Learner Performance In Integrated Science Process Skills and Attitudes in Hands-on Practical Work Versus Virtual Practical Work.

Chawapiwa Ndoro: NDRMUG002

A minor dissertation submitted in *partial] fulfillment* of the requirements for the award of the degree:

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[2017]

Supervisor: Prof. A. Hattingh

COMPULSORY DECLARATION

This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work or works, of other people has been attributed, and has been cited and referenced.

Signature: Signed by candidate Date: 10 March 2017

Supervisor's Approval of Submission of Dissertation for Examination

I confirm that I have seen/ have not seen the final version of CHAWAPIWA NDORO NDRMUG002 (candidate's name) dissertation and that it is submitted for examination with/without my approval.

15 March 2017

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Faculty ethical clearance

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11th May 2015

Ms M.C. Ndoro
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Dear Ms Ndoro,

RE: Ethical Clearance for Master's Project

I am pleased to inform you that ethical clearance has been granted by an Ethics Review Committee of the Faculty of Humanities for your Master's project entitled: *Learner performance and attitudes in regular traditional practical work versus computer simulated practical work.*
I wish you all the best with your study.

Yours sincerely,

Signed

Associate Professor M Prinsloo
Chair, Humanities Faculty Research Ethics Committee

Cc Associate Professor A Hattingh (Supervisor)

Faculty Declaration form

FACULTY OF HUMANITIES

DECLARATION FORM - MASTERS DEGREE CANDIDATES

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Word count	29553	**No. of pages**	169

DECLARATION:

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Dedication

This research study is dedicated to my dear husband, Mr T. Matenga, and to all my friends.

Acknowledgements

I would like to acknowledge the grace of God, the Almighty, who blessed me with the knowledge and understanding of all kinds of literature and learning. ‘Daniel 1:17’. I thank God for the all the people around me who contributed to the success of this research.

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To my family and friends, I thank you for your support and for allowing me the space and time to study.

I thank the school principal, the science educators and the learners of the school where this research study was conducted, for their support.

Abstract

This research study was conducted in an urban high school in the Western Cape Province of South Africa. The research study investigated the effect of virtual practical work on learner performance in integrated science process skills and attitude, working with a non-random sample group of grade 10 physical sciences learners. In this experimental design research, the treatment group of 22 learners was taught the concept of 'phase change in matter' through virtual practical work. On the other hand, the control group was taught the same concept through hands-on practical work. A pre- and post-test instrument of 30 multiple choice items on integrated science process skills was used to measure learners' performance. These test scores were statistically analysed using Quickcalcs, to compare the overall learner performance in the two groups, and also to compare learner performance in different categories of science process skills. A 12-item attitude questionnaire was designed to test the learner s' attitude towards virtual and hands-on practical. The statistical t test analysis on the average scores indicated insignificant difference between the performance of the two groups, with a p value greater than 0,05. When learners' performance in different process skills categories were compared, t test scores revealed significant differences in some categories and non-significant differences in some categories. The attitude questionnaire results indicated that the learners' attitude was biased towards hands-on practical work. The significance of this research study is that virtual practical can be used to develop some science process skills.

Contents

Acronyms

VG - Virtual practical group

HG - Hands-on practical group

VP - Virtual practical activity

HP – Hands-on practical activity

NSC - National Senior Certificate

CAPS - Curriculum Assessment Policy Statements

FET – Further Education and Training

GET- General Education and Training

SA – South Africa.

TISPS - Test of Integrated Science Process Skills

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Insert 4.14. A response to attitude questionnaire item # 3 from learner # 44 VG

Insert 4.15. A response to attitude questionnaire item # 3 from learner # 6 VG

Insert 4.16. A response to attitude questionnaire item # 3 from learner # 18 VG

Chapter One: Background of Research Study

1.1. Introduction

In chapter one, the background of the research study, the purpose and significance of the study to science learning are provided. The problem statement and the scope of the research study are also outlined in this chapter. The research question, hypothesis, assumptions and limitations as well as a list of definitions and the organisation of work are provided.

1.2. Background

One of the aims of South African education is to develop problem solving and decision making skills in learners through science learning.

"…Physical Sciences promote knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relationships to technology, society and the environment." (Department of Basic Education, 2011, p, 8).

The statement points to the construction of scientific knowledge through problem solving. The document emphasises the development of science process skills such as classifying, communicating, measuring, designing an investigating, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills. In science teaching and learning, inquiry and investigation are the instructional tools and methods that address these aims. Inquiry learning allows learners to design activities that provide solutions to problems encountered as they interact with their environment. The designed activities usually take the form of science practical investigations, experiments, laboratory work and research. Here there is an emphasis on the notion that practical work is central to science learning and teaching (Woolnough & Allisop, 1985). Some research studies have confirmed that science practical activities enhance the understanding of phenomena, laws, principles and concepts, and improve learner performance (Kibirige, Maake & Mavhunga, 2014).

The Curriculum and Assessment Policy (CAPS) document for natural sciences and physical sciences elaborates the range of science process skills that learners need to develop in science teaching (Department of Basic Education, 2011). These science process skills include experimental design, drawing conclusions and evaluating data, formulating hypothesis, identifying and controlling variables, communicating findings, and making inferences among other skills. The mentioned process skills are developed through practical work in science learning. The CAPS curriculum prescribes both formal assessment practical investigations as well as informal assessment practical investigations as ways of ensuring the development of these science process skills. The National Senior Certificate (NSC) exam also assesses these skills. For example, in the physical sciences paper of the matric NSC exam for November 2012, questions 5 and 6 assessed learners on practical investigation process skills. By including questions with investigation settings in the NSC physical sciences exam, the curriculum guarantees the development of inquiry skills while learners are being prepared for the NSC exams.

In order to maximise learner performance, more emphasis should be put on the teaching of practical work in science learning. In this research study, the focus is on understanding the impact of science practical work on learner performance in science process skills, in order to improve, inform, and enlighten instruction tool designers. Science practical work is defined as "…any science teaching and learning activity in which the students, working individually or in small groups, observe and/or manipulate the objects or materials they are studying." (Millar, 2010, p, 109). Some of the practical work activities that are used in science learning include; experiments, laboratory work, research projects, models, field work, investigations, and demonstrations. The focus of this research study is on practical investigations with prescribed procedure to confirm phenomena concepts or principles. The development of technology has seen the increased use of virtual practical activities, which is yet another practical work option. In virtual practical work, learners interact and manipulate virtual objects and materials, whereas the hands-on practical activities involve the manipulation of real objects and materials in a real environment.

Some researchers have established that virtual practical work promote learning better than the hands-on activities (Sentongo, Kyakulaga, & Kibirige, 2013; Weisman, 2009). However, other research studies obtained inconclusive results as some tests proved simulated practical activities to have significant impact on learner performance in some categories but in other categories there was no significant improvement (Roberts, 2011). In some instances, the hands-on practical activities and the virtual practical activities were proved to be equally effective (Tatli & Ayas, 2011). The varying findings from research studies is an indication that there is still more to be learnt on the topic of virtual practical work in science education.

If practical work is fundamental to understanding of scientific concepts and technology is providing an additional option to conducting practical activities in science learning, then it is of significant importance to understand the influence of these practical activity options on science learning. Therefore, the impact that virtual practical activities and hands-on practical activities have on learner performances in science process skills is investigated in this research study.

Some studies have shown that the attitude of learners influence their performance (George, 2000). Attitude is a mental inclination towards people, objects or events; it is a tendency to respond favourably or unfavourably to the situation (Oppenheim, 1966). Some research studies have portrayed that while attitude does impact learner performance, its influence is small, and that it is not the only factor (Olasehinde & Olatoye, 2014). This research study also looked at learner attitude towards virtual and hands-on practical activities to verify if attitude is related to learner performance. In view of the background outlined, the researcher set out to investigate the impact of virtual practical activity on learner performance in science process skills as well as learner attitude to the two practical activity options.

1.3. Problem statement

The CAPS documents for General Education and Training (GET) Natural Sciences and Further Education and Training (FET) physical sciences stipulate that learners develop an understanding of scientific concepts as well as master science process skills through inquiry learning (Department of Basic Education, 2011). In inquiry learning, learners are presented with scientific problems, to which they are then required to design practical investigation activities that will produce data or information to provide solutions for the identified scientific problem, or to verify laws and principles (Antink, Lederman & Lederman, 2013). This description emphasises the important role of practical work in science learning.

In the National Senior Certificate (NSC) physical sciences examinations, learners are assessed on their conceptual understanding in physical sciences and inquiry skills which encompass the science process skills developed through science practical activities. Therefore examination items include practical investigation-based questions. In the November 2014 and November 2015 matric examination, in the physical sciences paper 2 question 5, learners were tested on inquiry skills with practical investigation questions on the topic acids and bases. According to the examination diagnostic reports for these years, the national average learner performance for these questions were 35% in 2014 and 36% in 2015. The report cites some common errors including lack of basic skills to interpret graphs, or drawing graphs (Department of Basic Education 2015), and failure to identify and manipulate variables (Department of Basic Education 2014). Both diagnostic reports recommended that learners need more exposure to practical investigation type of exercises and activities starting from grade 10 to develop the inquiry skills in the early stages of FET.

The poor learner performance in inquiry skills show that science practical work still needs to be explored more. Some research studies have already revealed that most teachers do not use practical activities in teaching science for reasons such as lack of resources, class sizes that are too large, learner discipline, lack of time, lack of teacher expertise resulting in lack of confidence and negative attitude towards the implementation of practical activities (Score, 2008; Aldous, Hattingh & Rogan, 2007). More knowledge on how virtual and hands-on practical activities facilitate learning on specific topics could help boost teacher confidence on implementing practical activities, or even change the attitude of some teachers in favour of carrying out practical activities in their science teaching practices. If knowledge of learner attitude towards virtual or hands-on practical activities is provided, teachers would make informed decisions on which practical activity option to use in order to maximise learning. It is hoped that the results of this research study will contribute towards improving the quality and quantity of practical work implementation in science learning and even improve learner performance at NSC in related questions.

1.4. Purpose of study

The purpose of this research study was to investigate the impact that virtual practical work has on learner performance in science learning. Two groups of grade 10 physical sciences learners were taught with different practical interventions namely, virtual practical activity and hands-on practical activity. Their performance was assessed through pre- and post-test scores, which were compared to determine the effect each practical activity option had on learning. In addition to the test scores, learner attitude towards virtual and hands-on practical activities were also explored for the purpose of determining which practical variation was preferred and if any possible link between learner attitude and learner performance could be detected.

1.5. Significance of study

Practical work is central to science learning (Woolnough & Allisop, 1985). Through practical work, learners consolidate their understanding of concepts and they develop inquiry skills (Abrahams, 2011). As educators and researchers prepare their teaching and learning tools that would be effective in developing these required skills in learners, it calls for their deeper understanding of the integration of content knowledge, pedagogical knowledge and technological knowledge. Content knowledge is the teacher's knowledge about the subject matter to be taught and learned, pedagogical knowledge is knowledge about the process of teaching and learning while technological knowledge is the way of thinking about working with technology tools and resources (Koehler & Mishra, 2009). Teachers and instruction tool designers have to make informed decisions on which tool to choose, when and how to use it how it in order to facilitate learning (Andersen, 2013).

It is intended that this research study would contribute to the body of literature that enlighten educators on the integrated use of technology, more specifically, in science practical work. The results of this study could give more insight on the nature and design features of what virtual practical intervention or hands-on practical intervention could offer to lead to a better understanding of the concept 'phase change in matter'. It also hoped that results of this research study would shed more light on which process skills the virtual or hands-on practical activities promote. Such information could contribute significantly in developing a better understanding of the integration of the three knowledge bodies, thereby encouraging teachers to not only use technology as mere extras or replacement for real object practical tools (Koehler & Mishra 2013).

1.6. Scope of study

In this research study, the influence of virtual practical work on learner performance and attitude were investigated. The impact of virtual practical work in the teaching of the topic 'phase change in matter' to grade 10 physical sciences learners were explored. This topic is in the South African physical sciences CAPS curriculum. The concepts taught in this topic include; phases of matter, kinetic molecular theory and 'phase change in matter'. The structure of the topic also includes practical investigation on the macroscopic and microscopic properties of matter during phase change. Therefore, the focus in this research study was on the teaching of the concept 'phase change in matter' practical work.

The research study was conducted in a secondary school in Western Cape Province of South Africa, in the south district. The participants were grade 10 physical sciences learners in the school. The school was chosen by the researcher due to accessibility and availability of a functional computer laboratory, as well as a functional science laboratory. The issues of social-economic background, race and gender were not considered in this research study.

1.7. Research title

Learner Performance in Integrated Science Process Skills and Attitudes in Hands-on Practical Work versus Virtual Practical Work.

1.8. Research questions

The questions answered by this research study are:

How does virtual practical work affect the learning of integrated science process skills and the learners' attitudes, in grade 10 physical sciences in a school in the Western Cape?

This research study addressed the following two sub-questions:

1. Are there any differences between hands-on practical work and virtual practical work in terms of learner performance in integrated science process skills?
2. Are there any differences between hands-on practical work and virtual practical work in terms of learner attitude towards the two practical approaches?

1.9. Hypothesis

There will be significant change in learner performance in Integrated Science Process Skills due to the practical activity option used in developing the concept ‘phase change in matter’. There will be considerable differences in learner attitude towards virtual practica

1.9.1. Null hypothesis

There will be no significant difference in learner performance in Integrated Science Process Skills, between learners who were taught the concept ‘phase change in matter’ using a virtual practical intervention and those taught the same concept through a hands-on practical method.

1.10. Assumptions

For the purposes of this study, the following assumptions were made:

1. The level of performance of the learners before the administration of the instruments was the same, confirmed by the *t*- test analysis.
2. The changes in learner performance was solely attributed to the practical interventions used in teaching the concept.
3. The teaching of the concept to the two groups was the same, except for the practical method that was either virtual or practical.

1.11. Limitations

The small sample size of 44 participants and the demographics of the sample were limited to one school situated in a medium to high-income community. The researcher chose the school for its easy accessibility and technology infrastructure. The participants were not randomly selected and as a result, there was no equal representation of social economic groups, race and gender. With such limitations, the investigated group does not constitute a true representative sample; therefore, inferences and conclusions were made with this in consideration.

1.12. Definitions of terms

The following are definitions of terms used in the context of this research study.

Attitude - is mental inclination towards people, objects or events; it is a tendency to respond favourably or unfavourably to the situation (Oppenheim, 1966).

Practical work - is "…any science teaching and learning activity in which the students, working individually or in small groups, observe and/or manipulate the objects or materials they are studying" (Millar, 2010, p, 109).

Virtual practical work - any science teaching and learning activity in which the students, working individually or in small groups, observe and/or manipulate the virtual objects or materials they are studying.

Hands-on practical work - any science teaching and learning activity in which the students, working individually or in small groups, observe and/or manipulate the real objects or materials they are studying.

1.13. Organisation of research study

There are five chapters in this research study.

Chapter 1: Background of research

Chapter One provided the background and the purpose of this research study and the research questions as well as operational definitions. The first chapter also outlined the significance of the research study, the scope, assumptions and limitations.

Chapter 2: Literature Review

The second chapter presented the literature pertinent to this study as well as the theoretical framework of the study. The scientific inquiry skills developed through practical work in science learning is elaborated on and it also covers the work done by other researchers on virtual practical work.

Chapter 3: The methodology

The third chapter contains a description of the research methodology and design, participants, sampling technique and research variables. The chapter explains the designing and administration of instruments, the collection of data and data analysis procedure. Ethical considerations, validity and reliability of instruments were also outlined in this chapter.

Chapter 4: Data analysis

The fourth chapter outlined the details of the results and findings of the research study. The data collected from the pre- and post-test instrument and from the attitude questionnaire were presented here. The analysis of the quantitative and qualitative data was outlined in this chapter.

Chapter 5: Discussion and conclusion

The final chapter, provided discussions of research study findings and conclusions. The implications of the research study findings, limitations and recommendations were presented. This chapter also outlined the significance of the research study and ended with a summary.

1.14. Summary

Chapter one provided a summary of the background, aims, purpose, significance and the structure of this research study. It also outlined brief descriptions of aspects covered in each subsequent chapter.

Chapter Two: Literature review and conceptual framework

2.1. Introduction

This review will contain literature on learning in science, considering the models of learning by Piaget, Vygotsky and the constructivist view of learning. The effects of practical work on science learning as well as the various practical work approaches that are available in science learning will be discussed, with special emphasis on hands-on practical work and virtual practical work.

2.2. Literature Review

2.2.1. Learning in science education

Learning is considered as a process of conceptual change resulting in construction of knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994). In science education, learners' construction of knowledge is influenced by factors such as interest, motivation, autonomy and cognitive ability. There are different views of learning from literature.

Piaget's model of learning suggests that children construct knowledge through interaction with their world (Piaget, 1964). In this model, individuals develop knowledge as their cognitive ability matures and as they react to their environment. Piaget explains that when people interact with their environment, they encounter unfamiliar knowledge structures (schemas), thereby creating a disequilibrium in the knowledge structures of the individual. The person works towards making cognitive adjustment in order to assimilate the new knowledge. The new knowledge is accommodated into the existing knowledge schemas, thus establishing a new knowledge equilibrium, summarising the process of learning (Piaget, 1966). Piaget's model suggests that learning occurs through active participation of the learner as he or she investigates to find solutions to the problems encountered (Simatwa, 2010). Therefore, teachers and designers of learning activities should create an environment that incorporates learners' active involvement, interaction with objects and with peers.

The importance of social interaction in knowledge construction using socio-cultural tools is emphasised by Vygotsky (1978). In this learning model, cognitive development begins with social interaction between the learner and the more knowledgeable other, an expert. The social development of knowledge uses the socio-cultural tools such as play, language and symbols (Vygotsky, 1930). In this early stage of cognitive development, the mediator and the learner collaborate in constructing knowledge. Here there is interaction of the learner with the others (social) and with the cultural tools. The second part of knowledge development in the Vygotsky theory is the individual's integration and mastery of knowledge domains developed. The teacher or peer provides the necessary supporting skills and strategies to assist the learner in problem solving. In the task-based approach, the learner is taught how to create and adjust their ideas in problem solving in order to complete more complex tasks (Turuk, 2008). Vygotsky's model of learning postulates active collaboration and involvement of the learner in problem solving, and with mediations of the more experienced other, the learner develops a higher, more complex cognitive level.

The constructivist view of learning, just like the other two mentioned models, supports the idea of learners' active engagement in constructing their own knowledge, to answer their own queries and questions with a higher degree of autonomy (Driver et al., 1994). The constructivist learning approach is an active process where knowledge is dynamic and people are constantly investigating to find solutions (Taber, 2011). This model of learning is based on problem solving with learners as active researchers for solutions to authentic problems. With the guidance of a coach or teacher, the learners, in small groups, collaborate to design investigation activities in order to solve problems experienced in their interaction with the environment. The constructivist idea centres on the idea of learners actively constructing their own knowledge and assimilating it, and is viewed as a more effective way of learning than passively receiving facts from the teacher (Jones & Brade-Araje, 2002). Constructivist learning is authentic and meaningful, rather than solving hypothetical problems to which learners cannot relate (Taber, 2011).

The three views of learning discussed in the preceding paragraphs, Piaget's cognitive development, Vygotsky's social cultural theory and the constructivist learning approach, all have the following fundamental ideas:

- Learning is an active process where knowledge is individually and socially constructed through experience with the environment.
- Meaningful learning involves problem solving activities of realistic tasks.

2.2.2. Inquiry learning in science

Inquiry learning is centred on learners designing investigations to answer questions that are designed to provide solutions to problems encountered or to scenarios presented (Lederman & Lederman, 2012). Here, the learners are presented with authentic or near realistic situations to which they provide a solution through investigation (Lederman & Lederman, 2012. Inquiry is one of the most praised learning approaches in science education literature. The level of inquiry in any practical activity can be determined by using the Herron scale (Lederman, n.d.). The levels of inqury described by Lederman are:

- Exploration inquiry
- In direct inquiry
- Guided inquiry
- Open ended inquiry (Lederman, n.d.).

