONS" evaluation of virtual physics laboratory package for senior secondary school students in Nigeria. Unpublished PhD Thesis. Department of Educational Technology, University of Ilorin, Nigeria.

Falode, O. C., Usman, H. Sobowale, F. M., Folarin, M. E and Saliu R. M., 2015. Effect of Computer Simulation Instructional Package On Secondary School Geography Students" Achievement in Map Reading in Bida, Niger State, Nigeria. 3rd annual international conference of school of science and technology education, federal university of technology minnaPp.73-80.

Faour, M.A. and Ayoubi, Z., 2018. The effect of using virtual laboratory on grade 10 students' conceptual understanding and their attitudes towards physics*. Journal of Education in Science, Environment and Health (JESEH)*, 4(1), pp.54-68.

Fernández-Avilés, D., Dotor, D., Contreras, D. and Salazar, J.C., 2016. Virtual labs: A new tool in the education: Experience of Technical University of Madrid. In 2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV) [online] Available at< https://doi.org/10.1109/REV.2016.7444480 online>[Retrieved October 31, 2017].

Finstein, J., Darrah, M., and Humbert, R., 2013. Do students in general high school physics classes learn as much from virtual labs as from hands-on labs? National Teacher Education Journal, 6 (3), pp.61-70.

Fraser, B.J., 2012. Classroom learning environments: Retrospect, context and prospect. In B. J. Fraser, K. Tobin and C. McRobbie (Eds.), Second international handbook of science education. New York: Springer Verlag.

Fung, F. M., 2015. Using first-person perspective filming techniques for a chemistry laboratory demonstration to facilitate a flipped pre-lab. Journal of Chemical Education, 92, pp. 1518-1521.

Galloway, K.R., Malakpa, Z and Bretz, S.L., 2016. Journal of Chemistry. Education, 93(7), pp.227–238.

Garret, W. S., 2015. Combining physical and virtual laboratories: effects of perceptional features of science laboratory environment on learning conceptions. Thd Thesis, 1.

George-Williams, S. R., Ziebell, A. L., Kitson, R. R., Coppo, P., Thompson, C. D., and Overton, T. L., 2018. 'What do you think the aims of doing a practical chemistry course are?'a comparison of the views of students and teaching staff across three universities. Chemistry Education Research and Practice, 19(2), pp. 463-473.

Gilbert, J.K. and Justi, R., 2016. *Modelling-based Teaching in Science Education*. Cham, Switzerland: Springer International Publishing.

Gilmour, D., 2013. The State of School on System performance in South Africa. *Lecture given at University of the Free State*, 20(13), pp.1-48.

Goduka, N., 2012. From positivism to indigenous science: a reflection on world view, paradigms and philosophical assumptions. Africa Insight, 41(4), pp.123–138.

Government of Kenya (GOK). 2007. Kenya vision 2030. Nairobi: Government press.

Grant, C. and Osanloo, A., 2014. Understanding Selecting, and Integrating a Theoretical Framework in Dissertation Research: Creating the Blueprint for 'House'. Administrative Issues Journal: Collecting Education, Practice and Research, 9(3), pp.12-22.

Gregory, S.J., and Di Trapani, G., 2012. A blended learning approach to laboratory preparation. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International)*, 20(1).

Griffin, P. and Care, E., 2015. Assessment and teaching of 21st century skills: Methods and approach. New York: Springer.

Gryczka, P., Klementowicz, E., Sharrock, C., Maxfield, M., and Montclare, J. K., 2016. Lablessons: Effects of electronic prelabs on student engagement and performance. *Journal of Chemical Education*, 93(12), pp. 2012-2017.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P. and Valtonen, T., 2017. Preparing teacher-students for twenty-first-century learning practices (PREP 21): a framework for enhancing collaborative problem-solving and strategic learning skills. Teachers and Teaching: Theory and Practice, 23 (1), pp.25-41.

Hammersley, M., 2018. Methodological paradigms in educational research. [online] Available at:< http://www.tlrp.org/capacity/rm/wt/hammersley/hammersley4.html. online> [Retrieved October 1, 2019].

Hammersley, M., 2018. What is Qualitative Research? London and New York: Bloomsburry.

Hampden-Thompson, G. and Bennet, J., 2013. Science Teaching and Learning Activities and Students' Engagement in Science. *International Journal of Science Education*, 35(8), pp.1325-1343.

Harry, I.H., 2011. Attitudes of students towards science and science education in Nigeria. (A case study in selected secondary schools in Obio/Akpor Local Government Area of Rivers State). *Continental Journal of Education Research*, 4(2), pp.33-51.

Hearn, S. and Buffardi, A.L., 2016. What is impact? A Methods Lab Publication. London: Overseas Development Institute. [online] Available at: < http://www.esrc.ac.uk/research/evaluation-and-impact/what-is-impact. online> [Retrieved January 9, 2017].

Hirschfeld D., 2012. *Interest in science careers wanes in Latin America: Science and Development Network*. USA: SAGE.

Hofstein, A., and Mamlok-Naaman, R., 2013. The laboratory in science education: the state of the art. Chemistry Education Research and Practice, 8(2), pp. 105-107.

Hofstein, A. and Kind P.M., 2012. Learning in and from Science Laboratories. In: Fraser B., Tobin K., McRobbie C. (eds) Second International Handbook of Science Education. Springer International Handbooks of Education, vol 24. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9041-7_15

Jansen, J.D., 2011. University of the Free State Schools Partnership Program. *Executive Summary,* 3(6), pp.1–17.

Jatmiko, B., Widodo, W., Martini, Budiyanto, M., Wicaksono, I., and Pandiangan, P., 2016. Effectiveness of the INQF-based learning on a general physics for improving student's learning outcomes. *Journal of Baltic Science Education*, 15(4), pp.441-451.

Jeschofnig, L. and Jeschofnig, P., 2011. *Teaching lab science courses online: Resources for best practices, tools, and technology*; John Wiley and Sons, Inc: Hoboken.

John, M., 2014. *Evaluation of the Effectiveness of an Optics Teaching Module in Enhancing Conceptual Understanding of Grade 11 Learners at a Selected School in Mthatha.* Doctor of Education (Science Education). Mthatha, Walter Sisulu University, RSA.

Johnson, L., 2012. Virtual and remote laboratories. [online] Available at:< http://k12.wiki.nmc.org/Virtual+and+Remote+Laboratories. online> [Retrieved February 8, 2018].

Johnson. S., 2014. Advantages and Disadvantages of Positivism. eHow. Retrieved from http://www.ehow.com/info_12088541_advantages-disadvantages-positivism.html.

Johnson, R., and Burke, L., 2017. Dialetical pluralism: A metapadigm whose time has come. *Journal of Mixed Methods Research,* 11(6) pp.156-173.

Johnson, R., and Burke, L., Christensen, N., 2017. Educational research: Quantitative, qualitative, and mixed approaches. 6th. Los Angeles: Sage.

Joseph, S., 2012. Virtual laboratories perspectives from higher education institutes virtual laboratories perspectives from higher education institutes. Digital Learning, 8(3), pp.32-36. [online] Available at:< http://digitallearning.eletsonline.com/2012/03/virtuallaboratories-perspectives-from-higher-education-institutes/. online> [Retrieved June 12, 2018].

Kennepohl, D., 2011. Using computer simulations to supplement teaching laboratories in chemistry for distance delivery. *The Journal of Distance Education*, 16(2), pp.58–68.