Exploration inquiry refers to practical activities where the problem, procedure, and interpretation are provided. These are used for confirmation of principle. In direct inquiry activities, the problem and procedure are given, and learners have to make their own conclusions. This describes the level of inquiry that will be the focus of this study. Guided inquiry denotes a practical activity in which the research problem is provided, learners have to structure the method and find solution. Open ended inquiry leaves the problem, method and solutions open (Lederman, n.d.). Even though it is evident from this discussion that not all hands-on activities are open ended inquiry activities, they do address certain research problems or research questions (Dudu, & Vhurumuku, 2012). Educators have different opinions on whether inquiry learning promotes conceptual understanding. Research done by Ramnarain (2006) in selected schools in South Africa revealed that some educators in suburban and urban schools believe that inquiry learning promotes conceptual learning. Rural and townships school educators show preference for the didactic method. Some research findings indicate that inquiry learning improves learner performance in science learning (Abdi, 2014; Cox, Lambeth & Maxwell, 2015).

The inquiry learning approach develops inquiry skills such as:

- problem solving;
- planning and carrying out investigations;
- making observations and inferences;
- asking research questions;
- testing out ideas and hypothesis (Sails, 2014).

The literature reviewed so far highlight the importance of learner involvement in the learning activity in order to make meaning. The views of learning discussed here support the use of practical work in science learning. In science practical work, learners manipulate and interact with objects, and they have the opportunity to collaborate with peers, educators or learning programmes as they are mediated through scientific concepts. In the next section of the literature review, practical work in science learning, its role and the various forms of practical work available to science learning are elaborate on, with special focus on virtual practical work.

2.2.3. Practical work in science education

The role and purpose of practical work in science learning is emphasised in the literature on science education (Woolnough & Allisop, 1985; Millar, 2010). The roles and purposes of practical work in science highlighted by literature include motivation, authentic learning, gaining practical skills and help with learning concepts (Toplis & Allen, 2011; Millar, 2010; Hofstein & Mamlok-Naaman, 2007). Some research results have shown that science practical activities enhance the understanding of concepts and improve learner performance (Kibirige, Maake & Mavhunga, 2014). Other studies established that practical work motivates learners towards science learning (Score, 2008). Learners are keener to learn through practical work than passive assimilation of knowledge. Practical work aids learning of theoretical concepts, which are otherwise too abstract for some learners to grasp. Through practical work, learners get the opportunity to practice science as real scientists do when solving real life problems, they learn how science works in their lives and in the world around them. Since real scientists need practical skills, these can only be gained through practical work. Learners resound the same in their views of the role of practical work, indicating that practical work makes science classes interesting, vibrant and the participation gives them autonomy of their learning (Toplis, 2011). The importance of science practical work is further stressed by the large amounts of practical work being done by 11-13 year olds in England and Wales (Beatty & Woolnough, 1982).

2.2.3.1. Different types of practical work in science learning

There are several types of practical work in science education that are being implemented to enhance learning, such as simple investigation, demonstration, field work and diagnostics (Duggan & Gott, 2007). A simple practical investigation has two variables; independent and dependent, and will require learners to go through the scientific process. The scientific process engages the science process skills (explained in detail in other sections of the review). For the fieldwork, learners have to go to a physical site to collect data, and the diagnostic practical activity involves a series of procedures done to ascertain scientific facts or claims. The Department of Basic Education (2011a) physical Sciences CAPS document identifies two other types of practical work in addition to the afore mentioned. These are demonstrations, which limit the activity of the learners to observations, and experiments, which refer to a set of outlined instructions for learners to follow in order to obtain results to verify established theory and projects.

2.2.3.2. Structured and procedural practical work

Guided practical investigations signifies a practical activity in which the research problem is provided, and the overall structure the method is also provided, learners have to find solution. (Lederman, n.d.) Directed and open ended practical work are important, as they both develop skills which are important to learning. Not all practical activities have to be open ended as mentioned earlier, since there is no right or wrong practical approach as the approach is dictated by the learning goal to be achieved (Abrahams, 2011). In addition, assessment is difficult with open-ended investigations.

Duggan and Gott (2002) refer to two knowledge bases in science learning, conceptual knowledge and procedural knowledge. Conceptual understanding requires substantial knowledge of scientific concepts and laws. On the contrary, procedural knowledge encompasses problem solving, deciding on measurement ranges in the case of a practical activity, interpreting data, and mechanical or operational skills. Procedural knowledge is mostly applicable in the industries, while conceptual knowledge is used by the few that further their studies in science. In the findings of their case study, Duggan and Gott (2002) found that procedural knowledge was mostly in demand in the science industry and in everyday life. The point here is that critics of structured practical work view science learning as gaining only conceptual knowledge, yet problem solving requires learners to have the basic technical skills such as observation and measurement. These skills can only be obtained through practice and drill of structured practical activities. Through practical work, process skills and manipulative skills are acquired.

- Process skills, which are the six process skills in science learning that are observing, classifying, measuring, inferring, predicting and communicating findings.
- Manipulative skills, that include using and handling apparatus, handling specimen correctly, sketching specimen and science apparatus and maintaining science apparatus correctly and safely.

Just as conceptual and procedural knowledge are vital knowledge bases in science, manipulative skills and process skills should both be developed when learners do what scientists do.

2.2.4. Virtual and hands-on practical activities

In virtual practical work, learners carry out virtual experiments using virtual materials and apparatus. In hands-on practical learners carry out real experiments using real, concrete materials and apparatus. Debate on virtual practical activities is not new in the literature. The virtual practical work can be done for the same purposes as the hands-on practical activities. However, learning instrument designers should be aware of the benefits and limitations of each learning experience. The advantages and limitations revealed by some literature are discussed in this section.

2.2.4.1. Benefits and limitations of virtual practical work

One of the advantages of virtual practical work is that it can be modified by highlighting and modelling complex details, or by removing some aspects of phenomena that might be obstructing observations and interpretations (Linn, Long & Zacharia, 2013). Virtual experiments allow learners to observe the hidden detail that may not be observable with real object experiments, such as microscopic changes in chemical change. For example, in ion exchange chemical reaction, learners can see the ion models separating and then re-arranging into new compounds. This is demonstrated in Insert 2.1.

Insert 2.1. The ion exchange chemical reaction

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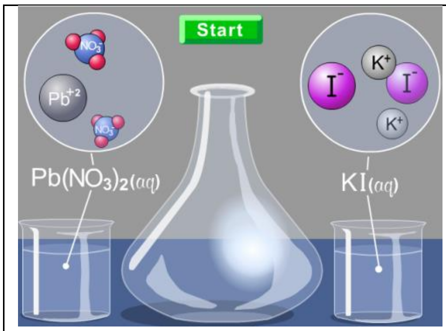
<td>
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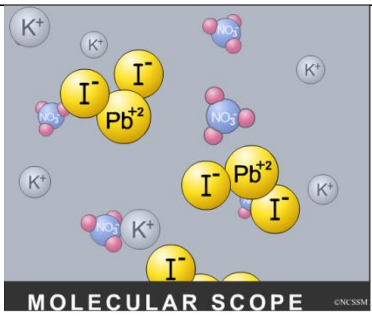
<td>
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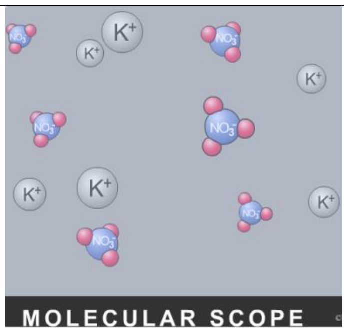
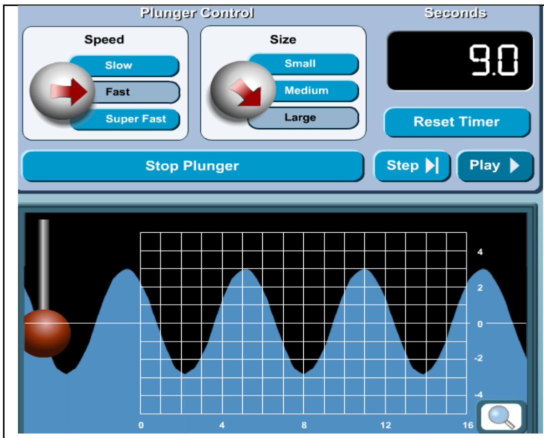
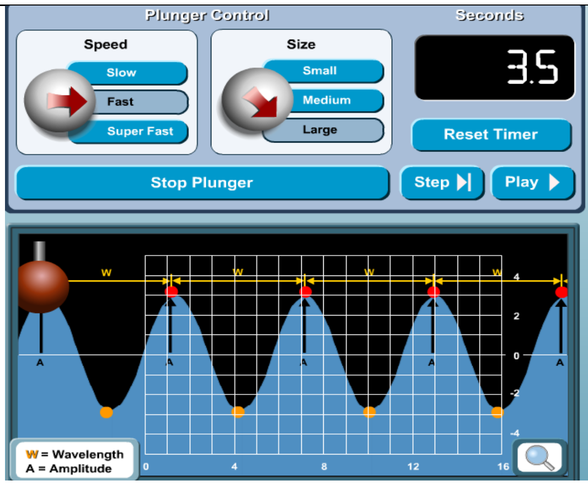
<td>
</td>
</tr>
<tr>
<td>Insert 2.1a. Original compounds</td>
<td>Insert 2.1b. Precipitate formation</td>
<td>Insert 2.1c. Spectator ions</td>
</tr>
</table>

Learners are shown ionic arrangement of each compound before the chemical change as illustrated in Insert 2.1a, then the experiment animation zooms in to show the re-arrangement of ions to form the products shown in Insert 2.1b, then spectator ions remain in the solution as demonstrated in Insert 2.1c (North Carolina School of Science and Mathematics, n.d., online)

The above illustration is important in clarifying some abstract concepts that may be too complex to achieve with hands-on practical activities. Some of the virtual practical tools have dialogue boxes that link users to tutorials or theory notes, linking the practical activity to the theoretical concept (Linn, Long & Zacharia, 2013). For example, in the transverse wave simulation illustrated in Insert 2.2., Insert 2.2a allows learners to generate waves of different properties by manipulating the speed of the plunger and the size of the plunger force. In Insert 2.2b the dialogue box 'step' provides details of properties of wave generated, linking the practical to theory (Glencoe, n.d.).

Insert 2.2. Transverse wave simulation





Insert 2.2.a. Transverse wave simulation plain	Insert 2.2.b. Transverse wave simulation with notes

This is a valuable tool to enhance the understanding of concepts. Such learning experiences are difficult to create in real object experiments as procedural techniques get in the way. However, there are arguments that these pop-up dialogue boxes may divert learners' attention from focusing on the actual practical activity (Scheckler, 2003)

The virtual practical activities require less time to prepare and less time to carry out. Results can be obtained faster, leaving more time in the lesson period to try out other variations. Students can repeat the experiments as many times as is necessary to get a better understanding (Scheckler, 2003). Experiments that may be too long to do in the actual laboratory can be done virtually, more so because simulated practical activities help to handle tedious data and calculations within manageable time frames (McKenzie, 1978; Moreno-Ger, et al., 2010). Research literature indicates poor performance in experiment reporting due to the poor quality of data generated by the learners (Hughes 2001). Measurements and procedural skills tend to clutter the activity thereby reducing the level of achieving the intended objectives. The virtual practical activities are handy for pre-rehearsal of complex procedures in order to reduce the level of difficulty of the practical exercise. This in turn will lessen time taken with procedure (Moreno-Ger, et al., 2010).

The virtual practical tools are always available to the learners and easily accessible at any time (Scheckler, 2003). Learners do not necessarily have to wait for school lesson time or to be in a science laboratory in order to access them. The virtual practical activities provide individualised learning (McKenzie, 1978). Furthermore, virtual practical websites make experimental data available to learners for them to manipulate (Linn, Long & Zacharia, 2013). On the contrary, arguments point out that virtual practical tools rely on servers that are not always functioning well, creating inconveniences (Scheckler, 2003). With too much virtual material available on the internet, it is difficult for learners to discern and distinguish the accurate from the inaccurate (Scheckler, 2003). In some instances, the language of presentation may be too difficult for learners to understand. Some presentations may be culturally insensitive, and learners maybe uncomfortable to access them again.

There are claims that virtual experiments are cheaper to run and require less space making them suitable for institutes with insufficient laboratory equipment or with no science laboratories at all (Lewis, 2014). Schools in the rural communities and low-income townships would benefit from virtual practical tool. The virtual tools become handy for covering the compulsory formal practical investigations prescribed by the physical science CAPS curriculum (Department of Basic Education, 2011). Although virtual practical tools are apparently cheaper to run, some sources cite the high cost of developing the tools and maintenance (Scheckler, 2003). Like all virtual tools they require constant debugging, routine back-ups and up-grades, the long run costs may not be low after all.

Virtual experiments do not present the safety and security challenges, as is the case with real equipment experiments (Scheckler, 2003). It is possible to learn from experiments considered too dangerous to be handled by the learners. Virtual experiments provide a solution to the ethical considerations on using animals or live tissue for experiments. Learners have the opportunity to virtually dissect organisms without interfering with ethical or environmental issues (Lewis, 2014).

In all practical investigations, (hands-on or virtual), there are opportunities for learner-teacher collaboration. However, the virtual practical websites provide links to other teachers and or learners broadening the level of collaboration and interaction across cities, provinces and even across states (Scheckler, 2003). In real practical activities, collaboration is limited to the immediate group.

Some research studies claim that they offer a wide range of learning opportunities (Edwards, 2015). Learners develop deeper understanding of concepts and principles when exposed to multiple representations in their learning (Edwards, 2015). Such learning opportunities include models, experiments (virtual or hands-on), demonstrations, group work, individual work, videos, graphs, and tables. Exposure to multiple learning experiences is in line with constructivist learning and differentiated learning. In this regard, combining virtual and hands-on practical activities create more diverse learning experiences, hence promote deeper understanding. It is confirmed that virtual practical work provides a wider range of learning experiences, promotes cognitive development and facilitates data collection and data presentation (Webb, 2005).

In real object practical activities, learners get more authentic experiences and they have the opportunity to develop procedural skills which are fundamental to science investigation (Linn, Long & Zacharia, 2013). In hands-on practical activities, learners get direct interaction with real materials, tools and instruments and collect real data. They experience the same troubles as real scientists do. This quality of real life experiences is not present in virtual activities (Scheckler, 2003). The virtual practical activities are not a close representation of the reality of sciences investigations.

The purpose of practical work, regardless of whether it is virtual practical or hands-on practical, can be any of the following:

- to reinforce knowledge and understanding of concepts and principles;
- to develop inquiry and experimental skills (Lewis, 2014);
- to improve learner motivation for science learning.

2.2.4.2. Combining virtual and hands-on practical activities

Combining virtual and hands-on practical activities is better than using one practical option. The combined approaches draw more highlights of each practical method, producing an even better tool than one. Both virtual and hands-on practical activities present shortcomings when used in isolation (Lewis, 2014). There is significant pedagogical benefits in combining virtual practical work and hands-on practical work (Kocijancic & O'sullivan, 2004). Both practical activity tools can enhance science learning by complimenting one another, not substituting each other (Scheckler, 2004). The argument here is that although virtual practical work equally enhances learning as the hands-on practical work and have a few advantages, this is not enough to warrant their replacement of the hands-on practical.

2.2.5. Empirical research on hands-on and virtual practical work

Research studies have revealed that while virtually supported practical investigations generated learner interest, the knowledge retention of learners taught through virtual practical and hands-on practical was equal (Chernobilsky & Granito, 2012). It has also been established that learners exposed to both hands-on and virtual practical intervention perform better than those exposed to only one of the practical methods (Amin Sabo, Ochanya & Omilani, 2016). On the other hand, there were no significant differences in the conceptual development of learners exposed to one practical method and those exposed to both (Bell & Trundle, 2010). Research studies have also reported some improvement in learner motivation when computer technology is used for learning (McHugh, Mitchel, Passey & Rogers, 2004).

There are some empirical research physics education technologies (phET) which are resource websites for physics virtual practical activities. Literature reviews of phET studies show that these simulations motivate, engage, and enhance learning (Adams, Perkins & Wieman, 2008). Furthermore, phET simulations provide environments that support inquiry learning (Herzog, Moore & Perkins, 2013). Opportunities for self-directed exploration and acquisitions are available. These virtual practical simulations promote guided inquiry, where learners can choose their own learning paths, but with constrains to stay within the focus of the leaning objectives (Adams, Perkins & Podolefsky, 2010). Some research findings show that phET virtual practical activities are effective in increasing both achievement and attitude (Özge & Serka, 2015).

In this current review, it has been established that practical work is central to science learning. There are various approaches to practical activities, each one of them praised or criticised for different reasons. The virtual practical activities are increasingly gaining popularity as a means of learning. There is a positive attitude towards virtual practical work and the levels of achievement in these are equivalent and sometimes higher than when practical hands-on activities are used.

While there is much praise for the virtual practical activities, this researcher does not call for the replacement of hands-on practical activity but for combining the two approaches for even better results. Learners perform better when exposed to both simulated and hands-on practical experiences. However, there seem to be apparent differences in terms of skills and attitudes for the two approaches, with virtual practical activities yielding better mastery of concepts. Even the learners have confirmed that they find the simulated experiments more beneficial (Weisman, 2010). Some literature on this topic reveals learner positive attitude towards the use of computer simulations in practical work, as well as higher achievement (Tüysüz, 2010; Pyatt, & Sims, 2007; Kassa, & Damtie, 2007). Where motivation is good and the attitude is positive, then learning is enhanced and computer simulations do the trick. With all the debate and studies on practical work in science education, it is noted that hands-on practical work does not really achieve the intended goal, namely conceptual learning (Abrahams & Millar 2008). This gap is bridged by virtual practical activities which reduce the complexity of the practical procedures and make conceptual understanding less abstract (Sentongo, Kyakulaga & Kibirige, 2013).

Research has been done on attitude and achievement on different topics of science learning, but none has been done on learner attitude and performance in grade 10 on water phase change. Most of the research study on virtual practical have been done in America, Asia and some African countries (Sentongo, Kyakulaga, & Kibirige, 2013). Similar research studies have been done in South Africa. These studies on the topic focused on learner attitude towards technology and the effects of virtual practical work on learner performance in the topic 'atomic bonding' (Kotoka, 2013; Van Ransburg & Ankiewicz, 2001).

The reviewed literature shows that practical work in science improves learner performance (Kiribirige, Maake & Mavhunga, 2014). Considerable research has been done on the impact of virtual practical work on learner performance and learner attitude. Some findings show that virtual practical work improves learner performance and that learners have a positive attitude towards this form of practical work (Javidi, 2004; Tuysuz, 2010). Some studies have suggested that both practical options are equally good (Ayas &Tatli, 2011). Others found no significant difference between the performance of learners taught through virtual practical activities and those taught through the hands-on practical. Studies have also revealed inconclusive results in learners' performance between the two forms (Robert, 2011). Since neither form of practical work is more prevalent than the other, some studies have compared the combined effect of virtual and hands-on practical work to the use of either of the two in isolation. The combined form proved to yield significantly higher results (Aminu Sabu, Omanu & Omilani, 2016).

Although there is considerable literature on virtual practical work in science learning, the previous discussion shows that there are still avenues that need to be explored in order to gain more insight into this learning tool. Some research studies on this topic were done in developed countries, others in developing countries. In South Africa, a study was done in which one group received computer-assisted teaching and the other group was taught using traditional teaching method on the same topic. The results revealed significant difference between the performance of learners taught through virtual practical, and that of learners taught through hands-on practical (Kotoka, 2013). Other South African studies revealed that virtual practical work promotes deep understanding (Hattingh & Scott, 2014). The research study investigated the effects of virtual practical work on learner performance and attitude of grade 10 physical sciences learners in the Western Cape in South Africa the learners were taught the topic ‘phase change in matter though virtual practical activity or through hands-on practical activity then compared on performance and attitude thereafter. ‘phase change in matter’. No research has been done on the topic in a Western Cape setting.

2.3. Conceptual framework

The purpose of science learning is to promote scientific literacy in individuals, who should be able to appreciate the strengths and limitations of science as well as use the scientific knowledge in making decisions in everyday life. Since the content necessary for scientific literacy is not defined, scientific literacy is measured by the individual’s ability to apply scientific knowledge in decision making in their lives. In science learning, learners should develop inquiry skills and the ability to use learnt skills and knowledge in new contexts. The learners should develop conceptual understanding and understanding of the nature of science. These qualities are organised into six domains of science learning (Enger & Yager, 2001), namely:

- Concepts
- Process
- Application

- Positive attitude
- Creativity
- Nature of science (Enger & Yager, 2001).

These six domains make up the assessment framework for science learning (see figure 2.1.). The conceptual framework elaborated in this research is based on these six domains of science. Since practical activities promote science learning, the assessment of practical work in science is also based on the same framework. The following diagram shows the six domains on which assessment in science learning should be based.

2.3.1. The six domains of science

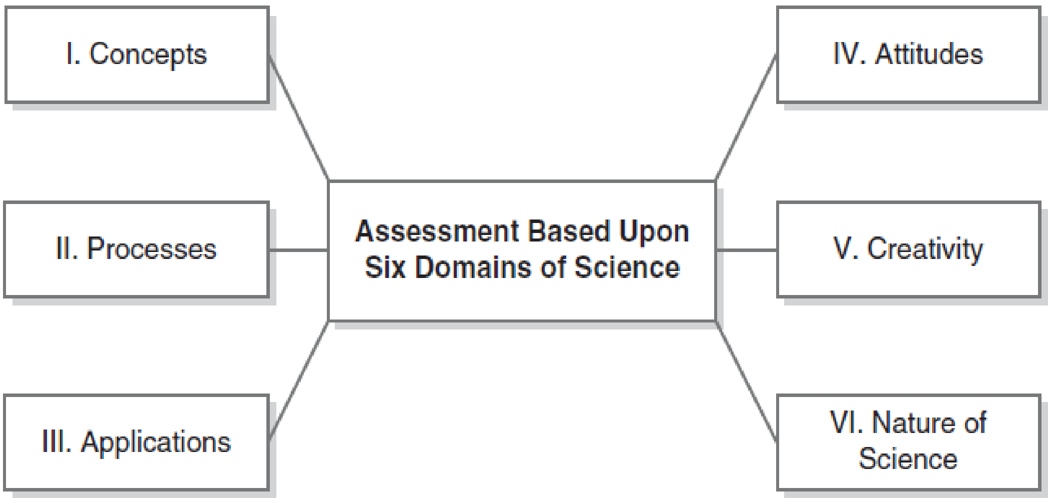


Figure 2.1. The six domains of science (From Enger & Yager, 2001, p 2)

2.3.1.1. Concept domain

Scientific concepts are facts, laws, principles or theories that explain phenomena. Conceptual knowledge is gained through practical application, which gives learners the opportunity for concrete experience with concepts, trying and applying concepts to construct scientific knowledge. Assessment of practical work should be done to assess where learners have mastered an understanding of scientific concepts as evidenced by their ability to apply these concepts.

2.3.1.2. Process domain

Scientific skills are tools that scientist use when they practice science. There are two categories of skills involved in science learning; manipulative and science process skills. The manipulative skills are needed for handling science equipment, maintaining equipment, apparatus safety and handling and sketching of specimens correctly. The science process skills, which fall into the process domain, are tools that scientists use in inquiry to investigate and explore the world around them, and learn scientific concepts. Some of science process skills considered in this research study include:

- Identifying and controlling variables
- Stating hypotheses
- Operational definitions
- Interpreting data
- Experimental design

It should be noted that as scientists think about science and do science, these process skills are involved in a manner that is interconnected and it is thus difficult to isolate them. In one practical activity, several process skills are involved in combination. However, they may be artificially separated for assessment and instruction purposes. Practical work that fosters learning should promote the development of these skills.

2.3.1.3. Application domain

Learners ought to be able to demonstrate their understanding of concepts by applying them to familiar and new context at school and in their daily lives. In problem solving, learners use existing knowledge (cognitive tools) relevant to the situation at hand. Learners use critical thinking skills in solving open ended problems and in doing so, they link their knowledge and skills of science to other context or subjects. With advancement in technology, knowledge of application of science concepts and skills to technological problems are equally important.

2.3.1.4. The attitude domain

Attitudes are mental inclinations towards people, objects or events; it is a tendency to respond favourably or unfavourably to the situation. There two types of attitudes; attitude towards science and scientific attitude. The later describes a tendency to think, act and demonstrate traits that characterise scientists, without necessarily being a scientist (Olasehinde & Olatoye, 2014). Such attitudes as curiosity, rationality, open-mindedness, objectivity, and critical thinking are always opinions based on empirical evidence. Attitude towards science is the general positive or negative feeling about science, and this is closely related to performance of learners. For this reason, it is imperative that instruction and assessment should aim to maintain or boost learner interest in science learning.

2.3.1.5. The creativity domain

Creativity in science learning is essential to most scientific processes. When hypothesising, problem solving and designing investigations, learners show imaginative, inventive and innovative capabilities. Creativity is promoted in a learning environment which is learner centred and where learners get more opportunities to practice scientific concepts. Creativity calls for experiences that promote visualisation, divergent thinking, multiple modes of communication and solving problems among other abilities.

2.3.1.6. The nature of science domain

The nature of science gives insight into how science works. Science is a body of knowledge in which ideas are interconnected and validated. The characteristics of science knowledge are described by the views of the nature of science which are briefly outlined below.

- Scientific knowledge is tentative; science knowledge is dynamic and ideas are reviewed and replaced by new ones. Instruction and assessment in science learning should reflect this.
- The empirical nature of science; scientific knowledge is based on evidence observations in research and investigations.
- Science is inferential, imaginative and creative; in order to design investigations, interpret and make conclusions on observations, scientists use their imagination and reactivity.
- Science knowledge is objective and subjective; although scientists try to be objective and avoid bias in their practices, the influence of culture, political and economic power, beliefs and prior knowledge are inevitable.
- Science is theory laden; scientists use theories, laws, and principles to explain what goes on in the world around them.
- Science uses many methods; there is no universal method to solve problems, a problem may have more than one solution, and science does not have solutions to all problems as it has limitations. There is a growing trend to use the scientific method in science investigation. Science is socially and culturally defined; scientists contribute to the body of knowledge as a community, sharing information and collaborating in teams.

This summarises the views of the nature of science in a certain sequence which is real. Scientists practice most of these simultaneously, not in a categorised fashion as noted earlier on. Teaching and learning should involve activities that help learners to understand more of the nature of science as this may help build positive attitude to science and increase levels of scientific literacy (Tytler, 2007). If learners' views of the nature of science are to be developed, they need to be explicitly integrated into instruction and assessment of science learning.

2.4. Assessment

This research will determine the performance of learners in practical work through assessment. Assessment is a process of gathering what would be used to evaluate learner performance from their learning experience. In science learning, it is used to examine procedural skills and an understanding of science processes (Enger & Yager, 2001; Score, 2008). There is no consensus on how science practical work should be assessed in the literature, or which skills should be assessed. There are several practical assessment tasks being practiced at present. These include:

- Science practical test; the assessment of learner behaviour and attitude when carrying out the experiment.
- Written practical test; evaluating learner's practical skills.
- Projects
- Field work
- Research (Watt, 2013).

Two other approaches of assessing practical work are direct assessment of skills and indirect assessment of skills (Abrahams, Reiss & Sharpe, 2012). In direct assessment of skills, learners demonstrate their ability, behaviour and attitude during the performance. Indirect assessment of practical skills assesses learners' performance through data from their experiment reports. The most common report used is the scientific report, generated from the supposedly scientific method of investigation. This is a way to ask and answer scientific questions (inquiry) by making observations and doing experiments using a series of techniques/ skills. The method is criticised for artificially organising skills in a systematic way that is not natural to doing science. In reality, these skills are interconnected. Both approaches (direct and indirect assessment) have their pros and cons but research evidence show that both approaches can be used with the same effectiveness. Assessment programmes are designed with multiple approaches to give a better profile of learners' understanding of the aspects of the domain of science. The learning objectives should be clearly defined as these dictate the nature and form of assessment. This research will use indirect assessment of practical skills, testing several aspects of the six domains of science learning.

2.5. Summary

This chapter reviewed literature on the learning models of Piaget, Vygotsky and the constructivist approach to learning. Literature on practical work in science learning, hands-on and virtual practical work activities were also discussed. The conceptual framework outlined in this chapter focused on the nature of sciences, the domains of science learning and the science process skills which are developed through science inquiry and the assessment thereof.

Chapter Three: Methodology

3.1. Introduction

This chapter elaborates the design and method employed in this research study, and illustrates how data collection instruments were developed and validated. Data collection methods and statistical data analysis procedures are outlined. A description of ethical considerations for this research study is also given in this chapter.

3.2. Research design and method

3.2.1. Research method

This research used a mixed method approach in which features of both quantitative and qualitative research approaches were combined (Creswell, 2013). The quantitative data to answer the question of influence of virtual practical intervention on learner performance was collected from the scores of the pre- and post-test instruments that were administered. The attitude questionnaire also provided quantitative data on learner attitude towards the two practical approach interventions used. The comments made by the participants to the open ended question section of the attitude questionnaire as well as the tables of experiment results and graphs obtained by the participants in their experiments, provided qualitative data. The qualitative data was vital for a more complete understanding when comparing the two variants of practical work. The research method is therefore quantitative and qualitative and such a method is described as the QUAN/qual model (Burk, 2007; Creswell, 2013).

3.2.1. Research Design

In order to collect empirical data, this research used a quasi-experimental design. In an experimental design, treatments are manipulated to establish their influence on the outcome

(Creswell, 2003). In this research, the influence of virtual practical intervention (treatment) on the performances and attitude (outcome) of learners was determined. The research population of 44 learners was divided into two groups, the virtual practical group (VG), which was the experiment group and a hands-on practical (HG), which was the control group. The VG were taught the concept of 'phase change of matter' using the virtual experiment simulation. The HG was taught the same concept through the hands-on experiment where real objects were used. In educational settings, true experimental designs where participants are randomly selected are difficult to conduct and in most cases researchers have to use pre-existing classes as participants which is then a quasi-experimental design (Cohen, Manion & Morrison, 2007). Selection of participants was not random, as the researcher had to work with existing grade 10 physical sciences classes in a South African public school.

The research was done in five phases, the research summary in table 3.1. In phase one, the pre-test instrument was administered to both the VG and the HG groups by the researcher. The test instrument used to determine the performance of the learners was the Test of Integrated Science Process Skills (TISPS) developed by Kazeni, (2005). This TISPS was used as the pre-test as well as the post-test. This instrument does not test content knowledge of "Phase change matter", the TISPS measures learners' knowledge of science process skills which are common across any science topic or any science practical investigation, (see Appendix. 1). In phase two the HG group was treated with the hands-on practical intervention on the topic "Phase change of matter" while the VG group was exposed to the virtual practical intervention on the same topic. Both groups had to write a scientific report for their corresponding practical activity, which included table of experiment results and graphs from which quantitative data were drawn to compare the two experiments. In the third phase both groups wrote the post-test to determine if there were any significant changes in their performance after the exposure to the treatment. For the post-test the research study used the same TISPS instrument which was used in the pre-test. Phase four, the intervention treatments were swapped, the HG had to do the virtual practical activity and the VG now had to do the hands-on practical activity. The research study swapped the practical method for the groups so that they would be able to compare the two approaches when giving responses to the attitude questionnaire. With the two groups now subjected to both interventions, they responded to the attitude questionnaire. The research design summary is given in the table: 3.1.

Table 3.1. Research design summary

	HG (control) group	**VG (experiment) group**
Phase 1	Pre--test	Pre--test
Phase 2	Hands-on practical	Virtual practical
	Experiment report	Experiment report
Phase 3	Post-test	Post-test
Phase 4 (swap)	Virtual practical	Hands-on practical
Phase 5	Attitude questionnaire	Attitude questionnaire

3.3. Sample

The total sample of participants in this research study was forty-four learners, comprising of twenty-two females and twenty-two males. The participants were learners from two grade 10 physical science classes at a school in the Western Cape Education Province in the Metro South district. Of the two classes, the researcher randomly selected one group for the virtual practical treatment, the other class was assigned for the hands-on practical treatment. One class, the HG, consisted of a total of twenty-two learners; eleven females and eleven males. The other class, the VG, also consisted of a total twenty-two learners; eleven females and eleven males.

The school is located in a middle class community area in the Western Cape Province in the Metro South District. Although the school caters for the local middle class population, there are learners from middle class society living, in the southern suburbs of Cape Town. the school also has learners from low income families living in the high density township of Cape Town. The school population is multiracial. The research sample had 44 learners of which 31 were of the coloured race, 7 were blacks, 4 whites and two asians. The school is a former model C and fall under the quintile index rating 4. In the South African quintile rating system, schools in the levels 4 and 5 are fees paying schools, the government subsidises part of the schools expenses. Quintiles 1, 2 and 3 are non fees paying schools, they are fully funded by the government. The average learner performance for grade 10 physical sciences in this school ranged from 42% to 53% in the last three years. The average learner performance for grade 10 physical sciences in 2012, 2013 and 2014 were 49%, 42% and 53% respectfully. The medium of instruction for this school is English. The sample demographics were summarised in table 3.2.

Table 3.2. Sample demographics

	VG		HG		Total
Sample size	22		22		44
Gender	Male	Female	Male	Female	44
	11	11	11	11	
Age range	15 years – 17 years				
Grade	10				
Race	Multi-racial				
	Black=7	White=4	Coloured=31	Asian=2	
Social economic background	From low income families From middle income families				

The control group (which is the hands-on practical group HG) was exposed to hands-on practical intervention before the post-test and experimental group (which is the virtual practical group VG) was exposed to the virtual practical intervention before the post-test. All twenty-two learners in HG participated in the pre-test, post-test and experiment report. Likewise, all twenty-two learners in the VG participated in the pre-test, post-test and experiment report. One learner from the HG did not participate in the attitude questionnaire due to absenteeism on the day the practical activity was carried out, Table 3.3. shows participants according to groups.

Table 3.3. Number of participants per phase

Participating category	Phase	Number of participants

		Males	Females	Totals
Total number of participants		22	22	44
HG	• Hands-on practical	11	11	22
HG	• Experiment report	11	11	22
HG	• Pre- and post-test	11	11	22
VG	• Virtual practical	11	11	22
VG	• Experiment report	11	11	22
VG	• Pre- and post-test	11	11	22
HG	Attitude questionnaire			21
VG	Attitude questionnaire			22

3.3.1. Sampling method and technique

The sampling technique in this research study had non-random, convenient and purposeful characteristics (Cohen, Manion & Morrison, 2007). The non-random sampling technique was used since the already existing grade 10 physical sciences classes were selected as the HG and VG for this research study. As there were only two Grade 10 classes taking physical sciences as an elective subject, the researcher randomly assigned one of these classes to be the HG and the other class to be the VG. Non-random sampling is biased as it does not give participants equal probability of selection (Cohen, Manion & Morrison, 2007). The researcher was aware of the fact that participants selected by non-random method may not be a true representation of a population, therefore inferences drawn from the data collected from this sample are true for this particular sample only. The school was chosen for its convenient accessibility to the researcher and also because it has a functioning computer lab as well as a functioning science laboratory. The virtual practical activity at the researcher's disposal from the internet is on the topic 'phase change in matter' which is one of the content topics in grade 10 physical sciences.

Grade 10 physical sciences classes were purposefully selected over other higher grades physical sciences groups for two reasons. They have not had any prior intervention on the topic at Further Education and Training level (FET), which might affect the reliability of the data. The practical activity on phase changes is one of the prescribed formal assessment tasks in grade 10 physical sciences according to the national Curriculum and Assessment Policy Statement (CAPS). The application of the instruments for data collection was therefore done during the normal lesson time, the participants were studied in their natural learning environment (Buckle & Dwyer, 2009). The fact that the practical activity selected for this research study was part of formal assessment program, meant that participation was guaranteed.

3.4. Study variables

The independent variable is the practical intervention approach, namely the virtual practical intervention and the hands-on practical intervention. The dependent variables are the pre- and post-test scores. Figure 3.1. describes the variables of this research study

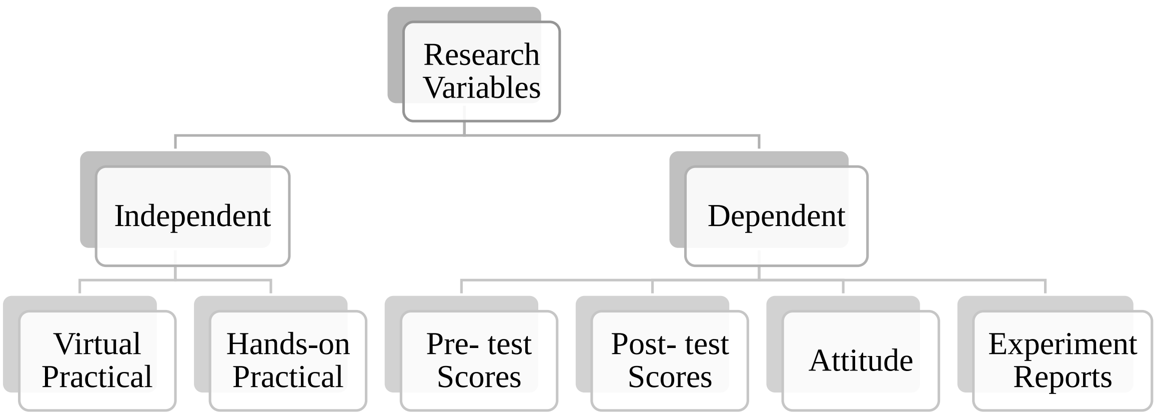


Figure 3.1. Research variables

3.5. Instrumentation

Data were drawn from two instruments; the test instrument and the questionnaire as well as from the experiment reports. The test instrument provided data for learner performance before and after the practical interventions, the virtual and hands-on practical interventions, and the attitude questionnaire provided information on the learners' opinion on the practical interventions used. From the experiment reports, information on measuring, recording and processing experimental results was obtained.

3.5.1. Instruments

3.5.1.1. The test instrument

The performance of the learners before and after the interventions was established using the Test of Integrated Process Skills (TISPS) developed and validated by Kazeni (2005). The instrument has thirty items of multiple choice, testing learners on the following practical investigation skills; 'identifying and controlling variables', 'stating hypotheses', 'operational definitions', 'interpreting data', and 'experimental design'. The pre- and post-test instrument was assessed by the marking memorandum developed by Kazeni, (2005); see Appendix 1. Table 3.4. summarises the process skill tested by each item in the test.

Table 3.4. TISPS test instrument item summary

Process skill tested	Item number on the test instrument	Total marks per skill
Identifying and controlling variables	2, 6, 16, 19, 25, 28, 29, and 30	8
Stating hypotheses	8, 20, 23, and 26	4
Operational definitions	1, 7, 10, 18, 21, and 22	6
Interpreting data	4, 5, 9, 11, 12, 14, 17, 24, and 27	9
Experimental design	3, 13, and 15	3

3.5.1.2. The attitude questionnaire instrument

This instrument was designed by the researcher to compare learner attitude towards virtual practical and hands-on practical activities; see Appendix 5a and Appendix 5b. The attitude questionnaire, which had 12 items, was applied to both groups by the researcher. The attitude questionnaire had questions to seek the learner's opinion on: user preference, items # 3 and 10: equipment usability, items # 4 and 5; completion time # 8; how realistic the experiment was, item # 7; functionality and learning experience, items # 6 and 9. The attitude questionnaire had thirteen items which included some open ended questions items # 3, 4, 11, 12 and. Learners responded to the items on the attitude questionnaire by choosing between two options, yes or no for items #2 and #11 and by selecting either 'hands-on practical ' or 'virtual practical' for items # 4 to # 10.

2.5.2. Validity of instruments

The validity of an instrument is an indication of the degree to which the instrument measures what it intends to measure (Vogt, 2007). The validation of the instruments was done by enlisting the help of three experienced expert educators; one experienced physical sciences educator, one head of science educator with experience in both physical and life sciences and one experienced matric English language educator. The experience and qualifications of the expert group is summarised in Table 3.5.