Kibirige, I., Rebecca, M.M. and Mavhunga, F., 2014. Effect of Practical Work on Grade 10 Learners' Performance in Science in Mankweng Circuit, South Africa. *Mediterranean Journal of Social Sciences*, 5(23), pp.1568-1577.

Kibirige, I. and Teffo W.L., 2014. Actual and Ideal Assessment Practices in South African Natural Sciences Classrooms. *International Journal of Educational Science*, 6(3), pp.509-519.

Kibirige, I. and Tsamago, H., 2013. Learners' Performance in Physical Sciences Using Laboratory Investigations. *International Journal of Educational Sciences*, 5(4), pp.425-432.

Kibirige, I., Osodo, J. and Tlala, K.M., 2014. The effect of Predict-Observe- Explain Sttrategy on Learners' Misconceptions about Dissolved Salts. *Mediterranean Journal of Social Sciences,* 5(4), pp.300-310.

Kim, M. and Chin, C., 2011. Pre-service teachers' views on practical work with inquiry orientation in textbook-orientated science classroom*. International Journal of Environmental and Science Education*. 6 (1), pp.23-37.

Kim, M. and Tan, A., 2011. Rethinking difficulties of teaching inquiry based practical work: stories from elementary pre-service teachers*. International Journal of Science Education*. 33(4), pp.465-486.

Kirschner, P. A., Sweller, J., Kirschner, F., and Zambrano, J., 2018. From cognitive load theory to collaborative cognitive load theory. *International Journal of Computer-Supported Collaborative Learning*, 13(2), pp. 213–233.

Kivunja, C., and Kuyini, A. B., 2017. Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of Higher Education*, 6(5), pp. 26-41.

KNEC. 2011. Kenya Certificate examination report: Kenya National Examinations Council. Nairobi: Government Printers.

KNEC. 2012. Kenya Certificate examination report: Kenya National Examinations Council. Nairobi: Government Printers.

KNEC. 2013. Release of 2012 KCSE Results: Kenya National Examinations Council. Nairobi: Government Printers.

Kolb, D.A., 1984*. Experiential learning: Experience as the source of learning and development.* New Jersey: Prentice-Hall.

Kolloffel, B. and Jong, D. 2013. The virtues of a virtual lab. ASEE Prism: *American Society for Engineering Education.* 4(1), pp.1-9.

Kolucki, B. and Lemish, D., 2011. Communicating with Children Principles and Practices to Nurture, Inspire, Excite, Educate and Heal. UNICEF. [pdf] Available at< http://www.unicef.org/ cbsc/files/ CwC_ Web.pdf> [Retrieved May 23, 2017].

Kudenko, I. and Gras-Velάzquez, A., 2016. *The Future of European STEM Workforce: What Secondary School Pupils of Europe Think About STEM Industry and Careers*. In Insights from Research in Science Teaching and Learning. Cham, Switzerland: Springer International Publishing.

Kumar, D., 2014. Digital playgrounds for early computing education. *ACM Inroads*, 5(1), pp.20-21.

Limniou, M., Papadopoulos, N., and Whitehead, C., 2009. Integration of simulation into pre-laboratory chemical course: Computer cluster versus webct. Computer & Education, 52, pp. 45-52.

Lynch, T. and Ghergulescu, I., 2018. *Innovative pedagogies and personalisation in STEM education with NEWTON Atomic Structure Virtual Lab. EdMedia + Innovate Learning*. Amsterdam, Netherlands: SAGE.

Mahya. B., 2017. Cognitive Knowledge, Attitude Toward Science, And Skill Development in Virtual Science Laboratories.

Makombe, G., 2017. An expose of the relationship between paradigm, method and design in research. The Qualitative Report, 22(12), 3363-3382. [online]Available at:<http://nsuworks.nova.edu/tqr/vol22/iss12/18> [Retrieved September 19, 2019].

Maree, K., 2017. *First steps in Research. 2nd ed*. Pretoria: Van Schaik publishers.
Massachusetts Institute of Technology (MIT). 2012. iLab Project at MIT. [online] Available at:http://icampus.mit.edu/projects/ilabs. online> [Retrieved Oct 25, 2018].

Massachusetts Institute of Technology (MIT). 2012. iLab Project at MIT. [online] Available at:http://icampus.mit.edu/projects/ilabs. online> [Retrieved Oct 25, 2018].

Mayer, R.E., Mautone, P. and Prothero, W., 2012. Pictorial Aids for Learning by Doing in a Multimedia Geology Simulation Game. *Journal of Educational Psychology*, 94(10), pp.171–185.

Mcfarlane, D.A., 2013. Understanding the challenges of science education in the 21st century: New opportunities for scientific literacy. *International Letters of Social and Humanistic Sciences*, 4(3), pp.35-44.

Mcfarlane, D.A., 2013. Understanding the challenges of science education in the 21st century: New opportunities for scientific literacy. *International Letters of Social and Humanistic Sciences,* 4(3), pp.35-44.

McMillan, J. and Schumacher, S., 2014*. Research in Education Evidence-Based Inquiry. 7th ed*. Essex: Pearson Education Limited.

Mertens, D.M., 2014. Research and evaluation in education and psychology: integrating diversity with quantitative, qualitative and mixed methods. 4th edition. Thousand Oaks, CA: SAGE.

Miller, A. L., 2014. A self-report measure of cognitive processes associated with creativity. *Creativity Research Journal*, 26 (2), pp.203-218.

Miller, A., and Dumford, A., 2016. Creative cognitive processes in higher education. *The Journal of Creative Behavior,* 50 (4), pp.1-17.

Ministry of Malaysia Education (MOE). 2014. Boarding School. [online] Available at:< http://www.moe.gov.my. online> [Retrieved September 24, 2018].

Ministry of Malaysia Education (MOE). 2013. *LAPORAN KEBANGSAAN TIMSS 2011*. Putrajaya: Ministry of Malaysia Education.

Ministry of Malaysia Education (MOE). 2013. *Malaysia Education Blueprint 2013-2025*. Putrajaya: Ministry of Education Malaysia

Mohammed, H. A., 2017. Effects of Computer Simulation Instructional Package on primary school pupils" motor skills development and interest towards physical education in Niger state, Nigeria. Unpublished Phd Thesis. Department of Educational Technology, Federal University of Technology Minna, Nigeria.

Molina-Azorin, J. F., 2016. Mixed methods research: An opportunity to improve our studies and our research skills.

Musasia, A.M., Abacha, O.A, and Biyoyo, M.E., 2012. Effect of Practical Work in Physics on Girls' Performance, Attitude change and Skills acquisition in the form two-form three Secondary Schools' transition in Kenya. *International Journal of Humanities and Social Science*, 2 (23), pp.151-166.

Muwanga-Zake, J.W.F., 2020. A Conundrum of Learning Theories and ICTS in Learning. Challenges and Possible Solutions. *International Journal of Technology and Managemen*t, 5(I), pp.1-21.

Nadelson, L. S., Scaggs, J., Sheffield, C., and McDougal, O. M., 2015. Integration of video-based demonstrations to prepare students for the organic chemistry laboratory. *Journal of Science Education and Technology*, 24, pp. 476-483.