Table 3.5. Details of the reference expert **group**

	Experience	**Qualification**
1	• Physical Sciences Educator • Physical Sciences paper 2 matric marker	Bachelor of Science + PGCE
2	• Head of Science department • Experience with FET, CAPS and other previous curricula	Bachelor of Science + PGCE
3	• English first language teacher FET • English language matric exam marker	Bachelor of Arts Languages + B. Ed Honors

For this study, content validity was important to ascertain, whether the items in the test instrument, the practical investigation guideline and the attitude questionnaire, measured the concepts they intended to measure (Cohen, Manion, & Morrison, 2007). The test instrument used in this research study (Test of Integrated Science Process Skills [TISPS]) (see appendix 1.) was developed and validated by Kazeni (2005) in the South African context and for the Revised National Curriculum Statement (NCS). The content validity value obtained was 0,988 which is within the acceptable standard range of ≥ 0.7. This meant that the test instrument carefully covered all the items it intended to measure. In this research study the test instrument (TISPS) was not further validated since it was applied in a similar South African school context. Although the curriculum has changed from RNCS through Outcome Based Education

(OBE) to Curriculum Assessment Policy Statement (CAPS), the objectives for science learning still emphasise teaching of science process skills through practical investigations as before.

When the reference expert group analysed the test instrument, they suggested the re- structuring of the test item # 9 to make it similar to the data processing the learners did in their scientific reports. Before the changes test item # 9 was testing learners' data interpreting skills using the results from a chemical reaction investigation, with time and volume of gas as the variables. The changes are described here;

Before the change, the test item # 9 read;

"… 9. Sandile carried out an invetication in which she reacted magnesium with dilute hydrochloric acid. She recorded the volume of the hydrogen produced from the reaction, every second. The results are shown below;

Time (seconds)	0	1	2	3	4	5	6	7	
Temperature (^{0}C)	0	14	23	31	38	40	40	40	

Table: 1.1 shows the volume of the hydrogen produced per second…"

After the changes test #9 was still testing learners' data interpreting skills, but on results from a phase change practical investigation, with time and temperature of the substance as the variables.

After the change, the test item # 9 read;

"… 9. Sandile carried out an investigation to see the effect of heat energy on the phase of a substance **X**. She recorded the temperature of the water every one minute. The results of are shown below;

Time (minutes).	0	1	2	3	4	5	6	7

Temperature (^{0}C)	0	14	23	31	38	40	40	40

Table 1.1 shows the temperature of the substance X per second...”

The learners were tested for the same skill but in the context similar to their experiences in the practical investigations.

The reference expert group evaluated the practical investigation guideline for both the virtual practical activity (see appendix 3.) and the hands-on practical activity (see appendix 2.). The reference expert group found them appropriate for physical sciences grade 10 and that they complied with the requirements of the CAPS prescribed formal practical assessment.

In this research study, the learners from both groups had to write a scientific report after carrying out the practical activity interventions. The researcher designed the scientific report template and its marking guidelines, (see appendix 4). These were evaluated by the reference expert group and suggestions to reduce the mark allocation for the graph from 10 to 7, as per CAPS regulation. The researcher effected the changes proposed. When verified for, language simplicity, clarity of questions and ambiguity by the English language expert in the group, the scientific report template and the memorandum were found be effective and valid.

The researcher designed the attitude questionnaire, the reference expert group verified the attitude questionnaire; for readability, comprehensiveness, language clarity and simplicity to ensure that it was well structured to a level suitable for grade 10 learners. In their evaluation of the attitude questionnaire, reference expert group proposed to reduce the option choices to two as many options could confuse the learners. The researcher made the changes as indicated here;

Before the changes, the learners had to choose their responses to the questionnaire items from five options, namely;

- strongly agree

- agree
- undecided
- disagree
- strongly disagree (see extract from the attitude questionnaire before the changes)

Table 3.6. Extract from the attitude questionnaire before the changes

No	Item	Strongly agree	Agree	Undecid	Disagree	Strongly disagree
4.	It was easy to learn and operate the computer simulation.					

After the changes, the learners could now choose their responses from the two options as shown here

Table 3.7. Extract from the attitude questionnaire after the changes

Question	Your response			
4. Which practical investigation was easy to learn and operate?	Hands-on		Virtual	

Explain ____ _______				

For face validity, the instruments were checked for readability and comprehensiveness to ensure that they were well structured and the reference expert group found them to be compliant. After all the suggested changes were effected, the reference expert group were satisfied that the attitude questionnaire and the practical investigation guideline and its marking guideline were relevant for collecting the required data.

2.5.3. Reliability of Instruments

Reliability is a measure of how consistent an instrument reproduces the stable and consistent results under the same conditions (Creswell, 2003). The test instrument (TISPS) used for pre- and post-testing in this research study had a reliability coefficient of 0,81 which is within acceptable range of 0,7-1,0 and the readability level of the same instrument was 70.3 on Flesch's reading ease scale which was within easy readable range (Kazeni 2005). No new reliability test or readability test were done on the test instrument for this research for the fact that it was being used in similar context as when it was developed.

A pilot study was conducted and the Kazeni (2005) TISPS, the virtual and the hands-on practical investigation and the attitude questionnaire were administered. The purpose of the pilot study was to check language clarity and comprehension of items, time of completion and the logistics of the data collecting process. The sample for the pilot study came from the grade 10 physical sciences learners of the same school as the sample for the main study. The pilot study used the grade 10 physical sciences learners of 2015 in term one for their first formal practical investigation. On the other hand, the main study was conducted with grade 10 physical sciences learners of 2016 in term one. After the administration of the pilot study, the time allocation for the test instrument was reduced from one hour to fifty minutes. The time allocated for the administration and facilitation of the hands-on and the virtual practical investigations was not adjusted. When the attitude questionnaire was applied during the pilot study, it did not present any problems of clarity and or comprehension.

3.6. Practical investigation intervention

Two variants of practical interventions were used; virtual practical on water heating curve and hands-on practical activity also on water heating curve (see Appendices 2 and 3). The hands-on practical was analogue to the virtual practical investigation. The guidelines for the virtual practical activity were structured by the researcher using the prescribed guidelines from the grade 10 physical sciences CAPs approved text book (Broster, Horn, & James, 2011a; 2011b). The guidelines for the virtual practical activity came from the virtual animation sourced from the internet (Flash Animations for MATTER, Change of State, (n.d). The materials that were used in the virtual practical activity were similar to the materials used in the hands-on practical activity, in the same manner; the method that was followed in carrying out the virtual practical activity had similar steps as the method used for the hands-on practical activity. The analogy of the properties of both methods is shown in Table 3.8.

Table 3.8. VP – HP similarities

	Hands-on practical investigation procedure	**Virtual practical investigation procedure**
	• Thermometer	• Virtual temperature sensor

Materials	• Heating apparatus burner, tripod stand, gauze wire)	• Virtual heating mantle
	• Ice	• Virtual ice water
	• Beaker	• Virtual Flask
	• Stop watch	• Virtual Timer
	• Recording material	• Values auto recorded
Method	• Write a scientific report for the practical investigation	• Write a scientific report for the practical investigation
	Worksheet with step by step method and guidelines is provided Basic steps	The virtual program provides step by step instructions Basic steps
	• Measure initial temperate of specific volume of water	• Put the flask with water on the heating mantle.
	• Heat the water, while recording its temperature at 1minute intervals on prepared recording table	• Click on the record button every one minute to record the temperature of water while its heating
	• Use results to write scientific report • Report to include table of results and graph	• Use results to write scientific report • Report to include table of results and graph

Mediation /intervention	Method mediated before the practical. Learners assisted during the practical by the teacher	Method mediated before the practical Learners assisted during the practical by the teacher
Science teacher	Mediated by the same teacher for both classes	

3.7. Data collection method

Two instruments were used to collect the data for this research study. The test instrument was used to collect the leaner performance data and the attitude questionnaire was used to collect data on learners' views of the practical interventions. The administration of the test and the questionnaire instrument, as well as the implementation of the practical activity interventions were executed in five phases which covered a period of about five school weeks. All the instruments were administered by the researcher. This section describes the process of data collection for this research study.

3.7.1. Collection of learner performance data; pre-test

In order to respond to the research question on the effect of the virtual practical intervention on learner performance, the test instrument was administered by the researcher. The test instrument used for this research study was the Test of Integrated Science Process Skills [TISPS]. The TISPS and its marking memorandum were developed by Kazeni (2005). Although the TISPS does not directly measure content knowledge performance, it measures the knowledge of integrated science process skills, which are presumably developed during practical work in science in any science topic.

In phase one refer to research design summary in table 3.1.), the pre-test was administered to both HG and VG. The purpose of the pre-test was to measure learners' performance before the practical interventions. The test was written under exam conditions with both groups writing the test at the same time in the same exam venue. The administration of the test was supervised by two invigilators; the researcher and one other science educator from the school. The administration of the pre-test took a duration of one hour, which was one lesson period on the school timetable, the test was done during normal school lesson time. The marking of all the pre-test scripts and the recording of the pre-test results was done by the researcher. The marked test scripts were moderated by the head of the science department to check for consistency with the marking memorandum. Moderation of assessment tasks is a requirement by the Department of Basic Education as a quality assurance measure.

3.7.2. The practical activity intervention

Phase two involved the execution of the practical investigation, the writing of the scientific report and the marking of the report, (refer to research design summary in table 3.1). In this phase, the researcher taught the concept of ‘phase change in matter’ using the virtual practical activity for the VG (see appendix 3.) and through the hands-on practical activity for the HG (see appendix 2.). Both practical interventions took place on the same day, about a week after the administration of the pre-test. In order to minimise contamination, and prevent learners exchanging ideas before their turn for intervention, the practical intervention lessons were organised on the day when the two groups had physical sciences in consecutive lesson periods. Thereafter both groups wrote experiment reports in monitored classroom conditions, one group at a time. In order to ensure uniformity, for the experiment report, the researcher provided the learners with a prepared template to guide them, (see appendix 4.). The researcher designed both the experiment report template and the marking memorandum and marked the experiment reports, in accordance with the marking guidelines. The head of the science department then checked the marked scripts for consistency with the marking guidelines.

3.7.3. Collection of learner performance data; post-test

Phase three was the administration of the post-test to the learners in both the VG and the HG, see table 3.1. The post-test was written approximately a week after the carrying out of the practical interventions. The purpose of the post-test was to measure learners' performance after the practical interventions. The same TISPS used as pre-test instrument was administered as the post-test to both groups again. Both groups wrote the post-test concurrently, under exam conditions with the supervision of the two invigilators, (the researcher and one science educator from the school). The post-test was marked and the results were recorded by the researcher and moderation of the marked post-test scripts was done by the head of science department. The administration of the post-test took a duration of one hour, which was one lesson period on the school timetable, the test was done during normal school lesson time.

3.7.4. The swap

In phase four of the data collection period, the researcher swapped the experiment method for the groups so that they would be able to compare the two approaches when giving responses to the attitude questionnaire. This meant that the HG group which was taught through the hands-on practical in phase two, was now being exposed to the virtual practical. In the same way the VG group which was mediated through the virtual practical activity was now getting the chance to experience the hands-on practical activity. The practical intervention lessons were organised on the day when the two groups had physical sciences in consecutive lesson periods on their time table. The researcher mediated the practical activities for both groups during the swap phase, which took place on the same day for both groups, about a week after the administration of the post-test. The purpose of this research study was to determine the impact of the practical interventions on learner performance as well as learner attitude towards the practical interventions. The swapping of the practical intervention methods provided a platform for learners from both groups to experience both practical activities. The reason for exposure to both practical methods was to allow for a deeper and more direct comparison of the groups' experiences when responding to the attitude questionnaire. The research study acknowledges the fact that at the stage of swapping, both groups now had prior knowledge of the topic 'phase change in matter' and the knowledge of the practical investigation. The learners were not required to write any scientific report, they were not expected to take any performance test after the swap had happened.

3.7.5. Collection of learner attitude data

Phase five of the data collection period involved the implementation of the attitude questionnaire (refer to research design summary in table 3.1.), in order to provide data for the research question on learner attitude towards the practical interventions used in this research study. The attitude questionnaires were administered by the researcher to both groups, one group at a time in controlled classroom conditions and it took place one week after the swapping of the practical interventions had occurred. Learners were discouraged from discussing and sharing views when responding to the attitude questionnaire. The results of the learners' responses to the attitude questionnaire were recorded and processed by the researcher.

The administration of the research instruments could only be done in the time when the two classes had physical sciences lessons, in their normal lesson time. The data collection period lasted for about five weeks. This was done during term one of the academic year 2016.

3.8. Approach to data analysis

Statistical analysis were done to the pre- and post-test results. The response from the attitude questionnaire were tallied in a table then percentages from these were calculated and compared.

3.8.1. Analysis of test score results

All statistical analysis was done using the online statistical software program Quickcalcs, to produce summary statistical representative data. Quickcalcs is an online software program for statistical analysis of data (online). Unpaired sample t-test for pre-tests was done to determine if there was any significant difference in the performance between both groups before the practical interventions. And after the practical interventions. Unpaired sample t-test for post-tests was done to determine if there was any significant difference in the performance between both groups after the practical interventions. The paired t test for the pre- and post-tests scores were calculated for each group to find out if there was any change in learner performance after the implementation practical of interventions. An average performance for each process skill category was calculated using Microsoft office excel tool and group performances in these were compared. The learners' responses to the attitude questionnaire were also computed and compared.

3.8.2. Analysis of the attitude questionnaire responses

The responses from the attitude questionnaire were analysed according to the groups of this research study. For each group, the responses to each questionnaire item were tallied in a table, (see table 3.9.)

Table 3.9. The questionnaire responses recording table

Question	**Response**		
	Male	**Female**	**Total**
1			
	Yes	**No**	

2			
	Hands-on	**Virtual**	
3			
4			
9			
10			
	Comments		
4			
11			

For items 1 to 10, response frequencies were tallied in the appropriate column in the table. The table also provided space for recording response to the open-ended questionnaire items 4, 11 and 12. Some of the most frequently used comments were selected and used for qualitative data for this research study. The data in the tally was then converted into a frequency table. The response data was then converted into percentages for easy comparison between the groups.

3.9. Position and role of researcher

The researcher had a substantially active role in the data collection process. The researcher administered the pre- and post-test to both groups with the help of another invigilator. The researcher then taught the concept of ‘phase change in matter’ through virtual practical to the VG and through hands-on practical to the HG. The researcher also administered the attitude questionnaire to both groups.

Being aware of bias due to participation and involvement, the researcher was cognisant to teach both groups in a similar and consistent way. For the attitude questionnaire, careful consideration was taken to participants' anonymity. It was explained to the respondents that they didn't have to reveal their identity. Furthermore, the learner consent form signed explained how the respondent identity was going to be protected (see Appendix 8.).

Researcher involvement brings about the insider perspective (participant) as well as the outsider perspective (researcher) in any study, thereby enriching the deductions and interpretations Buckle, & Dwyer, 2009). On the other hand, a researcher feels more obliged to protect data and respondents due to acquaintances developed during data collection.

3.10. Ethical considerations

A letter of ethical clearance for this research was obtained from the Faculty of Humanities (see Appendix 9.). Using the Faculty clearance to conduct research in schools, application for permission to conduct the research in the school was done with the Western Cape Education Department and it was approved (see Appendix 6.). The principal of the school was also consulted for his consent and it was granted (see Appendix 7.). Written informed consent was also obtained from all the learners who took part in the attitude questionnaire (see Appendix 8.). The practical interventions were done during normal lesson time, as part of the formal assessment tasks for grade 10 physical sciences, therefore no parent consent was required according to the Faculty of Humanities ethical policy. However, it was explained to the learners that their participation in the attitude questionnaire was voluntary and that their identity would be protected. The participants were made aware of the fact that any data collected from them for this research may be passed on to other researchers, or interested parties without disclosure of their identities.

3.11. Summary

This chapter provided the outline for the research design and method. Development of instruments and administration of the instruments were elaborated in this chapter. Descriptions of data collection methods, data analysis, ethical considerations, validity and reliability of instruments were discussed.

3.12. Conceptual framework, literature review and methodology

The theory underpinning this research study is that practical work supports science learning (Allisop and Woolnough, 1985) and that science learning is organised into domains namely; concept, process, attitude, application, creativity and nature of science (refer to section 2.3). Science practical work encompasses the mentioned aspects though not in categorised manner but they are tacitly integrated. Therefore, teaching and learning experiences with practical activities offer learning that is more wholesome, practical investigations that are inquiry in nature are widely used.

Research has explored practical work from various angles. Research studies have been done to find out the effect of practical activities on some learning areas of sciences as attitudes, conceptual development and science processes. Some literature reviewed report that practical work offer inquiry learning environment (Herog, Moore and Perkins, 2013). Some literature indicate practical work improves learner's attitude towards learning (Kassa and Damtie, 2007). Other research studies have concluded that practical work improves learner performance (Kiribiringe, Maake and Mavhunga, 2014).

This research set out to investigate the effect of virtual practical work on science learning. One way to establish the influence of the practical intervention is to measure learner performance on science process skills. This research study designed a quasi-experiment study in which two groups were virtual or hands-on practical interventions. The groups pre- and post- test scores were used to draw inferences which practical activity option (virtual or hands-on) influence learner performance in science process skills. Information on learner attitude towards the practical work options was collected through a questionnaire.

Chapter Four: Data analysis

4.1. Introduction

This chapter describes the analysis of the pre- and post-test scores to determine if there was any significant difference in the learner performance on integrated science process skills after the practical interventions. The responses of learners to the attitude test were also analysed in order to establish learners' opinion and disposition on the practical interventions.

4.2. Analysis of test score results

All statistical analysis was done using the online statistical software program Quickcalcs, to produce summary statistical representative data. Quickcalcs is an online software program for online statistical analysis of data. Unpaired sample t-test for pre-tests and post-test was done to determine if there was any significant difference in the performance between the two groups before and after the practical interventions. Paired t test for the pre- and post-tests scores were calculated for each group to find out if there was any change in learner performance after the implementation of practical interventions. An average performance for each process skill category was calculated and group performances in these were compared, and then processed graphically. The learners' responses to the attitude questionnaire were also computed and compared.

4.2.1. Statistical data analysis

The statistical data established that pre- and post-tests results for both groups had a normal distribution according to the Anderson test as illustrated in Table 4.1. A normal distribution is an arrangement of a data set in which most values cluster in the middle of the range and the rest taper off symmetrically toward either extreme.

Table 4.1. The statistical data for pre- and post-tests

Test	Group	N	Mean	SD	SEM	Normality Confidence (Anderson test)
Pre-test	HG	21	65,29	9,61	2,10	44.49
	VG	22	60,59	12,23	2,61	79,10
Post-test	HG	21	68,95	9,87	2,15	0,41
	VG	22	59,73	9,96	2,12	4,74

4.2.2. Statistical t test analysis

In order to determine if there was any significant difference in the learners' performance due to the type of practical approach applied, paired samples t-tests analysis were used, comparing pre-test and post-test scores for learners in each group. The results for the HG are shown in Table 4.2.

Table 4.2. Pre- and post-test analysis for HG

Test type	Group	N	X	SD	t	p
Pre-test	HG	21	65,29	9,61	1,5925	0,1277
Post-test	HG	21	68,95	9,87		

The data in Table 4.2. show the outcome of the t test analysis of the pre- and post-test mean scores for the HG. The significance level was determined using the p values, where p>0,05 indicate that there was no significant difference and p<0,05 show that there was significant difference in learners' performances. In this case, a p value of 0,1277 was obtained, therefore there was no significant difference in the learners' performance for the HG, before and after the hands-on practical intervention was applied.

Paired sample t-tests analysis were calculated for the pre-test and post-test scores for learners in the VG as illustrated in Table 4.3.

Table 4.3. Pre- and post-test analysis for VG

Test type	Group	N	X	SD	t	p
Pre-test	VG	22	60,59	12,23	0,3205	0,7518
Post-test	VG	22	59,73	9,96		

The data in Table 4.3. show the result of the t test analysis of pre- and post-test mean scores for the VG. A p value of 0,7518 (Table 4.3) was obtained which by convention indicate that there was no significant difference in the performance of the learners in this group before and after the virtual practical intervention was administered. The intra-group t test analysis revealed that there was no significant difference in learner performance after the practical instrument for both groups.

Unpaired sample t test analysis was determined for the pre-test scores of the two groups. Unpaired t tests analysis is used to compare data from two different and independent subjects in order to verify if the data is the same or not. Unpaired t-test for pre-test scores was done to establish if the performance of the two groups were equal before their exposure to the practical interventions. Unpaired t test analysis results are shown in Table 4.4.

Table 4.4. Pre-tests analysis for VG and HG

Test type	**Group**	**N**	**X**	**SD**	**t**	**p**
Pre-test	HG	21	65,29	9.69	1,3947	0,1706
Pre-test	VG	22	60.59	12,23		

The data in Table 4.4. show the results of the unpaired t test analysis of the pre-test mean scores of the two groups. The t test analysis revealed a p value of 0,1706, indicating no significant different in the performance of the learners. The significance level was measured with p values where $p>0,05$ indicates no significant difference and $p<0,05$ indicates significant difference in learners' performances. The results in Table 4.4. indicate that the two groups, the HG and the VG, were at similar performance levels before the practical interventions were applied.

Unpaired sample t test analysis was determined for the post-test scores of the two groups. Unpaired t-test for post-test scores was done to establish if the performance of the two groups were equal after their exposure to the practical interventions. Unpaired t test analysis results are shown in table 4.5.

Table 4.5. Post-tests analysis for VG and HG

Test type	**Group**	**N**	**X**	**SD**	**t**	**p**
Post-test	HG	21	68,95	9,87	3,0495	0,0040
Post-test	VG	22	59,73	6,96		

The data in Table 4.5. show the results of the unpaired t test analysis of the post-test mean scores of the two groups. When the post-test results of the two groups were calculated, a p value of 0,0040 was produced. The significance level was measured using p values, where $p>0,05$ indicates no significant difference and $p<0,05$ indicates significant difference in learners' performances. It was found that the performance of the two groups was significantly different after the administration of the practical intervention. The HG with an average score of 68,95% performed significantly higher than the VG with an average score of 59,73%.

Therefore, the students who were taught the concept of 'phase change in matter' through the hands-on practical intervention performed better than those who received the same topic through the virtual practical intervention. On the basis of this statistical analysis, the null hypothesis, 'that the *learners performance is not influenced by the type of practical approach* *used'* is rejected in this research study. The hypothesis: *The learners' performance is influenced by the practical intervention used* is therefore upheld.

4.3.

4.3.1. Overall data analysis of test scores

The pre- and post-test scores for the VG and the HG were recorded. The pre- and post-test scores for each group were calculated using Microsoft Excel tools. The percentage scores for these test scores were calculated and consequently the average percentage scores for the pre- and post-test scores were determined for both groups. An extract of the Excel page showing the overall test scores data analysis is shown in Insert 4.1.

Hands-on Group	HG			Pre-test		Post-test	
Name of learner	Gender	Code ID	Group	Test score	%	Test score	%
	F	2	HG	20	66.67	21	70
	M	1	HG	21	70	23	76.67
	M	4	HG	19	63.33	22	73.33
	M	7	HG	19	63.33	21	70
	F	8	HG	20	66.67	24	80
	M	10	HG	22	73.33	24	80
	F	20	HG	18	60	20	66.67
	M	23	HG	23	76.67	24	80
	M	25	HG	26	86.67	21	70
	F	26	HG	18	60	22	73.33
	F	29	HG	20	66.67	19	63.33
	M	30	HG	17	56.67	23	76.67
	F	31	HG	18	60	17	56.67
	F	33	HG	17	56.67	11	36.67
	M	35	HG	14	46.67	21	70
	F	39	HG	19	63.33	21	70
	M	41	HG	20	66.67	20	66.67
Average				19.58636	65.29	20.68636	68.95

Virtual Group				Pre-test		Post-test	
Name of learner	Gender	Code ID	Group	Test score	%	Test Score	%
	M	3	VG	19	63.33	16	53.33
	M	5	VG	19	63.33	20	66.67
	F	6	VG	20	66.67	13	43.33
	M	9	VG	26	86.67	18	60
	F	11	VG	13	43.33	16	53.33
	M	13	VG	17	56.67	20	66.67
	F	18	VG	22	73.33	20	66.67
	M	21	VG	15	50	17	56.67
	F	22	VG	14	46.67	15	50
	M	27	VG	25	83.33	21	70
	F	34	VG	18	60	21	70
	F	37	VG	16	53.33	20	66.67
	M	38	VG	19	63.33	16	53.33
	F	40	VG	20	66.67	16	53.33
	F	42	VG	17	56.67	16	53.33
	M	43	VG	20	66.67	18	60
	F	44	VG	19	63.33	21	70
Average				18.17727	60.59	17.9	59.73

Insert 4.1. Overall data analysis of test scores

Insert 4,1 show the results of the overall data analysis of the test scores. The results obtained from this analysis show that the average score of the HG increased from 65,29% before the practical intervention to 68,95% after the practical intervention, recording a 3,67% increase. However, the results for the VG show a 0,86% decrease from 60,59% before the intervention to 59,73% after the intervention. Since the same instrument (TISPS) was used for the pre-test and post-test, it was expected that the results of the post-test be either equal to or greater than the post-test, but in this case, they are slightly less. It is possible that some learners were not sure of some of the answers they gave for some questions in the pre-test and hence changed them when they had to answer the same questions in the post-test.

The variation of the group mean results were compared in a bar graph as shown in figure 4.1.

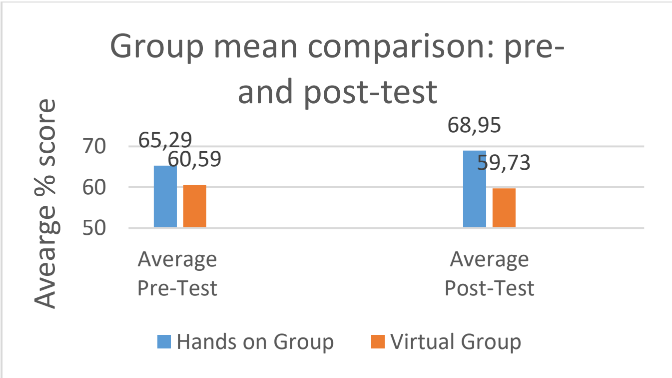


Figure 4.1. Groups' means comparisons

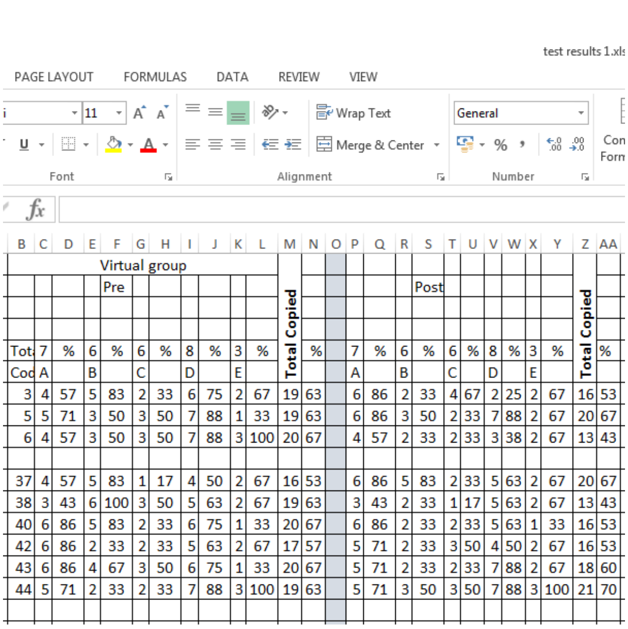
The bar graph in figure 4.1. highlights the difference in the performance of the two groups in the pre- and post-test. These results shown in the graph indicate that the HG performed better than the VG in the pre-test as well as in the post-test. For the pre-test, the VG scored an average of 60,59% and the HG scored an average of 65,29, thereby recording a 4,70% difference in the performance of the two groups. After the practical intervention the VG average score for the post-test was 59,73% while the HG produced an average score of 68,95% recording a 9.22% difference in the performance of the two groups. There was a wider difference in the performance of the two groups for the post-test, than for the pre-test scores. The t test analysis confirmed the widening difference in the performance of the two groups when the t test analysis for the pre-test results produced no significant difference and yet the t test analysis of the post-test results indicated a significant difference in learner performance. (See tables 4.4 and 5.5.)

A further analysis was done to compare the groups' performances in the science process skills tested. The instrument used for the pre- and post-tests in this research study had items to assess learners' knowledge in the following five science process skill categories: Each category was identified by a letter code as indicated in table 4.6.

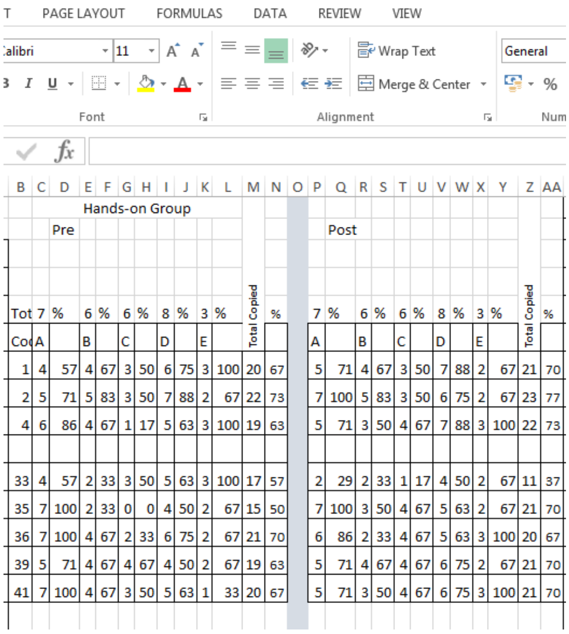
Table 4.6. Science process skills' letter codes

Science process skill	**Letter**
Identifying and controlling variables	A
Stating hypothesis	B
Operational definitions	C
Graphing and interpretation of data	D
Experimental design	E

Calculations were done for the group average percentages for each of the mentioned integrated science process skill. The learners' scores in each science process skill category were recorded. The average group score for each process skill category were calculated using Microsoft office excel tools. Inserts 4.2a. and insert 4.2b. summarise the calculations done on for each process skill.



Virtual group																								
	Pre												Post											
Tot	7	%	6	%	6	%	8	%	3	%	Total Copied	%	7	%	6	%	6	%	8	%	3	%	Total Copied	%
Cod	A		B		C		D		E				A		B		C		D		E			
3	4	57	5	83	2	33	6	75	2	67	19	63	6	86	2	33	4	67	2	25	2	67	16	53
5	5	71	3	50	3	50	7	88	1	33	19	63	6	86	3	50	2	33	7	88	2	67	20	67
6	4	57	3	50	3	50	7	88	3	100	20	67	4	57	2	33	2	33	3	38	2	67	13	43
37	4	57	5	83	1	17	4	50	2	67	16	53	6	86	5	83	2	33	5	63	2	67	20	67
38	3	43	6	100	3	50	5	63	2	67	19	63	3	43	2	33	1	17	5	63	2	67	13	43
40	6	86	5	83	2	33	6	75	1	33	20	67	6	86	2	33	2	33	5	63	1	33	16	53
42	6	86	2	33	2	33	5	63	2	67	17	57	5	71	2	33	3	50	4	50	2	67	16	53
43	6	86	4	67	3	50	6	75	1	33	20	67	5	71	2	33	2	33	7	88	2	67	18	60
44	5	71	2	33	2	33	7	88	3	100	19	63	5	71	3	50	3	50	7	88	3	100	21	70



Hands-on Group																								
	Pre												Post											
Tot	7	%	6	%	6	%	8	%	3	%	Total Copied	%	7	%	6	%	6	%	8	%	3	%	Total Copied	%
Cod	A		B		C		D		E				A		B		C		D		E			
1	4	57	4	67	3	50	6	75	3	100	20	67	5	71	4	67	3	50	7	88	2	67	21	70
2	5	71	5	83	3	50	7	88	2	67	22	73	7	100	5	83	3	50	6	75	2	67	23	77
4	6	86	4	67	1	17	5	63	3	100	19	63	5	71	3	50	4	67	7	88	3	100	22	73
33	4	57	2	33	3	50	5	63	3	100	17	57	2	29	2	33	1	17	4	50	2	67	11	37
35	7	100	2	33	0	0	4	50	2	67	15	50	7	100	3	50	4	67	5	63	2	67	21	70
36	7	100	4	67	2	33	6	75	2	67	21	70	6	86	2	33	4	67	5	63	3	100	20	67
39	5	71	4	67	4	67	4	50	2	67	19	63	5	71	4	67	4	67	6	75	2	67	21	70
41	7	100	4	67	3	50	5	63	1	33	20	67	5	71	3	50	4	67	6	75	3	100	21	70

Insert 4.2a. Mean scores per skill VG **Insert 4.2b. Mean scores per skill HG**

Insert 4.2a. is an extract from the excel page showing the data on VG scores for each science process skill and group averages in each category. Insert 5.2b. is an extract from the excel page showing the data on HG scores for each science process skill and group averages in each category. The average scores were then converted to percentages for comparison of data.

3.3.3. Inter group comparison analysis

An analysis was done in which the pre-tests average scores of each group were compared to show their variation in each integrated science process skill category. Figure 4.2. shows the variation of the pre-test average scores for both groups for each of the five integrated science process skills.

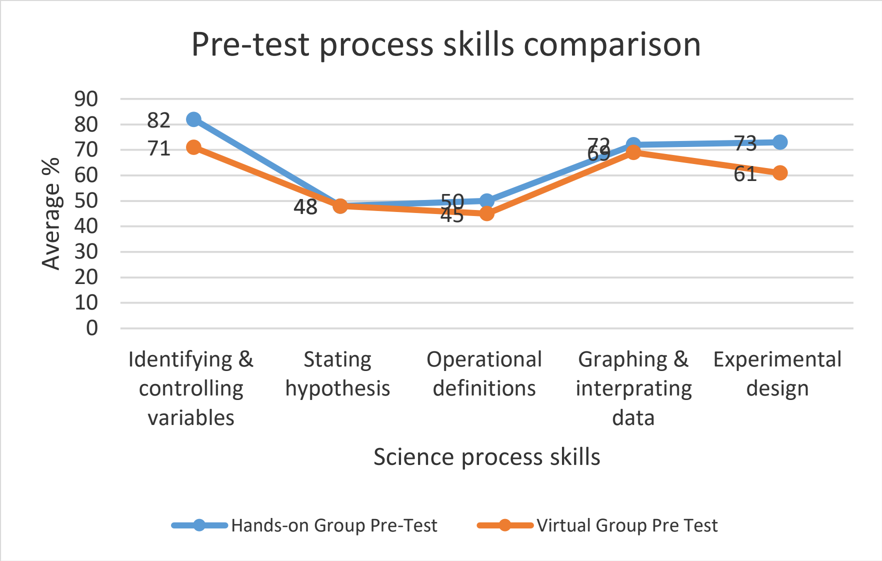


Figure 4.2. Pre-test skills comparison

The data in the graph show that the highest average percentage score for both groups was recorded for the same skill; ‘identifying and controlling variables.’ It was noted that the performance of the VG was lower than that of the HG in all the process skills except on ‘stating hypothesis’, for this category, the average percentage obtained by both groups was equal, at 48%. The pre-test results show noticeable differences in the performances of the two groups in two categories mentioned here; For the science process skill ‘identifying and controlling variables’, the VG scored and average of 71% and the HG produced an average score of 82% , showing a difference of 11%. For the science process skill category ‘experimental design’, a difference of 12% was obtained from the 73% scored by the HG and the 61% scored by the VG.

In a similar way, an analysis was done in which the post-tests of each group were compared to show their variation in each process skill category. Figure 4.3. shows the variation of the post-test average scores for both groups for each of the five science process skills.

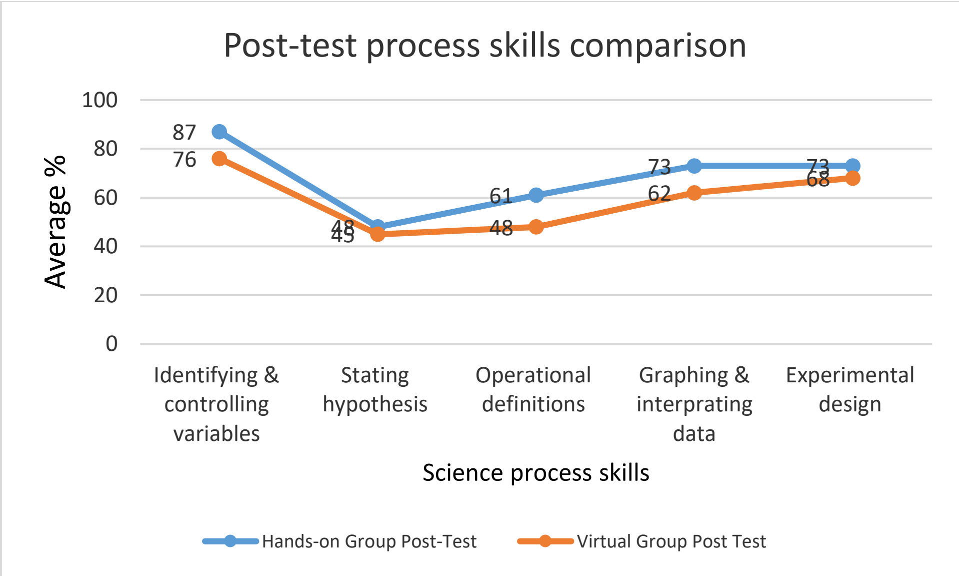


Figure 4.3. Post-test skills comparison

When the group post-test results were compared, as shown in the graph in figure 4.3, the following patterns were noticed; the highest average score for both groups was recorded in the category ‘identifying and controlling variables’ just like in the pre-test results (see figure 4.2.) In all science process skill categories, the HG average scores were higher than those of the VG. The lowest average score for both groups was recorded in the category ‘stating hypotheses. In this category, the VG scored 45%, this score was 3% lower than their score in their score in the pre-test. The HG on the other hand scored 48%, the same score as in the pre-test results. Therefore there was no change in their performance in this category. This could be an indication that both groups struggle in this category. The difference in the performances of the learners was wide for the ‘graphing and interpreting data’ process skill category with 11% difference. In the category ‘operational definitions’ the VG got an average of 48% and the HG scored 61%, see figure 4.3. Here an even wider difference of 13% difference was noticed, implying that the HG’s knowledge on operating definitions was enhanced by the practical intervention. The gap in the performance of the two groups in the post-test was reduced from 12% (in the pre-test) to 5% in the category ‘experimental design’. This change may be attributed to the fact that the VG’s performance improved from 61% to 68% while the HG’s performance remained at 73%.

Consequently, the virtual practical intervention enhanced the group's knowledge on 'experimental design'.

3.3.4. Intra-group performance analysis

An intra-group performance analysis was done in which the pre- and post-tests of each group were compared. Figure 4.4. show how the HG performance in the pre-test score compared with the group's performance in the post-test scores.

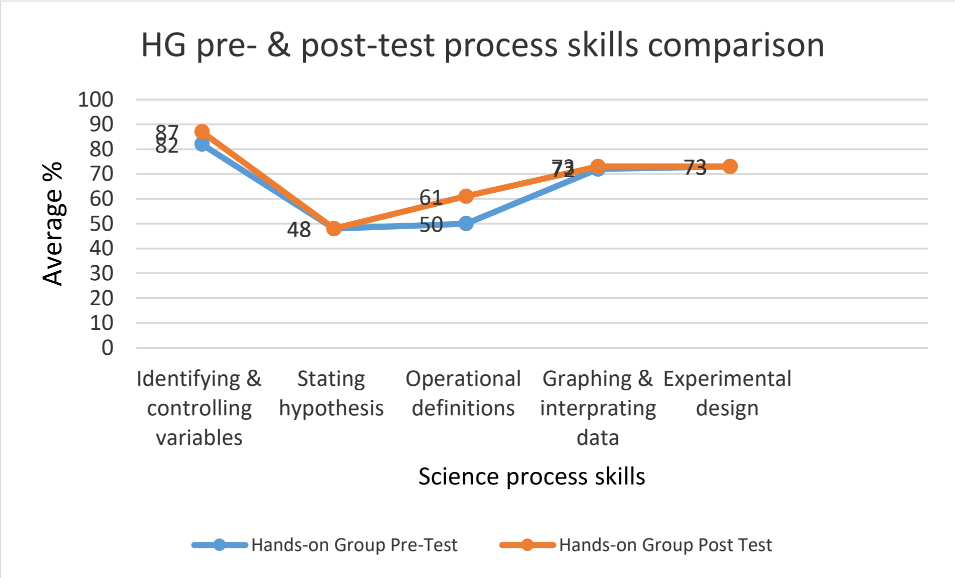


Figure 4.4. HG pre- & post-test skills

The results in the HG performance increased after the application of the instrument except for the: 'stating hypothesis' process skill category which remained at 48% and 'experimental design' which remained at 73%. In the categories, 'identifying and controlling variables and 'operational definitions', the HG's average score was higher in the post-test than in the pre-test, see figure 4.4.