National Board for Professional Teaching Standards (NBPTS). 2013. Adolescence and young adulthood science portfolio instructions. [pdf] Available at:< http://www.nbpts.org/sites/default/files/documents/certificates/Aaag/AYA_Science_AssessAtaGlance_05.16.13_Final.pdf> [Retrieved May 23, 2018].

National Research Council (NRC). 2012. *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, D.C.: National Academy Press.

National Research Council (NRC). 2014. *Literacy for Science: Exploring the Intersection of the Next Generation Science Standards and Common Core for ELA Standards: A Workshop Summary.* Washington, D.C.: The National Academies Press.

National Science Teachers Association (NSTA). 2013. NSTA position statement: Accountability. [online] Available at:<http://www.nsta.org/about/positions/accountability.aspx.online> [Retrieved October 23, 2018].

Ndlovu, M.C., 2011. Re-envisioning the scholarship of engagement: Lessons from a university-school partnership project for mathematics and science teaching*. South African Journal of Education,* 25 (7), pp.1397-1415.

Ngman-Wara, E.I. and Edem, D.I., 2016. Pre-Service Basic Science Teachers' Self-Efficacy Beliefs and Attitudes towards Science Teaching*. Ghana. International Journal for Innovation Education and Research,* 4(8), pp.20-41.

Nevin, K.C. and Mustafa, S., 2010. An evaluation of science process skills of the science teaching majors. Procedia Social and Behavioral Sciences, 9(3), pp.1592–1596.

Njoroge, G.N., Changeiywo, J.M., Ndirangu, M., 2014. Effects of inquiry-based teaching approach on Secondary School students' achievement and motivation in Physics in Nyeri County, Kenya. *International Journal of Academic Research in Education and Review*. 2(1), pp.1-6.

North American Network of Science Labs Online (NANSLO). 2012. [online] Available at:<http://www.wiche.edu/nanslo. online > [Retrieved October 25, 2018].

OECD. 2014. PISA 2012 Results. Washington: OECD Publishing.

OECD. 2016. PISA 2015 Result in Focus. Washington: OECD Publishing.

Ojediran, I.A., Oludipe, D.I. and Ehindero, O.J., 2014. Impact of laboratory-based instructional intervention on the learning outcomes of low performing senior secondary students in physics. Creative Education. [online] Available at:< m.scirp.org. online> [Retrieved July 25, 2018].

Okeke, C., 2015. Educational Research: An African approach. South Africa: Oxford University Press.

Okeke, C. and van Wyk, M., 2015. *Educational Research: An African approach*. Cape Town: Oxford University Press.

Omiko, A., 2015. Chemistry teachers' attitude and knowledge of the use of Information Communication Technology (ICT) in chemistry Instruction Delivery at the secondary school level in Ebonyi State of Nigeria. *Journal of Curriculum Organization of Nigeria (CON)* In print.

Ören, T., Turnitsa, C., Mittal, S. and Diallo, S.Y., 2017. Simulation-Based Learning and Education. In: Mittal S., Durak U., Ören T. (eds) *Guide to Simulation-Based Disciplines. Simulation Foundations, Methods and Applications* Gewerbestrasse 11. New York: Springer.

O'Sullivan, S. K. E., and Harrison, T. G., 2016. A study into the design of a pre-laboratory software resource in effectively assisting in the chemistry proficiency of students of chinese origin undertaking post-16 chemistry in the uk. *Acta Didactica Napocensia,* 9(1), pp. 51-64.

Palmiero, M., Giacomo, D. D., and Passafiume, D., 2016. Can creativity predict cognitive reserve? *The Journal of Creative Behavior*,50(1), pp.11-20.

Park, J., 2013. Developing the format and samples of teaching materials for scientific creativity in the ordinary science curriculum. *Journal of the Korean Association for Science Education*, 32 (3), pp. 446-466.

Piaget, J., 1970. The child's conception of physical causality. Adams, NJ, USA: Littlefield.

Playfoot, J., 2016. Exploring the Role of Gamification Within Stem Teaching as a Mechanism to Promote Student Engagement, Develop Skills and Ultimately Improve Learning Outcomes for All Types of Students. *EDULEARN Proceedings*, 16(3), pp.2140–2147.

Prahani, B.K., Limatahu, I., Winata, S.W., Yuanita, L., and Nur, M., 2016. Effectiveness of physics learning material through guided inquiry model to improve student's problem solving skills based on multiple representation. *International Journal of Education and Research,* 4(12), pp.231-244.

Putnam, H., 2012. 'How to Be a Sophisticated "Naive Realist"'. In 'Philosophy in an Age of Science'. Harvard University Press, Cambridge, Mass.

Pyatt, K. and Sims, R., 2012. Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access*. Journal of Science Education and Technology,* 21(10), pp.133-147.

Ramnarain, U. and Fortus, D., 2013. South African physical sciences teachers' perceptions of new content in a revised curriculum. *South African Journal of Education*, 33(1), pp.1-15.

Ratamun, M. M., and Osman. K., 2018. The Effectiveness comparison of virtual laboratory and physical laboratory in nurturing students" attitude towards chemistry. Creative Education, 9, pp. 1411-1425. https://doi.org/10.4236/ce.2018.9910

Reddy, K.J, Menon, K.R, and Thattil, A., 2016. Academic Stress and its Sources Among University Students. *Biomed Pharmacol Journal 2018*; 11(1) [online] Available at:<http://biomedpharmajournal.org/?p=19485>[Retrieved August 19, 2020].

Reese, M.C., 2013. *Comparison of student achievement among two science laboratory types: Traditional and virtual* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No 3590234) [Retrieved 12, June 2019].

Rehman, A. A; and Alharthi, K., 2016. An Introduction to Research Paradigms. *International Journal of Educational Investigations* Available online @ www.ijeionline.com 2016 (October), 3(8), pp. 51-59

Rice, L., Barth, J.M., Guadagno, R.E., Smith, G.P.A., McCallum, D.M. and ASERT. 2012. The role of social support in learners' perceived abilities and attitudes toward math and science*. Journal of Youth and Adolescence*, 42(7), pp.1028-1040.

Riyami, A., T., 2015. Main Approaches to Educational Research. *International Journal of Innovation and Research in Educational Sciences*, 2(5). Retrieved from https://www.researchgate.net/publication/283071843_Main_Approaches_to_Educational_Research

Russell, C. B., and Weaver, G. C., 2011. A comparative study of traditional, inquiry-based, and research-based laboratory curricula: impacts on understanding of the nature of science. *Chemistry Education Research and Practice*, 12 (1), pp. 57-67.

Scalise, K., Timms, M., Moorjani, A., Clark, L., Holtermann, K. and Irvin, P.S., 2011. Student learning in science simulations: Design features that promote learning gains. *Journal of Research in Science Teaching*, 48(9), pp.1050-1078.

Schwichow, M., Zimmerman, C., Croker, S. and Härtig, H., 2016. What students learn from hands-on activities? *Journal of Research in Science Teaching*. [online] Available at:<doi: 10.1002/tea.21320. online> [Retrieved September 4, 2018].

Searle, J. R., 2015. 'Seeing Things as They Are; A Theory of Perception', Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199385157.001.0001

Seery, M.K., Agustian, H.Y. and Zhang, X., 2019. A Framework for Learning in the Chemistry Laboratory. Chemistry Education. [online] 59(6-7), pp. 546-553 Available at< https://doi.org/10.1002/ijch.201800093> [Retrieved June 3, 2019]

Shuttleworth, M., 2009. Internal consistency reliability. [online] Available at:<http://www.experiment-resources.com/internal-consistency-reliability.html?online > [Retrieved June 17, 2019].

Siew, N. M., Chong, C.L., and Chin, K.O., 2014. Developing a scientific creativity test for fifth graders. *Problems of Education in the 21st Century*, 62(1), pp.109-123.

Siew, N. M., Chong, C. L., and Lee, B. N., 2015. Fostering fifth graders scientific creativity through problem-based learning. Journal of Baltic Science Education, 14 (5), pp.655-669.

Simon, A. and Goes, P., 2012. Sample Size Matters: What type of cook (researcher) are you? [online] Available at: >http://www.investorwords.com/3738/population.html#ixzz1JhksqO9Z.pdf>[Reprived 20, November 2019].

Sin, C., 2014. Epistemology, Sociology, and Learning and Teaching in Physics. *Science Education*, 98(2), pp.342–365.

Singleton, R.A. and Straits, B.C., 2010. *Approaches to social research. 5th edition*. New York: Oxford University Press.

Slavin, R.E., 2011. Educational psychology, theory and practice. Boston: Pearson Education.

Song, K., Goh, A., Wee, L.K., Yip, K.W., Yong, P., Toh, J. and Lye, S.Y., 2013. Addressing learning difficulties in Newton's 1st and 3rd Laws through problem based inquiry using Easy Java Simulation. *In NIE Redesigning Pedagogy Conference*, 2(4), pp.1–5.

Steely, S., 2012.Traditional and alternative delivery methods of general chemistry labs: environmental, monetary, and pedagogical comparisons. [online] Available at:< cedar.wwu.edu. online> [Retrieved August 31, 2019].

Stott, A., and Hobden, P., 2019. Implementation challenges influencing the efficacy of group-work tasks that require inductive or deductive reasoning during physical sciences lessons http://journals.ukzn.ac.za/index.php/joe *Journal of Education*, 77

Sunarti, T., Wasis, W., Madlazim, M., Suyidno, S. and Prahani, B.K., 2018. The effectiveness of CPI model to improve positive attitude toward science (PATS) for pre-service physics teacher. *Journal of Physics: Conference Series*, 997(13), pp.1-7.

Tamin, R.M., Bernard, R.M., Borokhovski, E., Abrami, P.C. and Schmid, R.F., 2011. What forty years of research says about the impact of technology on learning a second-order meta-analysis and validation study. *Review of Educational Research*, 8(1), pp.4-28.

Tatli, Z., 2011. *Development, application and evaluation of virtual chemistry laboratory experiments for chemical changes unit at secondary school 9th grade curriculum*. PhD thesis, Karadeniz Technical University. Turkey.

Tatli, Z. and Ayas, A., 2012. Virtual chemistry laboratory: Effect of constructivist learning environment. *Turkish Online Journal of Distance Education*, 13(1), pp.183-199.

Tatli, Z. and Ayas, A., 2013. Effect of a Virtual Chemistry Laboratory on Students' Achievement*. Educational Technology and Society*, 16(1), pp.159-170.

Tesfaye, C.L. and White, S., 2012. Challenges High School Teachers Face. American. USA: Institute of Physics. Statistical Research Centre.
The National Science and Technology Centre. 2014. Shell Questacon Science Circus Questacon. [online]Available at<https://www.questacon.edu.au/outreach/programs/science-circus.online> [Retrieved November 24, 2018].

Tigere, E., 2014. *Investigating the Problem Solving Skills Proficiency of Grade 12 Physical Science Learners in Highveld Ridge East and West Circuits when Solving Stoichiometry Problems.* MSC dissertation. Pretoria: University of South Africa, RSA.

Toplis, R. and Allen, M., 2012. I do and I understand: Practical work and laboratory use in United Kingdom schools, *Eurasia Journal of Mathematics, Science and Technology Education,* 8(1), pp.3-9.

Towns, M., Harwood, C. J., Robertshaw, M. B., Fish, J., and O'Shea, K., 2015. The digital pipetting badge: A method to improve student hands-on laboratory skills. *Journal of Chemical Education*, 92(12), pp. 2038-2044.

Trivedi R. and Sharma, M.P., 2013. A Study of Students' Attitude towards Physics Practical at Senior Secondary Level. *International Journal of Scientific and Research Publications*, 3(8), pp.1-4.

Trochim, W., Donnelly, J.P., and Arora K., 2015. Research Methods: The essential Knowledge Base, United Kingdom: CENGAGE Learning.

United Nations Development Programme (UNDP). 2015. *Human Development Index and its component Tabel 1* [Retrieved February 15, 2018].

United Nations Scientific and Cultural Organisation (UNESCO). 2013. The Malaysia Education Policy Review. Abridged Report. [pdf] Available at:< unesdoc.unesco.org/images/0022/002211/221132e.pdf> [Retrieved January 16, 2017].

van de Heyde, V., and Siebrits, A., 2019. Students' attitudes towards online pre-laboratory exercises for a physics extended curriculum programme. *Journal of Science and Technological Education*, 37(2), pp.168-192.

Van Griethuijsen, R.A., van Eijck, M.W., Haste, H., den Brok, P.J., Skinner, N.C., Mansour, N. and BouJaoude, S., 2015. Global patterns in learners' views of science and interest in science*. Research in Science Education*, 45(4), pp.581-603.

Vilaythong, T., 2011. *The Role of Practical Work in Physics Education in Lao PDR*. Doctoral Thesis Department of Physics SE–901 87. Umeå University of Sweden.

Vogt, P., 2010. "Werbeaufgaben" in Physik: Motivations- und Lernwirksamkeit authentischer Texte, untersucht am Beispiel von Werbeanzeigen. Wiesbaden: Vieweg+Teubner

Vogt, N.P., Garden, P.C. and Haeffele, L.C., 2012. *When to Use What Research Design*. New York: Guilford Press.

Vygotsky, L., 1978. *Mind in Society*. Cambridge Mass: Harvard University Press.

Watts, A., 2013. *The assessment of practical science: a literature review*. Cambridge Assessment. London: Sage.

Weibel, J. D., 2016. Working towards a paperless undergraduate physical chemistry teaching laboratory. *Journal of Chemical Education*, 93, pp. 781-784.

Wicaksono, I., Wasis, W. and Madlazim, M. 2017. The effectiveness of virtual science teaching model (VS-TM) to improve student's scientific creativity and concept mastery on senior high school physics subject. *Journal of Baltic Science Education*, 16(4), pp.549-561.

Whealon, T. M., 2016. Impact of supplemental video pre-lab material for a biochemistry lab practical on student overal preparedness. (Master of Science Master's Thesis), Southern Illinois University, Edwardsville.

Wolf, T., 2010. Assessing Student Learning in a Virtual Laboratory Environment. *IEEE Transactions on Education,* 53(2), pp.216-222.

Woolfolk, A., 2010. *Educational Psychology*, Ohio: Ohio State University.

Woodfield, B., 2005. Virtual chemlab getting started. Pearson Education website. [pdf] Available at: < http://www.mypearsontraining.com/pdfs/VCL_getting_started.pdf> [Retrieved January 22, 2019].

Woodfield, B.F., Catlin, H.R., Waddoups, G.L, Moore, M.S., Swan, R., Allen, R. and Bodily, G., 2004. The Virtual ChemLab Project: A Realistic and Sophisticated Simulation of Inorganic Qualitative Analysis. *Journal of Chemical Education*, 81(11), pp.1672-1679.