Figure 4.5. shows how the HG performance in the pre-test score compared with the group's performance in the post-test scores.

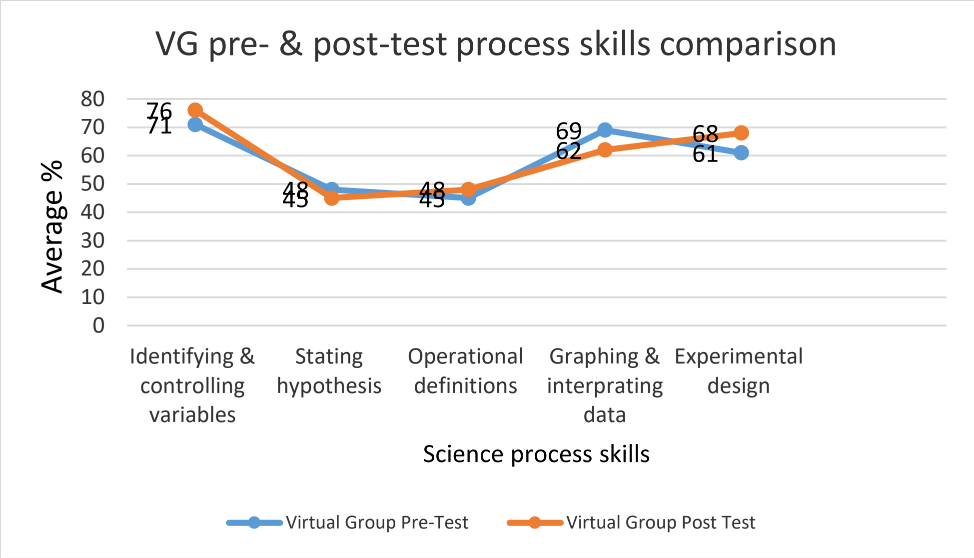
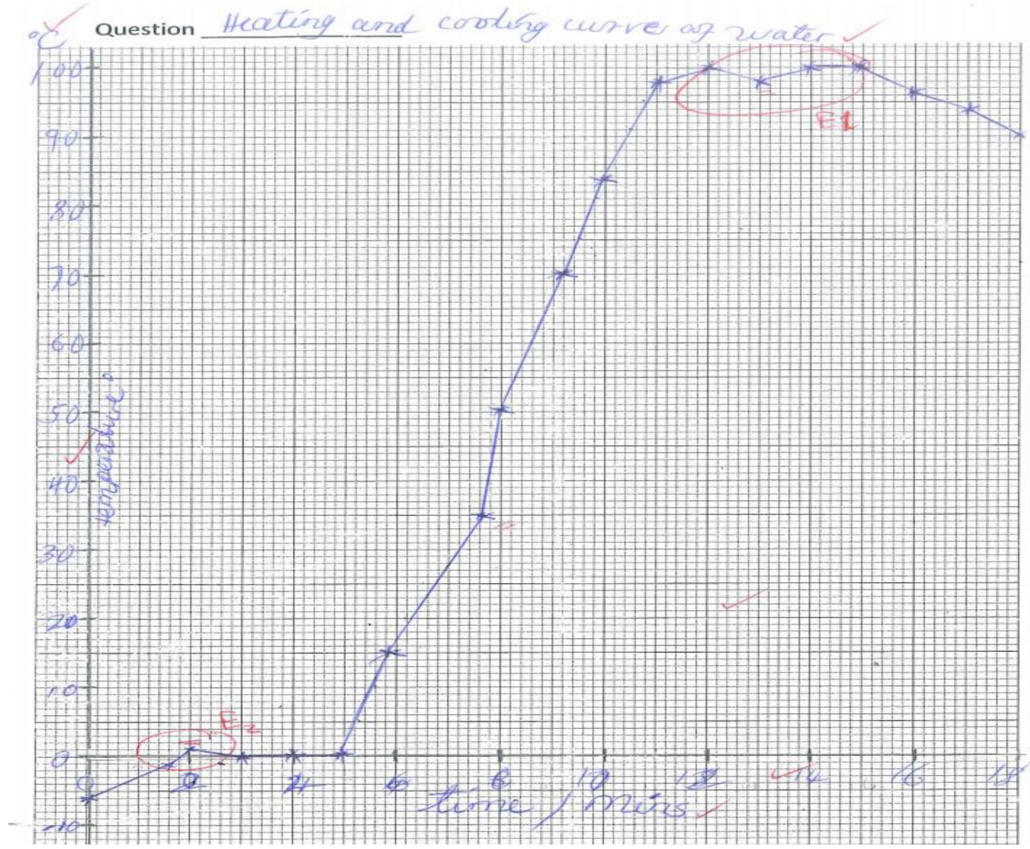


Figure 4.5. VG pre- & post-test skills

The VG pre- and post-test scores shown in figure 4.5. indicate a decrease in the group's performance for the 'stating hypothesis' and 'graphing and interpretation of data' process skill categories. In the category 'stating hypothesis', the average scores dropped by 3% from 48% to 45%. And in the category 'graphing and interpretation of data', the average scores decreased from 69% to 62%, resulting in a 7% decrease see figure 4.5.

4.4. Experimental results obtained by learners

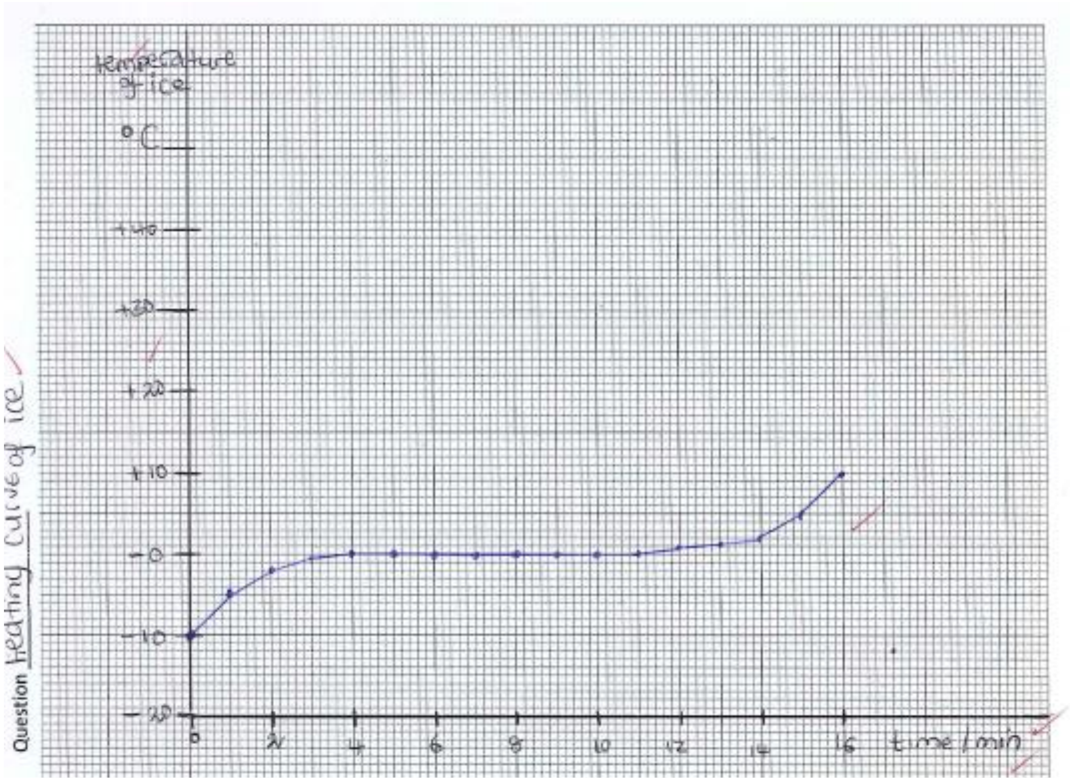
There was no intention of comparing the learners' performance for the scientific reports from the practical investigation in this research study, but rather to compare the quality of the experimental data collected by learners from each group and the graphs drawn from these. Learners from both groups collected meaningful experimental data and from these, functional graphs were plotted. Most of the experimental data from some of the HG learners show evidence of errors in measurement of the variables (temperature and time).



Insert 4.3. A graph from learner # 2 HG

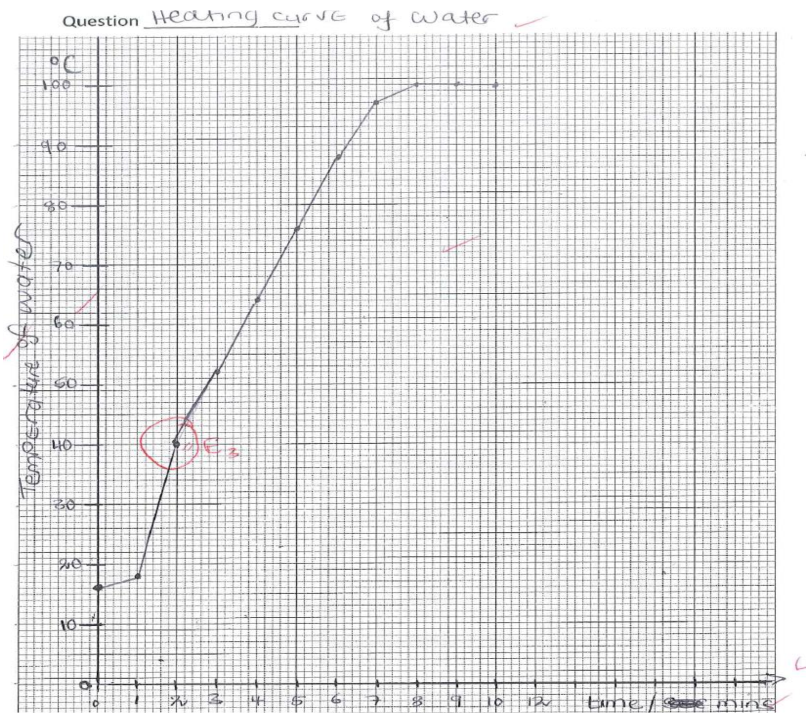
The graph in insert 4.3. shows two instances of error in measurement, the areas on the graph marked E_1 and E_2 reveal inconsistencies in data collection and recording during the process of the practical investigation, or that could also be attributed to the learner's inability to draw a smooth curve. This could be a result of poor judgement on reading the temperature measurement, or judgement in time interval. Such graphs did not clearly show the phase change stages, and could have interfered with the inferences the learners drew from them. Most of the learners managed to interpret and make conclusions from these graphs regardless of their scattered data.

Some of the experimental data obtained by the VG learners were neat, and so were the graphs produced from the data and therefore easier to interpret, (see Insert 4.4.).



Insert 4.4: A graph from learner # 28 VG

There were some learners in the VG group whose results could not produce the perfect heating or cooling curve, (see insert 4.5.)

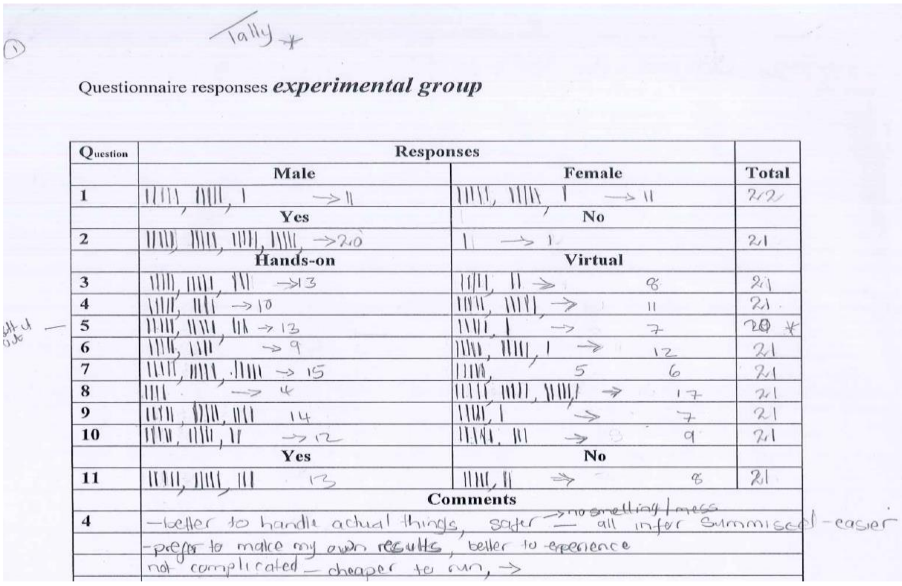


Insert 4.5. A graph from learner # 6 VG

The graph shown in insert 4.5. indicates an area marked E_3, this part of the graph revealed there might have been errors in recording and management of the time sensor during the experiment. This finding show that the virtual practical can also be affected by procedural errors just like the hands-on practical. Interesting though is the fact that, when tested on graphing and interpreting data, this group's performance was not only lower than that of the HG, but their post-test results were lower than the pre-test by 7%.

4.5. Learners responses to the attitude questionnaire

The research study used an attitude questionnaire to find out about the learners' mental inclination and tendencies towards the virtual and hands-on practical activities. The attitude questionnaire was administered to both the VG and the HG after they had experienced both the virtual and hands-on practical interventions. The responses from each group were first recorded in a tally table like the one shown in Insert 4.6.



Tally

Questionnaire responses *experimental group*

Question	Responses		Total
	Male	Female	Total
1	→ 11	→ 11	22
	Yes	No	
2	→ 20	→ 1	21
	Hands-on	Virtual	
3	→ 13	→ 8	21
4	→ 10	→ 11	21
5	→ 13	→ 7	20 *
6	→ 9	→ 12	21
7	→ 15	5 6	21
8	→ 4	→ 17	21
9	14	→ 7	21
10	→ 12	→ 9	21
	Yes	No	
11	13	→ 8	21
	Comments		
4	–better to handle actual things, safer → no smelling / mess — all info summarised – easier		
	–prefer to make my own results, better to experience		
	not complicated – cheaper to run, →		

Insert 4.6. The Tally for the VG Responses to the attitude questionnaire

The attitude questionnaire had 12 items. The first item required learners to state their gender. Item number two was to find out if the learner had participated in both practical interventions, for them to be able to compare their experiences. For items 3; 4; 6; 7; 8; 9; and 10, the learners had to choose the practical option that best described their disposition, or their opinion of the experiences they had during the activity, (see Appendix 5b.). For some items there was provision for the learners to make comments which gave more insight into their opinions. Item 12 was intended to find out if the learners found any of the practical activities helpful in understanding the concept of ‘phase change in matter’. Responses from the learner who had not participated in both practical activities were not included in this analysis as he/she was not in a position to make meaningful comparison.

4.5.1. HG responses to the attitude questionnaire

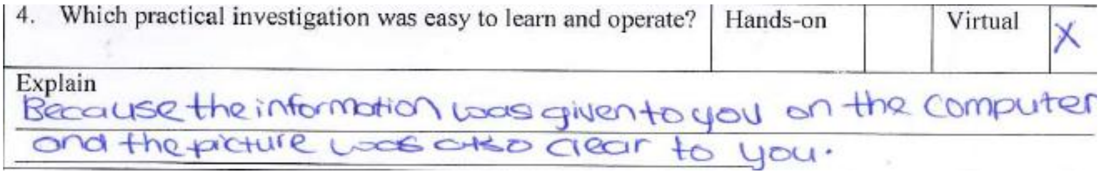
All the 22 learners in the HG were present for both practical activities, their responses were recorded in a table and for each category and the percentages of the responses were calculated. Table 4.7 shows the data of the HG learners’ responses to attitude questionnaire for items 3 to 11.

Table 4.7. The HG responses to the attitude questionnaire

Item #	Statement	Responses			
		HP	**%**	**VP**	**%**
3	Which practical investigation did you enjoy the most?	18	82	4	18
4	Which practical investigation was easy to learn and operate?	15	68	7	32
6	The practical investigation which made understanding of concepts on phase change and kinetic molecular theory easy is...	17	77	5	23
7	Which practical gave you a better sense of the kind of problems to be encountered in real life?	15	68	6	27
8	The ------ practical investigation took less time to complete.	7	32	14	64
9	The practical investigation that helped me understand science better is the -----	19	86	3	14
10	State the practical investigation that you would prefer to use in future practical investigation.	19	86	3	14
		Yes	**%**	**No**	**%**
11	Is there any difference in your understanding of practical investigation skills before and after the practical investigation?	14	64	8	36

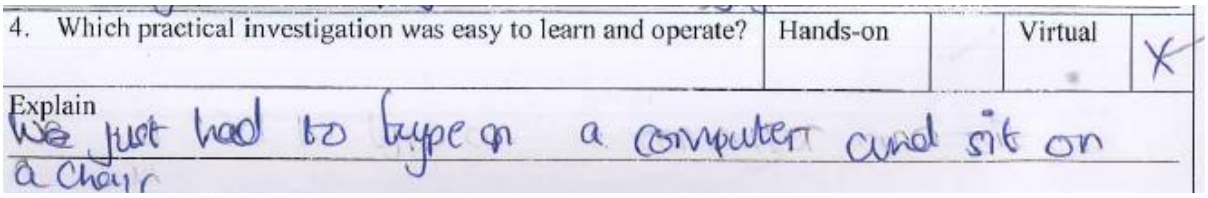
The item # 3 on the attitude questionnaire required learners to indicate the practical activity option which they enjoyed most during their experience. In the HG group 82% enjoyed the hands-on practical more than the virtual practical, (see table 4.7.). Some of the reasons cited were that they enjoyed working with actual things and also the fact that they got to work with their friends and not alone as in the virtual practical. 18% of this group found the virtual practical activity more enjoyable than the hands-on practical.

The questionnaire item # 4 solicited information on equipment usability, learners had to indicate the practical investigation which was easy to learn and operate see table 4.7. A smaller group constituting of 32% of the learners from the HG found the virtual practical easy to learn and operate, some of the comments made are shown here (see insert 4.7.).


4. Which practical investigation was easy to learn and operate?	Hands-on		Virtual	X
Explain Because the information was given to you on the computer and the picture was also clear to you.				

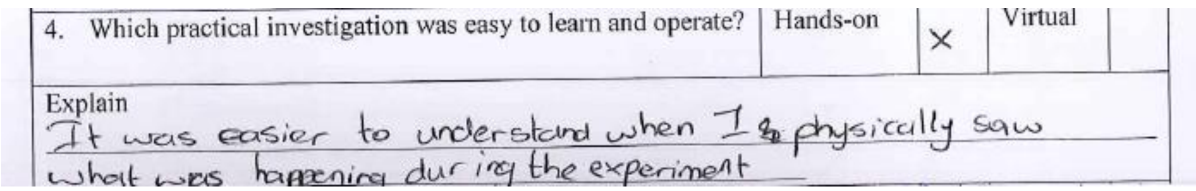
Insert 4.7. A response to attitude questionnaire item # 4 from learner # 10 HG

The comment in insert 4.7. indicates that the participant found the pictures on the virtual practical activity guideline to be helpful. Some learners found the virtual practical easy to learn because they didn't have to do much, this was revealed by the comment shown in insert 4.8.


4. Which practical investigation was easy to learn and operate?	Hands-on		Virtual	X
Explain We just had to type on a computer and sit on a chair				

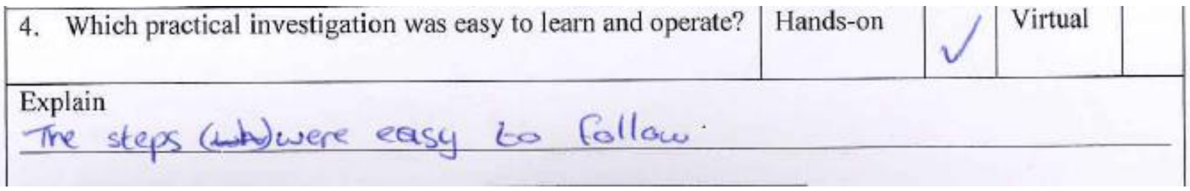
Insert 4.8. A response to attitude questionnaire item # 4 from learner # 23 HG

From the HG 68% favoured the hands-on practical activity in this category. The majority of this group found the hands-on practical task easy to learn and operate citing some of the reasons scanned here, (see insert 4.9.).