Woodley, E., 2009. Practical work in school science-why is it important? *School Science Review,* 91(335), pp.48-51.

Yoon, H. and Kim, M., 2010. Collaborative reflection through dilemma cases of practical work during practicum. *International journal of science education*, 32 (3), pp.283-301.

Zgheib, R.S., 2013. *Organizational support of technology integration in one school in Lebanon*. (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No. 3596298) [Retrieved 14, September 2019]

Zimbardi, K., Bugarcic, A., Colthorpe, K., Good, J.P. and Lluka, L.J., 2013. A set of vertically integrated inquiry-based practical curricula that develop scientific thinking skills for large cohorts of undergraduate students*. Advances in Physiology Education*, 37(4), pp.303-315.

Zimmerman, B.J., 2010. Self-regulation involves more than metacognition: A social cognitive perspective*. Educational Psychologist*, 30(4), pp.217-221.

APPENDIX A: LETTER TO PRINCIPALS OF SELECTED SCHOOLS REQUESTING PERMISSION TO CONDUCT RESEARCH

P.O. Box 205
Mthatha
Eastern Cape
5099
5 June 2017

Holly Cross High School
P. O. Box 396
Mthatha
5099

Dear Sir/Madam

PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOL

I, SINCUBA MUTHANDWA C, (Student no: 211 111 589) hereby request permission to conduct research at your school as part of my study as a M. Ed student at Walter Sisulu University. The research topic is 'Evaluation of the Effectiveness of Virtual Laboratory Delivery Environment on Achievement and Attitudes towards Physical Sciences among Grade 11 Learners: A Case study of two schools in the O.R. Tambo District Municipality'.

I will be working with one Physical Sciences educator and two intact classes of the eleventh grade learners who are doing Physical Sciences and taught by one educator. I promise that all the information that I will be getting from your school will remain confidential and all participants and your school will also remain anonymous.

I hope that my request will receive you good consideration. For any queries please contact me on 071 802 0241 or at mcsincuba@gmail.com.

Yours faithfully

(Signature: m.csincuba

M.C. Sincuba, Contact details: 071 802 0241

APPENDIX B: WSU ETHICS COMMITTEE APPROVAL TO CONDUCT RESEARCH

WSU
Walter Sisulu University

FACULTY OF EDUCATIONAL SCIENCES

Postgraduate Research and Higher Degrees

FEDS RESEARCH ETHICS COMMITTEE CLEARANCE CERTIFICATE

Nelson Mandela Drive, Private Bag X1, Mthatha, WSU, Eastern Cape, South Africa
Tel: 047-5022534
E-mail: ssongxaba@wsu.ac.za

MEETING	: 25July 2017
PROTOCOL NUMBER	: REC/1/2017
TITLE OF PROJECT	: Effectiveness of Virtual Laboratory Delivery Environment (VLDE) on Learners' achievement and attitude in Physical Sciences: A Case study of two schools in the O.R. Tambo District Municipality
RESEARCHER	: Mr Muthandwa Sincuba
SUPERVISOR	: Dr Dr Merlin John
CO-SUPERVISOR	: N/A
DEPARTMENT	: CPTD
DEGREE	: M Ed
COMMITTEE DECISION	: Approved

Sgaba
DR SL SONGXABA
CHAIRPERSON

25 July 2017
Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Walter Sisulu University

APPENDIX C: WSU FEDS HIGHER DEGREES COMMITTEE APPROVAL TO CONDUCT RESEARCH

WSU
Walter Sisulu University

FACULTY OF EDUCATIONAL SCIENCES

Postgraduate Research and Higher Degrees

FEDS HIGHER DEGREES COMMITTE

Nelson Mandela Drive, Private Bag X1, Mthatha, WSU, Eastern Cape, South Africa
Tel: 047-5022534
E-mail: ssongxaba@wsu.ac.za

MEETING	: 25July 2017
PROTOCOL NUMBER	: REC/1/2017
TITLE OF PROJECT	: Effectiveness of Virtual Laboratory Delivery Environment (VLDE) on Learners' achievement and attitude in Physical Sciences: A Case study of two schools in the O.R. Tambo District Municipality
RESEARCHER	: Mr Muthandwa Sincuba
SUPERVISOR	: Dr Merlin John
CO-SUPERVISOR	: N/A
DEPARTMENT	: CPTD
DEGREE	: M Ed
COMMITTEE DECISION	: Approved

DR SL SONGXABA
CHAIRPERSON

27 July 2017
Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Walter Sisulu University

APPENDIX D: THE EASTERN CAPE DEPARTMENT OF BASIC EDUCATION, GRANTING PERMISSION TO CONDUCT RESEARCH IN SCHOOLS

Province of the
EASTERN CAPE
EDUCATION

STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES
Steve Vukile Tshwete Complex • Zone 6 • Zwelitsha • Eastern Cape
Private Bag X0032 • Bhisho • 5605 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)40 608 4773/4035/4537 • Fax: +27 (0)40 608 4574 • Website: www.ecdoe.gov.za

Enquiries: B Pamla Email: babalwa.pamla@ecdoe.gov.za Date: 31 January 2018

Mr. Muthandwa Chinamora Sincuba

Khanyisa High School

P.O. Box 205

Mthatha

5099

Dear Mr Sincuba

PERMISSION TO UNDERTAKE A MASTERS' STUDY: EFFECTIVENESS OF VIRTUAL LABORATORY DELIVERY ENVIRONMENT ON LEARNERS' ACHIEVEMENT AND ATTITUDE IN PHYSICAL SCIENCES: A CASE STUDY OF TWO SCHOOLS IN THE KSD MUNICIPALITY

1. Thank you for your application to conduct research.
2. Your application to conduct the abovementioned research involving 224 learners from two Secondary Schools of O.R. Tambo Inland under the jurisdiction of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:
   a. there will be no financial implications for the Department;
   b. institutions and respondents must not be identifiable in any way from the results of the investigation;
   c. you 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;
   d. you will make all the arrangements concerning your research;
   e. the research may not be conducted during official contact time;
   f. 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: Strategic Management Monitoring and Evaluation;

PGDP EASTERN CAPE 2004 - 2014

building blocks for growth

Page 1 of 2

Ikamva eliqaqambileyo!

g. your research will be limited to those institutions for which approval has been granted, should changes be effected written permission must be obtained from the Chief Director: Strategic Management Monitoring and Evaluation;

h. 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.

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

j. you are requested to provide the above to the Chief Director: Strategic Management Monitoring and Evaluation upon completion of your research.

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

l. you comply with your ethical undertaking (commitment form).

m. You submit on a six monthly basis, from the date of permission of the research, concise reports to the Chief Director: Strategic Management Monitoring and Evaluation

3. The Department reserves a right to withdraw the permission should there not be compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE.

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

5. The Department wishes you well in your undertaking. You can contact the Director, Ms. NY Kanjana on the numbers indicated in the letterhead or email nykanjana@live.co.za should you need any assistance.

NY KANJANA
DIRECTOR: STRATEGIC PLANNING POLICY RESEARCH & SECRETARIAT SERVICES

FOR SUPERINTENDENT-GENERAL: EDUCATION

APPENDIX E: LETTERS FROM SCHOOL PRINCIPALS, GRANTING PERMISSION TO CONDUCT RESEARCH

School A

12 June 2017

TO : MR SINCUBA MUTHANDWA C

SUBJECT :PERMISSION TO CONDUCT RESEARCH-SINCUBA MUTHANDWA C

Sir/Madam

Kindly be advised that Mr Sincuba Muthandwa C. has been granted permission to conduct a research in the above referred school in pursuance of his studies towards Masters of Education in Education performance with Walter Sisulu University.

The school wishes him all the best in her studies.

Yours sincerely

Mr. S. Vattakunnel

Principal

School B

5 June 2017

TO : MR SINCUBA MUTHANDWA C

REF : PERMISSION TO CONDUCT RESEARCH-SINCUBA MUTHANDWA C

Sir/Madam

Mr Sincuba has been granted permission to conduct a research in the school. He is a Masters of Education student at Walter Sisulu University (WSU) under the supervision of DR Merlin John. The title of his study is*: effectiveness of virtual laboratory delivery environment on learners' achievement and attitude in physical sciences: A case study of two schools in the KSD Municipality.*

We wish you the best during your study.

Yours sincerely

nluthango

HOLY CROSS HIGH SCHOOL
P.O. BOX 396
MTHATHA
5099

APPENDIX F: LETTER OF INVITATION TO PARENTS AND GUARDIANS

Dear parent/Guardian

Subject: **INVITATION TO YOUR CHILD TO PARTCIPATE IN A RESEARCH STUDY**

I, MUTHANDWA CHINAMHORA SINCUBA, (Student No: 211 111 589), doing Masters of Education with Walter Sisulu University have to conduct a research study on Grade 11 learners. I kindly request your child to take part with your consent thus, if your child is willing to participate. If you and your child are willing, please duly complete the consent form and give it to your child to bring it back to school the next day.

For further inquiries, kindly contact me on 071 802 0241 or at mcsincuba@gmail.com

Yours faithfully

M.C. Sincuba

Signature: m.csincuba Date: 11/05/2017

APPENDIX G: WSU INFORMED CONSENT FORM

APPENDIX P

WSU

WALTER SISULU UNIVERSITY

DIRECTORATE OF POSTGRADUATE STUDIES

INFORMED CONSENT FORM (EXAMPLE) **(SAVE AS PORTRAIT FOR FINAL USE)**

Title of the project: EVALUATION OF THE EFFECTIVENESS OF VIRTUAL LABORATORY DELIVERY ENVIRONMENTON ACHIEVEMENT AND ATTITUDES TOWARDS PHYSICAL SCIENCES AMONG GRADE 11 LEARNERS: A CASE STUDY OF TWO SCHOOLS IN THE OR TAMBO MU.

Name of Researcher: MUTHANDWA CHINAMHORA SINCUBA

Researcher's Institution: WALTER SISULU UNIVERSITY **Phone:** 079 2685763

Name of the Main Supervisor (in case of students): DR. MERLIN JOHN

Purpose of the study/research: (if research is for a qualification, which one?): M.Ed BY DISSERTATION

PARTICIPANT'S INFORMED CONSENT

The purpose of the study and the extent to which I will be involved was explained to me by the researcher or another person authorized by the researcher in a language which I understood. I have understood the purpose of the study and the extent to which I will be involved in the study. I unreservedly agree to take part in it voluntarily. I understand that I am free to withdraw from the study at any time at any stage at my own will. I am aware that I may not directly benefit from this study. I am made aware that my responses will be recorded anonymously and that I may be audio- or video-taped for the purpose of this research.

For participants who are under 18 years (minors): I have explained to my parent/guardian that I am willing to be part of this study and they too have agreed to it.

Signed at (place) Mthatha **on (date)** 11/05/2017 **by (full name)** **of (address)** Thandie Mqolomba

Witness: Name: Wanda Magenu **Signature:** WMagenu **Date:** 11-05-2017

In case where minors are participants, the parent/guardian, also needs to sign below (In such cases, a letter of introduction in a language which the parent/guardian understands will accompany this form)

PARENT'S/GUARDIAN'S INFORMED CONSENT

I NOSIPHO MQOLOMBA **am the father/mother/guardian of the minor. The purpose of the study/project and the extent to which the minor under my care will be involved was explained by the researcher or another person authorized by the researcher to me in a language which I understood. I have understood the purpose of the study and the extent to which the minor will be involved in the study. I unreservedly agree for him/her/them to take part in it if he/she/they have no personal objection. I understand that I and/or the minor are free to withdraw our consent at any time at any stage at our own will. I have explained to the minor under my care that I have no objection in him/her in taking part in this study and he/she too have agreed to it.**

Signed at (place) MTHATHA **on (date)** 15 May **by (full name)** NOSIPHO

of (address): PAYNE ADMINISTRATIVE AREA MTHATHA 5099

Witness: Name: ZAMELE SAUTI **Signature:** [signature] **Date:** 11/05/2017

ENDORSEMENT BY THE HEAD OF THE PARTICIPANT'S INSTITUTION

Name: MISS A-N. LAWANA **Signature:** [signature]

KHANYISA HIGH SCHOOL
P.O. BOX 205 MTHATHA 5099
TEL:047 537 1224
FAX:047 537 1962

APPENDIX H: EDITOR'S CERTIFICATE

23 Elfin Glen Road, Nahoon Valley Heights, East London, 5200

Professional EDITORS Group

To whom it may concern:

This document certifies that the research document whose title appears below has been edited for proper English language, grammar, punctuation, spelling and overall style by Rose Masha, a member of the Professional Editors' Group whose qualifications are listed in the footer of this certificate.

Title:

IMPACT OF VIRTUAL LABORATORY DELIVERY ENVIRONMENT ON GRADE 11 LEARNERS' LEARNING OUTCOMES IN PHYSICAL SCIENCES: A CASE OF TWO LOW PERFORMING SCHOOLS IN O.R. TAMBO INLAND

Author:

MUTHANDWA CHINAMHORA SINCUBA

Date Edited:

12 November 2019

Signed

Dr. Rose Masha

B. Library & Inf. Sc.; HDE; Hons. ELT; M. Phil. Hyll.; PhD Ed.

APPENDIX I: DATA COLLECTION INSTRUMENT ON GRADE 11 LEARNERS' ACHIEVEMENT IN PHYSICAL SCIENCES

Physical Science Achievement Test on Conceptual Understanding (PSATCU)

Name: ………………………… Gender: …………… Type of test: ………….

Duration: 60 Minutes Total: 100 Marks

This instrument aims at testing the understanding of stoichiometric concepts among the Grade 11 Physical Sciences learners. There is one correct answer for each of the following questions. Circle the most correct answer.

Question 1 of 20

A balanced chemical equation allows one to determine the …………………

A. energy released in the reaction.
B. mechanism involved in the reaction.
C. mole ratio of any two substances in the reaction.
D. electron configuration of all elements in the reaction. (5)

Question 2 of 20

The coefficients in a chemical equation represent the …………………

A. number of valence electrons involved in the reaction.
B. relative numbers of moles of reactants and products.
C. number of atoms in each compound in a reaction.
D. masses, in grams, of all reactants and products.

(5)

Question 3 of 20

What is the ratio of the actual yield to the theoretical yield, multiplied by 100 %?

A. Avogadro yield.
B. Excess yield.
C. Percent yield.
D. Mole ratio.

(5)

Question 4 of 20

The actual yield of a chemical reaction is generally ……………………..