4. Which practical investigation was easy to learn and operate?	Hands-on	X	Virtual	
Explain It was easier to understand when I physically saw what was happening during the experiment				

Insert 4.9. A response to attitude questionnaire item # 4 from learner # 1 HG

The Insert 4.9. shows the statement made by a learner in the HG who found the hands-on practical easier to learn because he/she could actually see what was taking place in the experiment, the reality made the difference for this learner. On the other hand some learners simply found the steps for the hands-on practical easier to follow, (see insert 4.10.).



4. Which practical investigation was easy to learn and operate?	Hands-on	✓	Virtual	
Explain The steps (~~...~~) were easy to follow.				

Insert 4.10. A response to attitude questionnaire item # 4 from learner # 41 HG

The item # 6 in the attitude questionnaire required information on the functionality of the practical activities used in the research study. The learners had to indicate which of the two practical's made understanding of the concept of 'phase change in matter' easier. The hands-on practical activity made understanding of concepts easier for 77% of the group, see table 4.10. The matter of working with others which had come up in some responses to item # 3, also came up here. On the other hand, for 23% of the same group virtual practical activity made understanding of the concept easier.

The item # 7 in the attitude questionnaire asked learners for their opinion on which practical intervention gave them a sense of the kind of problems to be encountered in life. Although most learners were enthusiastic about handling real objects and experiencing the real thing, as they commended in items 4 and 6 of the attitude questionnaire, only 68% of HG felt that the hands-on practical activity gave them a better sense of the kind of problems to be encountered in life. A smaller group of 27% claimed that the virtual practical activity gave them a sense of real life problems. One participant abstained from responding to this item accounting for the 5%, no reason could be established for this omission.

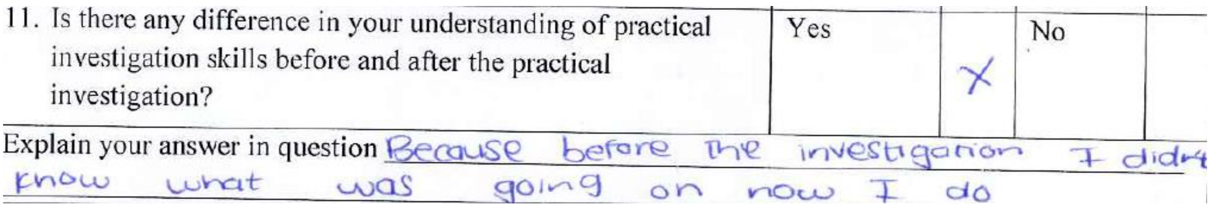
The item # 8 enquired on which practical took less time to complete. 64% of the HG indicated that the virtual practical activity took less time to complete, while 32% of this group felt the hands-on practical activity took less time to complete,(see table 4.7.). There was one participant who did not respond to this item, accounting for the 5%, no reason could be established for this. For items # 7 and 8 five percent of the HG learners did not respond to the question.

The item # 9 solicited learners' opinion on the practical work that helped them to understand science better. This item was a complimentary to item the # 6 which inquired on the practical activity that made understanding of the concept of 'change phase in matter' easier. A larger group pf 86% of the learners in the HG claim that the hands-on practical activity help them to understand science better. A smaller group of 14% that virtual practical activity help them to understand science better, (see table 4.7.). The group's responses to item # 8 confirm their responses to question # 6, in the sense that for both questions, a larger percentage claimed that hands-on practical activity help them to understand better.

The statement in item # 10 asked the learners on the practical activity they would prefer to use in future investigations. When asked which practical option they would use in the future, 86% chose the hands-on practical activity. Only 14% of the learners in this group would choose to use virtual practical work in the future see table (4.7.).

In general, the HG learners' attitude is biased towards the hands-on practical option. In items #; 3, 4, 6, 7; 9 and 10, the group favoured the hands-on practical. It's only in item # 8 when the group favoured the virtual practical for spending less time.

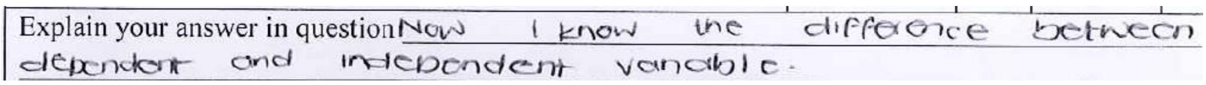
The item # 11 was intended to find out if the learners' understanding of practical investigation skills changed due to the practical activity intervention. 64% of the HG acknowledged having learnt some practical investigation skills from the practical activity administered during this research study. On the other hand 34% of the learners from this group claim that the practical activity administered during the research study did not help to improve their understanding of practical investigation skills. On whether there was a difference in their understanding of practical skills before and after the practical intervention, the learners acknowledged having learnt something from the practical work stating reasons such as the ones cited in insert 4.11. and 4.12.



11. Is there any difference in your understanding of practical investigation skills before and after the practical investigation?	Yes	X	No	

Explain your answer in question Because before the investigation I didn't know what was going on now I do

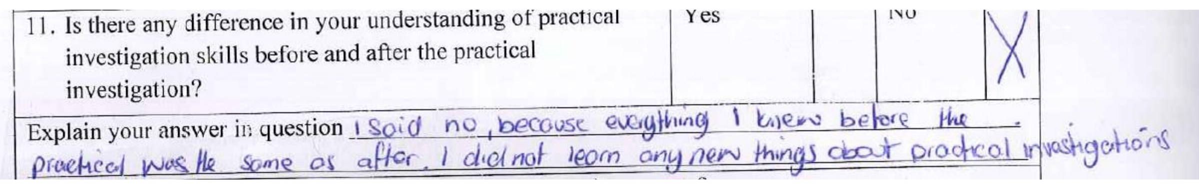
Insert 4.11. A response to attitude questionnaire item # 11 from learner # 8 HG



Explain your answer in question Now I know the difference between dependent and independent variable.

Insert 4.12. A response to attitude questionnaire item # 11 from learner # 29 HG

The Insert 4.12. shows the comment made by a learner from the HG, in response to whether the practical intervention helped them to learn practical investigation skills or not. It's worth pointing that this learner not only affirms that he/she learned from the practical activity, but is also specific on the skill learnt, that is to distinguish between dependent and independent variables. However, some learners from the same group did not have the same opinion as shown by the following response, (see insert 4.13.).



11. Is there any difference in your understanding of practical investigation skills before and after the practical investigation?	Yes		No	X

Explain your answer in question I said no, because everything I knew before the practical was the same as after. I did not learn any new things about practical investigations

Insert 4.13. A response to attitude questionnaire item # 11 from learner # 2 HG

The response shown in insert 4.10 is from a learner in the HG who claimed not to have learnt anything new from the practical activity.

In general the responses of the HG group to the attitude questionnaire have shown that they have general positive attitude towards the hands-on practical activity, this is due to the fact that, it's is only in questionnaire item # 8 that the majority of the HG favour the virtual practical. Where as in all the other categories analysed, the majority of the learners favoured the hands-on practical. The data in table 4.7. show that for each category, the highest percentage was recorded for the hands-on practical activity except for item # 8.

4.5.2. VG responses to the attitude questionnaire

The VG responded to the same attitude questionnaire as the HG. All the 22 learners in this group responded to the attitude questionnaire. However, the total number of participants in the VG was reduced to 21 after eliminating the responses of one learner who was absent when the group did their virtual practical activity. Responses from the learner who had not participated in both practical activities were not included in this analysis as he/she was not in a position to make meaningful comparison. The VG responses to the attitude questionnaire are recorded in Table 4.8.

Table 4.8. The VG responses to the attitude questionnaire

Item #	Statement	Responses

		HP	**%**	**VP**	**%**
3	Which practical investigation did you enjoy the most?	13	62	8	38
4	Which practical investigation was easy to learn and operate?	10	48	11	52
6	The practical investigation which made understanding of concepts on phase change and kinetic molecular theory easy is...	9	43	12	57
7	Which practical gave you a better sense of the kind of problems to be encountered in real life?	15	71	6	29
8	The ------ practical investigation took less time to complete.	4	19	17	81
9	The practical investigation that helped me understand science better is the -----	14	67	7	33
10	State the practical investigation that you would prefer to use in future practical investigation.	12	57	9	43
		Yes	%	**No**	%
11	Is there any difference in your understanding of practical investigation skills before and after the practical investigation?	13	62	8	38

Table 4.8 shows the data of the VG learners' responses to the attitude questionnaire for items 3 to 11.

For the item # 3 on the attitude questionnaire required learners to indicate the practical activity option which they enjoyed most during their experience. 62% of the learners in the VG enjoyed the hands-on practical more than the virtual practical, see table 4.8. Some of the reasons cited here include, learners indicating that they prefer to make own results, and that working with real apparatus was fun. They also indicated that they enjoyed working with their friends in the hands-on practical activity, the same sentiments echoed by the HG group when they responded to the same item, # 3. 38% of this group found the virtual practical activity more enjoyable than the hands-on Practical activity. Learners made some very generic remarks like ‘technology was great to work with’ when responding to stating what they enjoyed about the practical they chose, (see insert 4.14.).

3. Which practical investigation did you enjoy the most?	Hands-on		Virtual	✓

What did you enjoy about the practical investigation you chose in question 3? The technology was great to work with

Insert 4.14. A response to attitude questionnaire item # 3 from learner # 44 VG

There were some comments made which showed that learners enjoyed the virtual practical because they could read the temperature values easier, see insert 4.15.

3. Which practical investigation did you enjoy the most?	Hands-on		Virtual	✓

What did you enjoy about the practical investigation you chose in question 3? You could view the temperature easier. not having to worry about incorrect reading.

Insert 4.15. A response to attitude questionnaire item # 3 from learner # 6 VG

In response to the questionnaire item # 4, 52% of the learners in the VG found the virtual practical easy to learn and operate, (see table 4.8.). The reasons like it was safer, less messy and gave better results were stated in the comments section. From this group, 48% indicated that the hands-on practical was easier to learn.

In response to the questionnaire item # 6, 57% of the learners in the VG claimed that the virtual practical made understanding of concepts easier, while 43% of the same group thought the hands-on practical made understanding of concepts easier,(see table 4.8.).

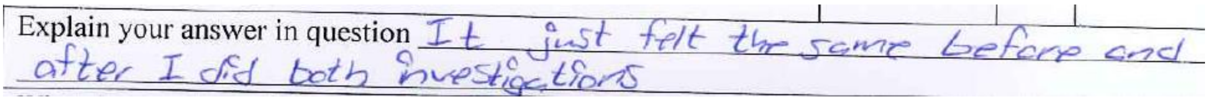
The item # 7 solicited for the information on which practical activity gave the learners a better sense of real life problems. The attitude questionnaire results also reveal that 71% of the VG learners felt that the hands-on practical activity gave them authentic experiences. However, 29% of the learners from this group claim that the virtual practical activity gave them a better sense of the kind of problems they would encounter in real life, (see table 4.8.).

The item # 8 on the attitude questionnaire requested information on the practical work that took less time to complete. For the VG, 81% of the learners stated that the virtual practical took less time to complete, while 19% of the same group indicated the virtual practical activity took less time.

When responding to item # 9, the majority of the learners in the VG have shown that the hands-on practical helped them to understand science concepts better. The results in table indicate that 67% of the learners in this group felt that the hands-on practical activity helped them understand science better. In the same group, 33% of the learners understand science better through virtual practical work, see table 4.8. In their responses to item # 6, a larger percentage (57%) of the VG claimed that the virtual practical made them understand the concept of "phase change in matter' better. When the same group responded to questionnaire item # 9, the larger percentage of the group, (67%) indicated that the hands-on practical activity helped them to understand the science better. There seem to be inconsistence in the group's opinion of the practical that help them in understanding.

The statement in the item # 10 of the attitude questionnaire intended to find out which practical leaners would prefer to use in future practical investigations. In this category, 57% of the VG indicated they would prefer to use the hands-on practical activity in the future. While for the same group, 43% of learners confirmed they would prefer to use virtual practical activity in the future, see table 4.8.

The questionnaire item # 11 was meant find out from the learners if there were any differences in their understanding of science practical investigation skills before and after the practical interventions. In response to this question, 62% of the learners in the VG indicated that they have gained some knowledge of practical investigation skills due to the practical intervention. On the other hand, 38% of this group felt the practical activity intervention did not change their understanding of practical investigation skills. The insert 4.16. shows some comments made by a learner who felt he/she did not learn any practical investigation skills from the interventions.


Explain your answer in question It just felt the same before and after I did both investigations

Insert 4.16. A response to attitude questionnaire item # 3 from learner # 18 VG

The analysis of the data on responses from the VG learners to the attitude questionnaire revealed that the group had mixed reactions to the practical activities. The data in table 4.7 show that the in responding to each of the questionnaire items # 3, 7, 9, 10 and 11, the majority of the learners favoured the hands-on practical activity. Whereas in their responses questionnaire items # 4, 6, and 8, the group favoured the virtual practical activity.

4.5.3. Group Responses Compared

Responses of the two groups recorded in a table to compare the responses of the groups in each category, (see table 4.9.).

Table 4.9. Group responses compared

	Responses			
	HG		**VG**	
	Hands-on Practical	**Virtual Practical**	**Hands-on Practical**	**Virtual Practical**
Item	% frequency	% frequency	% frequency	% frequency

3	82	18	62	38
4	68	32	48	52
6	77	23	43	57
7	68	27	71	29
8	32	64	19	81
9	86	14	67	33
10	86	14	57	43
	Yes	**No**	**Yes**	**No**
11	64	36	62	38

In general, the HG have a positive attitude towards the hands-on practical activity, coincidentally the group was taught the concept of "phase change in matter' through this practical intervention. In all their response to the attitude questionnaire items, the majority of the learners in this group favoured the hands-on practical activity, except in the questionnaire item # 8. Here the group favoured the virtual practical activity for taking less time to complete. For items # 7 and 8 five percent of the HG learners did not respond to this question. The VG on the other hand, had mixed opinions about their views of the two practical options. In this regard, the data from their responses indicate that for some categories, the group favoured the hands-on practical activity, and in some categories they favoured the virtual practical. The data in table 4.9. show that in responding to each of the questionnaire items # 3, 7, 9, 10 and 11, the majority of the learners favoured the hands-on practical activity. Whereas for questionnaire items # 4, 6, and 8, the group favoured the virtual practical activity.

Both groups had similar response patterns to the attitude questionnaire items # 3, 7, 9, 10 and 11. For these categories, the data in table 4.8. show that the HG and the VG favoured the hands-on practical activity when responding to the questionnaire item # 8, data analysis show that both groups preferred the virtual practical activity for taking less time to complete.

4.6. Summary

This chapter described the data analysis of the pre- and post-test scores. The analysis revealed that there was no significant difference between the performance of VG learners and the HG learners before the administration of the practical interventions. However, the HG performed significantly better than the VG after the administration of the practical interventions. The chapter also analysed the learner responses to the attitude questionnaire, which revealed that a greater proportion of the learners from both groups favoured the hands-on practical intervention. The VG on the other hand, had mixed opinions about their views of the two practical options.

Chapter Five: Discussion and conclusion

5.1. Introduction

Chapter Five provides the discussion of the significances of the test score analysis in science learning. The results obtained from analysing the learner's responses to the attitude questionnaire are discussed in this chapter. A discussion of the research results, limitations of the research study, and recommendations are outlined in chapter five.

5.2. Effects of virtual practical on learning

There was no significant difference between the performance of the VG in the pre- and post-tests. This was confirmed by the paired t test analysis which yielded a p value of 0,7518 (see Table 4.3. in Chapter 4) where p>0,05 indicates that there was no significant difference. The statistical results imply that the instrument used (virtual practical intervention) did not influence the performance of the learners on science process skills in this research study. When analysed from another angle, the VG results show a 0,86% decrease from 60,59% before the intervention to 59,73% after the intervention, a minimal increase.

A p value of 0,1277 (see Table 4.3. in Chapter 4) was obtained for the paired t test of the pre- and post-test scores for the HG. The results also point to the insignificant difference in learner performance, further confirming that the hands-on practical intervention did not impact learner performance either. The mean scores of this group changed from 65,29% to 68,95% recording a slight increase of 3,66%, confirming the insignificant difference obtained by statistical t tests.

In this regard, the results of this research study compliment the findings of (Bell and Trundle, 2010) in which the virtually simulated teaching and learning instruments do not necessarily result in better learner performance than when learners are taught through the traditional methods of instruction. (Bell and Trundle, 2010) did a similar study and concluded that there was no significant difference between the performance of the experimental and the control groups. Some studies have shown that there is no concrete basis to claim that virtually supported teaching and learning improves learning more than the other teaching and learning instruments. Others report that virtual learning enhances deeper learning (Hattingh & Scott, 2014). Roberts (2011) found that some categories of the assessment instrument registered significant difference in performances of the group taught by virtually supported instruction and those taught by traditional methods of instruction. Likewise, the current research study established that learners who were taught through hands-on practical work did not improve their performance in the science process skills of 'stating hypothesis' and 'experiment design' (see Graph 4.5.in Chapter 4). However, the same group show improvement in other categories such as 'identifying and controlling variables' and 'operational definitions'. With virtual practical intervention, some categories such as 'stating hypothesis' and 'graphing and interpreting data', there were decreases in learner performance. There is no definite pattern as to how virtually supported instruction affects learning. The unpaired t test analysis for the pre-test of both the VG and the HG revealed no significant difference between the performance of the two groups, with a p value of 0,7706 (see Table 4.4 in Chapter 4). This is an indication that the two groups in this research study were at the same level of performance in science process skills before applying any research instruments. When a statistical analysis was done on the post-test scores of the VG and the HG, the t test yielded a p value of 0,004 (see Table 4.5. in Chapter 4) indicating a significant difference in the performance of the learners after the application of the practical interventions. Since the $p < 0.05$ is, it is therefore established that there was a significant difference in learner performance due to the type of practical intervention applied. The practical activity was the only different variable between the two groups in this research study. This research study therefore credits the significant difference in learner performance to practical interventions used. On comparing the mean scores of the groups, it is noticeable that the average score for the HG increased by 3,66%. Not so for the VG, here the average score decreased by 0,86%. On the basis of this analysis, it is noted that the HG performed better than the VG that was taught the same concept of 'phase change of water' through virtual practical intervention.

The results of this research study differ from findings of some previous research studies. Some studies established that conceptual software on tutoring students on the concept of density promoted learning for understanding (Hattingh & Scott, 2014). These findings are similar to those of Tüysüz (2010) who confirmed that virtual laboratory learning produces better student achievement than traditional methods. Other studies demonstrated that while there was no significant difference in terms of skills, attitude and group interaction, there was significant differences in understanding of concepts, with the virtual practical group having the upper hand (Kassa & Dantie, 2007).

Although the practical interventions used in this research study were different, the pedagogical applications was analogous in the following manner. The two groups had prior knowledge on the concept of "phase change" gained through mediated instruction or teaching. Both groups received pre- practical orientation and the procedures of the virtual and the hands-on practicals were more similar than different (refer to section 3.6 table 3.8 VP-VG similarities). The similarities pointed out here may explain the similarities noted in the overall results analysis of the test scores. Both groups registered an overall increase in learner performance after the practical interventions (refer to section 4.3.1). The fact that the results of the two groups present similar patterns, alludes to the fact that practical activities whether virtual or hands-on may influence learning in the same fashion.

When the test scores for both groups were analysed in categories, it emerges that the learners' performance increases for some process skills such as; 'identifying variables; interpreting data and experimental design' after the application of the practical interventions. The test score results for the VG and HG on the 'stating hypothesis' process skill category produced no improvement in learner performance after the practical interventions (refer to section 3.3.3.). If the two practical intervention methods produced matching result patterns, they have comparable effect on the learning of the concept. This research suggests that the two practical interventions may be used interchangeably or in conjunction seeing that they produce similar effects of learner performance.

5.3. Attitude of learners to virtual practical

In addition to looking at how the type of practical investigation affect learner performance, this study also investigated learner's attitude towards the practical interventions used in the research. It emerged that leaners favoured the hands-on practical intervention for reasons such as that it made understanding of concepts easy and that they enjoyed handling real objects rather than simulated ones. Furthermore the test performance compliment this finding and it is suggested that the HG performed better because of their positive attitude towards the hands-on practical activity, which was their mode of instruction. The VG on the other hand did not fare so well in their performance and it might be because they did not favour the mode of practical activity used in their teaching. In answering the attitude questionnaire, this group expressed their preference for the hands-on practical. According to some literature, attitude affects learner performance, in that a positive attitude will contribute to good performance (Score, 2008). Based on such literature, this researcher proposes a similar assertion that the VG group's attitude towards the virtual practical work could have led to the insignificant difference in their performance.