A. greater than the percentage yield.

B. equal to the percentage yield.

C. less than the theoretical yield.

D. greater than the theoretical yield.

(5)

Question 5 of 20

To determine the limiting reagent in a chemical reaction involving known masses of the two reactants, which of the following would be most useful?

A. Calculating bond energies

B. Determining the masses of 100 mol of each reactant

C. Calculating the mass of a single product formed from each reactant

D. Determining the molar masses of the products.

(5)

Question 6 of 20

How many mole ratios can be correctly obtained from the chemical equation?

$2Al_2O_3(l) \longrightarrow 4Al(s) + 3O_2(g)$?

A. 4

B. 3

C. 6

D. 8

(5)

Question 7 of 20

In the equation $2KClO_3 \longrightarrow 2KCl + 3O_2$, how many moles of oxygen are produced when 3 mol of $KClO_3$ decompose completely?

A. 1 mol

B. 4.5 mol

C. 2.5 mol

D. 3 mol

(5)

Question 8 of 20

In the equation $2Al_2O_3 \longrightarrow 4Al + 3O_2$, what is the mole ratio of aluminium to oxygen?

A. 10:6

B. 4:3

C. 3:4

D. 2:3

(5)

Question 9 of 20

Fewer steps are required to solve stoichiometry problems when …………………

A. the reactant is given in moles and the product is sought in moles.

B. the reactant is given in grams and the product is sought in grams.

C. the reactant is given in grams and the product is sought in litres.

D. the reactant is given in litres and the product is sought in number. (5)

Question 10 of 20

For the reaction $C + 2H_2 \longrightarrow CH_4$, how many moles of hydrogen are required to produce 10 mol of methane, CH_4?

A. 20 mol
B. 1o mol
C. 2 mol
D. 4 mol

(5)

Question 11 of 20

Which reactant controls the amount of product formed in a chemical reaction?

A. Limiting reactant
B. Composition reactant
C. Mole ratio
D. Excess reactant

(5)

Question 12 of 20

For the reaction $2H_2 + O_2 \longrightarrow 2H_2O$, how many grams of water are produced from 6 mol of hydrogen?

A. 54 g
B. 6 g
C. 2 g
D. 108 g

(5)

Question 13 of 20

For the reaction $2Na + 2H_2O \longrightarrow 2NaOH + H_2$, how many grams of NaOH are produced from 3.00 mol of water?

A. 240 g
B. 40 g
C. 120 g
D. 80 g

(5)

Question 14 of 20

For the reaction $HCl + NaOH \longrightarrow NaCl + H_2O$, how many moles of HCl are required to produce 150 g of water?

A. 4.16 mol
B. 1.50 g mol
C. 12.20 mol
D. 8.32 mol

(5)

Question 15 of 20

For the reaction $HCl + NaOH \longrightarrow 2KCl + Br_2$, how many grams of KCl can be produced from 300 g KBr?

A. 188 g
B. 451 g
C. 111 g
D. 98.70 g

(5)

Question 16 of 20

For the reaction $2Na + Cl_2 \longrightarrow 2NaCl$, how many grams of NaCl can be produced from 500 g of chlorine?

A. 825 g
B. 409 g
C. 112 g
D. 319 g

(5)

Question 17 of 20

For the reaction $SO_3 + H_2O \longrightarrow H_2SO_4$, calculate the percentage yield if 500.00 g of sulphur trioxide react with excess water to produce 575 g of sulphuric acid.

A. 91.20 %
B. 88.30 %
C. 93.90 %
D. 82.70 %

(5)

Question 18 of 20

For the reaction $Cl_2 + 2KBr \longrightarrow 2KCl + Br_2$, calculate the percentage yield if 200.00 g if chlorine react with excess potassium bromide to produce 410,00 g bromine.

A. 82.10 %
B. 98.90 %
C. 73.40 %
D. 91.00 %

(5)

Question 19 of 20

What is the mole of H_2O to H_3PO_4 in the following chemical equation?

A. 3 to 2
B. 2 to 3
C. 1 to 6
D. 4 to 6

(5)

Question 20 of 20

10 moles of hydrogen gas (H2) and 2,5 moles of nitrogen gas (N2) are mixed and allowed to react to form ammonia (NH3) according to the following balanced equation:

$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$

If 4 moles of $NH_3(g)$ is formed during the reaction, the number of moles of $H_2(g)$ and $N_2(g)$ that remain in the container are respectively:

	Moles of $H_2(g)$	**Moles of $N_2(g)$**
A	0	0
B	7	1,5
C	4	0,5
D	4	2

(5)

APPENDIX J: DATA COLLECTION INSTRUMENT ON LEARNERS' GRADE 11 PROFICIENCY IN THE ACQUISITION OF PHYSICAL SCIENCES TECHNIQUES AND PRACTICAL EXPERTISE

Physical Science Process Skills Test (PSPST)

Name: ……………………… Gender: ………… Type of test: ………….

Multiple choice questions: There is one correct answer for each of the following questions. Circle the most correct answer

Section A: General Rules of Conduct

1. You may do an unassigned experiment, only ………..

a) if you are sure it is safe

b) if you have found it on the internet

c) if you have designed it carefully yourself

d) if you are finished early in the laboratory

e) none of the above

2. In the laboratory you are allowed to eat and drink only………..

a) if you are very hungry

b) if you have washed your hands well

c) if the food is healthy and can be digested fast and easily

d) if the food has been covered well to avoid contamination

e) none of the above

3. If you notice an unexpected chemical reaction of your experiment………….

a) proceed with caution to the next step

b) check with your neighbour to see if his experiment is doing the same

c) leave the laboratory immediately

d) notify your instructor

e) none of the above

4. The following should be reported to the instructor ………………

a) minor injuries only; major injuries should be directed to the nurse on site

b) major injuries only; minor injuries can be dealt with at home

c) all accidents except minor chemical splashes and minor spills

d) all injuries except small burns

e) all accidents no matter how minor

5. If you accidentally mix the wrong chemical, you must ……………

a) immediately dispose of the mixture down the sink

b) repeat the experiment one more time

c) add an acid to neutralize it

d) report it to your instructor

e) share your neighbour's experimental results

Section B: Dress Code for the laboratory

6. Goggles should be worn …………………

a) when working with solutions and liquids

b) when fumes are present

c) when doing specific dangerous experiments

d) all the time during the laboratory

e) none of the above

7. Proper footwear in the laboratory is …………

a) sandals that allow proper ventilation to the feet

b) a comfortable pair of slippers

c) closed- toe shoes

d) shoes with low heel

e) none of the above

8. For safety, long hair needs to …………………

a) be tied back

b) hang over your face and cheeks for protection

c) be cut short

d) be dyed without using harsh chemicals

e) none of the above

Section C: Handling Chemical Spills

9. You should get under the shower in the laboratory ………………………

a) if you spill chemicals on your hands or fingers

b) if there is a large chemical splashed on your body

c) if chemicals get splashed into your eyes

d) if there is a large chemical spill on the bench or floor

e) none of the above

10. If you spill a large amount of chemical on the floor …………

a) ignore it and keep working on your experiment so you can finish on time

b) walk straight over the spilled chemical to notify the instructor

c) keep it confidential and do not let the other learners around you know about it

d) alert nearby learners and call the instructor for instructions about how to clean it up

e) none of the above

Section D: Working with Chemicals

11. To dilute a concentrated acid …………………………………

a) add acid to the water

b) add water to the acid

c) mix both, the water and the acid, simultaneously

d) never mix acid and water; the result could be quite hazardous

e) none of the above

12. Wash bottles should be filled 'only' with ……………

a) washing or cleansing solution

b) tap water

c) distilled or de-ionized water

d) distilled alcohol

e) none of the above

13. To add water to a reagent used in an experiment …………

a) use water from the faucet

b) use distilled or de-ionized water

c) use tap water from the wash bottle

d) use your own water bottle from home

e) none of the above

14. To weigh 2 grams of salt in the laboratory ………………………

a) place salt into a beaker before weighing it on the balance

b) place salt directly on the balance to avoid contamination

c) do not use a balance and just eye-ball a sample that may look to be about 2 grams

d) mix the salt with water before weighing it on the balance

e) none of the above

15. If you spill solid chemicals on a balance …………………

a) clean it immediately using a bucket filled with water and a mop

b) brush off any spills

c) use a disinfectant like "Dettol"

d) allow the chemicals to rest on the balance for at least 15 minutes before brushing it off

e) ignore it since you are not trained to handle spilled chemicals

16. After dispensing a chemical from a container, ……………………

a) keep the stopper off the container for a few minutes to allow for proper ventilation

b) no need to replace the stopper, since someone else will be using it right after you

c) replace the stopper immediately

d) allow the chemical to drip gently on the outside of the bottle

e) get rid of the container as soon as you can

17. You should always hold containers that have chemicals ……………

a) with a pair of rubber gloves

b) with a clean pair of tongs

c) away from your body

d) close to your chest and with a strong grip

e) after rotating the lid in the counterclockwise direction

18. Before using the contents of a bottle, check ……………………

a) the size of the bottle

b) the color and consistency of the reagent inside

c) the odor and concentration of the reagent inside

d) the label on the bottle

e) none of the above

19. To remove solid chemicals from a bottle …………………

a) use your spatula to remove the solid

b) use your spoon to remove the solid

c) pour the solid directly into your container

d) pour the solid first into the palm of your hands

e) none of the above

20. The unused or leftover chemical should be ……………………

a) returned back 'immediately' to its original container

b) returned back to its original container right 'before' you leave the laboratory

c) taken outside the laboratory and dumped on the soil to fertilize it

d) sent out to the Safety Committee

e) disposed of in the designated waste container

APPENDIX K: DATA COLLECTION INSTRUMENT ON GRADE 11 LEARNERS' ATTITUDES TOWARDS PHYSICAL SCIENCES

Semi-structured Interview for Physical Sciences Learners in Grade 11.

Theme 1: *the use of Virtual Laboratory Delivery Environments to improve learner performance*

1.1 What in your opinion as a learner can be done to improve learner performance in Physical Sciences?
1.2 If you get stuck on a Physical Sciences problem for the first time, what do you do?
1.3 What are the benefits of doing lots and lots of problems when learning Physical Sciences?
1.4 Does your science teacher use science resources in his/her teaching of Physical Sciences concepts?
1.5 Does your school provide you with the required text books and study guide for studying physical science?
1.6 In your daily class lessons, are you able to assist your friends and vice versa thereby helping to improve your understanding of science concepts?

Theme 2: *strategies that are employed in teaching science via the Virtual Laboratory Delivery Environments*

2.1 Do you engage in practical activities at school for Physical Science? If so, how does it help you to improve your understanding of various Physical Sciences concepts?

2.2 Are you sometimes allowed by the teacher to design and investigate your own topics or projects?

2.3 Are your practical activities related to your theoretical topics and if not what type of topics do you do in your practical work.

2.4 Does your teacher encourage you to do group work during practical lessons?

If so how does he/she do it?

Theme 3: *the educational benefit of using the Virtual Laboratory Delivery Environments*

3.1 Do you find practical work via Virtual Laboratory Delivery Environments to be exciting and thought provoking?

Theme 4: *what are the educational challenges of using the Virtual Laboratory Delivery Environments*

4.1 What are some of the major difficulties you as a grade 11 learner experience in doing practical work via Virtual Laboratory Delivery Environments in the Physical Science lessons?

APPENDIX L: FOCUS GROUP INTERVIEW SCHEDULE

INTERVIEW PROTOCOL: EFFECTIVENESS OF VIRTUAL LABORATORY DELIVERY ENVIRONMENT IN PHYSICAL SCIENCES EDUCATION

Interviewee: …………………………………… Date: ………………………

Time: ……………………………………………..

Thank you for participation in this study. You have been selected to participate because you are one of the Physical Sciences learners who have an opportunity to interact with the VLDE during Physical Sciences classes. I am interested in examining your views regarding the use of VLDE. I am a graduate student at Walter Sisulu University conducting my study in partial fulfilment of the requirements for the Masters of Education degree. The study is entitled:

Evaluation of the Effectiveness of Virtual Laboratory Delivery Environment on Achievement and Attitudes towards Physical Sciences among Grade 11 Learners: A Case study of two schools in the O.R. Tambo District Municipality.

The purpose of this study is to investigate the effectiveness and possible use of virtual Laboratory Delivery Environment in science education in South African schools. My research will be based on the following interview questions. After this interview, I am hoping to be able to determine your views regarding the use of virtual laboratory delivery environments and experiences of acquiring technology skills. The interview will include questions regarding your experiences in skills acquisition in Physical Sciences and using technology. There are no right or wrong answers to any of my questions. If you prefer not to address a question, you may refrain from answering. All statements made in response to this interview will be kept confidential. Your participation in this interview is completely voluntary. Your responses will remain confidential and will be used to develop a better understanding of how you and your peers view the use of virtual laboratory delivery environments and what might influence it. Thank you for your willingness to participate in this study. If at any time you have questions or concerns regarding the study and the interview questions, please do not hesitate to contact me.

Physical Sciences learner interview

Learner Background:

1) First, let's start with your educational background; tell me about your highest learning experiences.

2) How do you describe your skill acquisition regarding Physical Sciences? What is the role, if any, of laboratory work in your classroom?

Curriculum and Instruction- Science in General:

3) Describe the curriculum here [at school]

4) What types of teaching strategies or instructional methods are used by your educators delivering a lesson using laboratory work or science experiments?

5) With the lack of a Science lab here [at school] how do you conduct science experiments?

Technology:

6) What types of technology are you using during instruction time? And how often do you use it?

7) Can you rate your comfort level with using technology for learning purposes from (1-10).

8) How significant do you feel is the impact of technology on learner engagement? How about achievement and attitude?

9) Could you describe your experiences in acquiring technology knowledge and skills?

10) What are the primary barriers for using technology in your classroom?

11) Can you describe an ideal implementation of technology in your science classroom?

Virtual Laboratory delivery environments:

12) What is your view on Science Virtual laboratory delivery environments?

13) How do Science Virtual laboratory delivery environments influence your skills acquisition in Physical Sciences?

16) What, if any, are your major concerns about incorporating Virtual Science labs into your Physical Sciences classroom?
17) What benefits do you perceive in your attempts to embrace Virtual Science labs in the Science curriculum?

Thank you so much for your participation in this project. Please add any additional information or anecdotes that you think may help to increase my understanding. In order to increase the quality of my research, I may need to contact you with follow-up questions after reviewing your responses.