5.4. Practical intervention and the domains of science learning

Practical activity experiences in science learning offer the opportunity for refining science ideas and combine the science domains of learning to bring about the conceptual development. As learners think, inquire and do science during practical investigations, virtual or hands-on, manipulative skills, procedural skills and science process skills are developed. The process skills tested in this research study form part of the six domains of science learning (refer to section 2.3.1.). Practical investigations provide inquiry experiences in which learners apply their inquiry skills and the acquired concepts to the investigation scenario. Some aspects of the nature of science are evident in the practical activity discussed here; there is more than one method to solve a problem, virtual or hands-on alternatives were used in this research study.

Learners used empirical data to make inferences such as melting points, boiling points and phase change. In addition, practical activities allow learners to apply the learnt concepts, laws or principles.

This discussion illustrates that the domains of science learning are linked in practical activity experiences. As discussed in section 3.3.3. Learners' performance in certain categories of science process skills improved after the practical interventions, the performance of both groups were similarly affected. The results confirm the notion that practical work whether virtual or hands-on, practical work has positive effects aspects of science learning (Roberts, 2011). The important issue to consider will be the pedagogical choices made when implementing the practical activity (Bell and Trundle, 2010). This goes to show that science learning, when mediated through practical activities encompasses the nature of science, process skills of science, inquiry, conceptual development and attitudes giving an all-round learning experience. Practical work is therefore vital to science learning (Allisop and Woolnough, 1985).

5.5. Conclusion

The statistical tests have indicated that there is a significant difference in learner performance of the two groups due to the practical intervention used. Therefore, the null hypothesis that: *The learners' performances is not influenced by the type of practical approach used*' is rejected in this research study. The hypothesis: *The learners' performance is influenced by the practical intervention used* is therefore upheld. When test scores were analysed in categories, the results of this study seem to imply that virtual practical intervention may not be the best instruction instrument or tool for teaching learners some process science skills such as; the 'stating hypothesis' skills and 'graphing and interpretation of data' skills. Although the population sample for this research study is too small to make claims on the findings, attention is drawn to the need to gain a better understanding of either how virtual learning instruments aid science learning, or which learning skills are positively impacted by their use. This area needs to be further explored to enlighten the education fraternity.

If practical work is fundamental to understanding of scientific concepts and technology is providing an additional option to conducting practical activities in science learning, then it's of significant importance to understand the influence of these practical activity options on science learning. Therefore, this research study investigated the impact that virtual practical activities and hands-on practical activities have on learner performance

5.6. Limitations

The research used a sample of grade 10 learners from a Western Cape school. The sample of 44 learners was not randomly selected; rather it was selected because they were the group that took physical sciences making them the only participants available to the researcher in this school. The limitation presented by this research is therefore sample size as well demographic representation. Generalisations, conclusions and observations made in this study are thus limited to this sample only.

The instruments used in this investigation were specifically focused on the practical activity on phase change in water. This topic was chosen because the researcher had access to the virtual practical on this topic and also because it is the grade 10 physical sciences formal assessment task according CAPS requirement. The inferences made in this regarded are true only to the mentioned topic.

Some limitations came from the application of the instrument. When the virtual simulated practical was administered, the school's internet connection was very slow, leading to frustrations on the part of the participants. There is a possibility that this could have contributed to the disfavour of the virtual practical intervention. In addition, due to resource limitations, the two groups could not do the virtual practical concurrently and learners discussing the work beforehand across groups cannot be ruled out.

5.7. Recommendations

An inference drawn from this research study was that the type of practical work used in teaching a concept does affect learner performance. In general, the hands-on practical had a positive impact on learner performance and was favoured by most learners. With a closer look at learner performance in each process skill category, results are inconclusive since in some cases there is positive change due to the hands-on practical and in some instances there is significant change due to the virtual practical.

In view of the aforementioned, this research proposes the following recommendations:

There is need to do more research on the topic of virtual practical work in science learning. So far studies on virtual practical versus hands-on practical work have been random as researcher decide on which aspect of virtual practical work they want to study. If the education policy makers can direct this field of research by deciding which science practical activities should be investigated, the proposed formal practical assessments could be put up for research to any interested researchers. If research is done to find out which type of practical (virtual or hands-on) is more effective for all formal practical assessments from grade 10 to 12 physical sciences, then results from such studies can be used to create a national resource that can be used in science learning. Such a resource is important to enhance teachers' knowledge and provide insight into integrating knowledge of technology, content and pedagogy in their teaching.

It is also recommended that a further study be done on the same topic but with a larger, more representative population and a large sample size. A population of learners from more diverse backgrounds and a true experimental design with a randomised sample population will produce results that are generalisable.

The results of this research study and others that were reported before, reveal that virtual practical work can be used to the same effect as or sometimes a better effect than hands-on practical. Research is therefore recommended to investigate the technological knowledge that science educators have and how they integrate this knowledge into teaching practical investigations.

5.8. Significance of the research study

The research study has established that the practical option used in teaching the concept 'phase change' results insignificant difference in learner performance of the two groups. It was also revealed in this study that the two practical interventions influence the development of some process skill in a similar way. This research study may serve as a basis for further research into the effect of virtual practical work in science learning. Is more research is done to establish for certain which process skills maybe developed by using virtual practical interventions, that will provide more options for teaching the same concept, 'phase change in matter'.

5.9. Research Summary

This research study focused of the impact of virtual practical work in science learning. A quasi-experimental study was conducted at a school in the Western Cape in South Africa, using grade 10 physical sciences learners. A non-random sample of 44 learners was divided into two groups; one group was taught the concept of 'phase change in matter' through hands-on practical while the other group was taught the same concept using virtual practical activity. The impact of the practical intervention was measured by the learners' performances in a TISPS and the learners' attitude towards the practical interventions. The attitude was determined by the learners' responses to the attitude questionnaire.

Statistical t test analysis of the pre- and post-test scores have revealed that the hands-on group performed significantly better than the virtual group after the practical intervention. Further analysis of test scores revealed no significant difference in learner performance between the groups after the practical activity intervention. However, some variations were noted in learner performance for each of the five science process skills categories. Here test score results indicated that learners in the same group would have a higher average score for one process skill category and yet the same group produced low average score in another category. The results for the learners' responses to the attitude questionnaire were varied, some favoured virtual practical in some in some areas while others preferred hands-on practical in some cases.

The research study concluded that the effect of virtual practical work on science learning is complex. Therefore, the researcher recommends that more research to be done on the same topic but with a larger population and a true experimental design. It is also recommended that more research be done on the effect of virtual practical work on learner performance on other concepts from physical sciences CAPS curriculum. The results from this research study contributes to the body of literature available to the science learning fraternity by providing insight into understanding the integration of the knowledge of technology with content knowledge and pedagogical knowledge.

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Appendices

Appendix 1. The pre- and post-test instrument

The test of integrated science process skills

Duration 50 minutes

Instructions

1. Do **not** write anything on the question paper
2. Answer all questions on the answer paper provided.
3. Do not give more than one answer per question
4. There are four possible options for each answer in the following questions. Each question has only ONE correct answer. Choose the correct answer and write only A, B, C or D next to the question number.

1. A learner wanted to know whether an increase in the amount of vitamins given to children results in increased growth.

How can the learner measure how fast the children will grow?

A. By counting the number of words the children can say at a given age.
B. By weighing the amount of vitamins given to the children.
C. By measuring the movements of the children.
D. By weighing the children every week.

2. Nomsa wanted to know which of the three types of soil (clay, sandy and loamy), would be best for growing beans. She planted bean seedlings in three pots of the same size, but having different soil types. The pots were placed near a sunny window after pouring the same amount of water in them. The bean plants were examined at the end of ten days. Differences in their growth were recorded.

Which factor do you think made a difference in the growth rates of the bean seedlings?

A. The amount of sunlight available.
B. The type of soil used.
C. The temperature of the surroundings.
D. The amount of chlorophyll present.

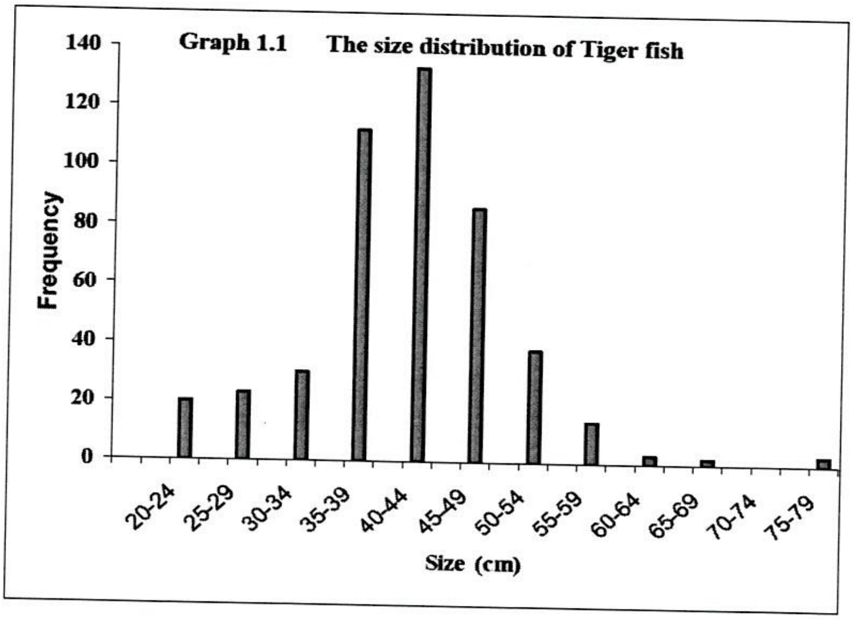
3. A lady grows roses as a hobby. She has six red rose plants and six white rose plants. A friend told her that rose plants produce more flowers when they receive morning sunlight. She reasoned that when rose plants receive morning sunlight instead of afternoon sunlight, they produce more flowers.

Which plan should she choose to test her friend's idea?

A. Set all her rose plants in the morning sun. Count the number of roses produced by each plant. Do this for a period of four months. Then find the average number of roses produced by each kind of rose plant.
B. Set all her rose plants in the morning sunlight for four months. Count the number of flowers produced during this time. Then set all the rose plants in the afternoon sunlight for four months. Count the number of flowers produced during this time.
C. Set three white rose plants in the morning sunlight and the other three white rose plants in the afternoon sun. Count the number of flowers produced by each white rose plant for four months.
D. Set three red and three white rose plants in the morning sunlight, and three red and three white rose plants in the afternoon sunlight. Count the number of rose flowers produced by each rose plant for four months.

Questions 4 and 5 refer to the graph below.

The fishery department wants to know the average size of Tiger fish in Tzaneen dam, so that they could prevent over-fishing. They carry out an investigation, and the results of the investigation are presented in the graph below.



4. What is the most common size range of Tiger fish found in Tzaneen dam

A. 75 – 79 cm.
B. 40 – 44 cm.
C. 20 – 79 cm.
D. 45 – 49 cm.

5. In which size range would you find the longest Tiger fish?

A. 75 – 79 cm.
B. 40 – 44 cm.
C. 20 – 79 cm.
D. 35 – 49 cm.

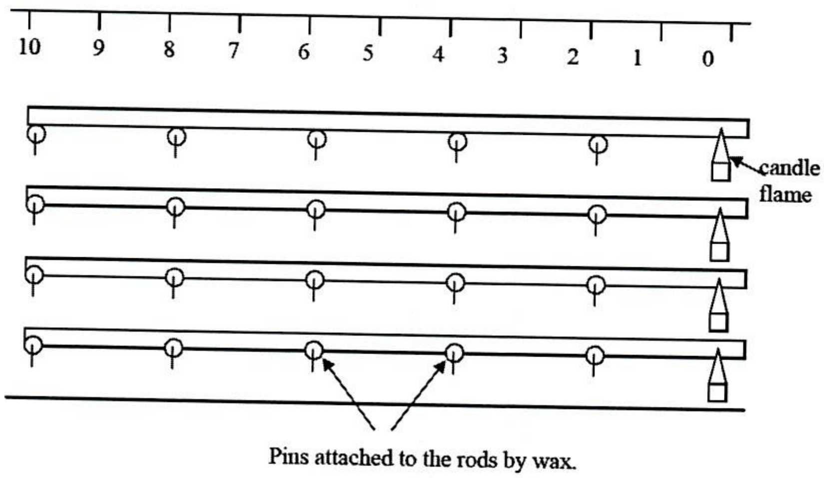
6. Mpho wants to know what determines the time it takes for water to boil. He pours the same amount of water into four containers of different sizes, made of clay, steel, aluminium and copper. He applies the same amount of heat to the containers and measures the time it takes the water in each container to boil.

Which one of the following could affect the time it takes for water to boil in this investigation?

A. The shape of the container and the amount water used.
B. The amount of water in the container and the amount of heat used.
C. The size and type of the container used.
D. The type of container and the amount of heat used.

7. A teacher wants to find out how quickly different types of material conduct heat. He uses four rods with the same length and diameter but made of different types of material. He attaches identical pins to the rods using wax, at regular intervals as shown in the diagram below. All the rods were heated on one end at the same time, using candle flames. After two minutes, the pins that fell from each rod were counted.

Diagram 1.1



How is the speed (rate) of heat conduction by the various rods measured in this study?

A. By determining the rod, which conducted heat faster when heated.
B. By counting the number of pins that fall from each rod after 2 minutes.
C. By counting the number of minutes taken for each pin to fall from the rod.
D. By using wax to measure the rate of heat conduction.

8. A farmer wants to increase the amount of mealies he produces. He decides to study the factors that affect the amount of mealies produced.

Which of the following ideas could he test?

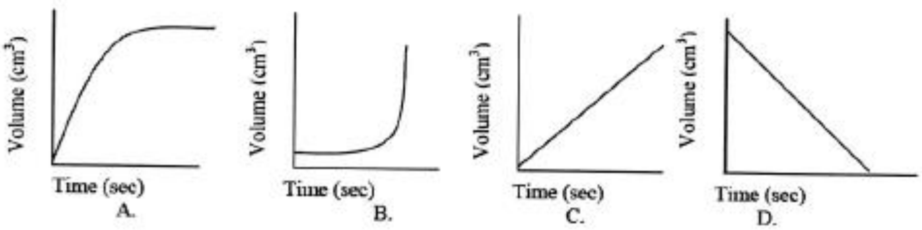
A. The greater the amount of mealies produced, the greater the profit for the year.
B. The greater the amount of fertilizer used, the more the amount of mealies produced.
C. The greater the amount of rainfall, the more effective the fertilizer used will be.
D. The greater the amount of mealies produced, the cheaper the cost of mealies.

9) Sandile carried out an invetication in which she reacted magnesium with dilute hydrochloric acid. She recorded the volume of the hydrogen produced from the reaction, every second. The results are shown below;

Time (seconds)	0	1	2	3	4	5	6	7	
	0	14	23	31	38	40	40	40	

Table: 1.1 shows the volume of the hydrogen produced per second.

Which of the following graphs show these results correctly?



10. A science teacher wanted to find out the effect of exercise on pulse rate. She asked each of three groups of learners to do some push-ups over a given period of time, and then measure their pulse rates: one group did the push-ups for one minute; the second group for two minutes; the third group for three minutes and then a fourth group did not do any push-ups at all.

How is pulse rate measured in this investigation?

A. By counting the number of push-ups in one minute.
B. By counting the number of pulses in one minute.
C. By counting the number of push-ups done by each group.
D. By counting the number of pulses per group.

11 Five different hosepipes are used to pump diesel from a tank. The same pump is used for each hosepipe. The following table shows the results of an investigation that was done on the amount of diesel pumped from each hosepipe.

Size (diameter) of hosepipe (mm)	Amount of diesel pumped per minute (litres)
8	1
13	2
20	4
26	7
31	12

Table 1.2. Shows the amount of diesel pumped per minute.

Which of the following statements describes the effect of the size of the hosepipe on the amount of diesel pumped per minute?

A. The larger the diameter of the hosepipe, the more the amount of diesel pumped.
B. The more the amount of diesel pumped, the more the time used to pump it.
C. The smaller the diameter of the hosepipe, the higher the speed at which the diesel is pumped.
D. The diameter of the hosepipe has an effect on the amount of diesel pumped.

12. Doctors noticed that if certain bacteria were injected into a mouse, it developed certain symptoms and died. When the cells of the mouse were examined under the microscope, it was seen that the bacteria did not spread through the body of the mouse, but remained at the area of infection. It was therefore thought that the death is not caused by the bacteria but by certain toxic chemicals produced by them.

Which of the statements below provides a possible explanation for the cause of death of the mouse?

A. The mouse was killed by the cells that were removed from it to be examined under the microscope.
B. Bacteria did not spread through the body of the mouse but remained at the site of infection.
C. The toxic chemical produced by the bacteria killed the mouse.
D. The mouse was killed by developing certain symptoms.

13. Thembi thinks that the more the air pressure in a soccer ball, the further it moves when kicked. To investigate this idea, he uses several soccer balls and an air pump with a pressure gauge. How should Thembi test his idea?

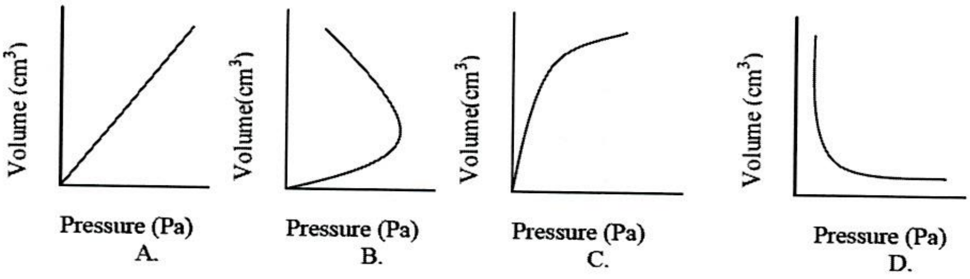
A. Kick the soccer balls with different amounts of force from the same point.
B. Kick the soccer balls having different air pressure from the same point.
C. Kick the soccer balls having the same air pressure at different angles on the ground.
D. Kick the soccer balls having different air pressure from different points on the ground.

14. A science class wanted to investigate the effect of pressure on volume, using balloons. They performed an experiment in which they changed the pressure on a balloon and measured its volume. The results of the experiment are given in the table below.

Pressure on balloon (Pa)	Volume of the balloon (cm^3)
0.35	980
0.70	400
1.03	320
1.40	220
1.72	180

Table 1.3. Shows the relationship between the pressure on a balloon and its volume.

Which of the following graphs represents the above data correctly?



15. A motorist wants to find out if a car uses more fuel when it is driven at high speed. What is the best way of doing this investigation?

A. Ask several drivers how much fuel they use in one hour, when they drive fast, and find the average amount of fuel used per hour.
B. Use his own car to drive several times at different speeds, and he should record the amount of fuel used each time.
C. He must drive his car at high speed, for a week, and then drive it at low speed for another week, and record the amount of fuel used in each case.
D. Ask several drivers to drive different cars covering the same distance many times, at different speeds, and record the amount of fuel used for each trip.

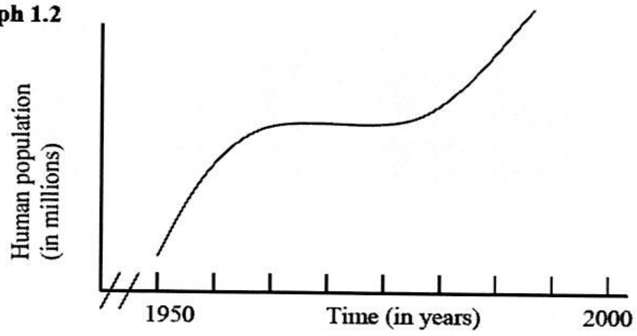
16. A learner observed that anthills (termite moulds) in a certain nature reserve tend to lean towards the west, instead of being straight. In this area, the wind blows towards the direction in which the anthills lean.

Which of the following statements can be tested to determine what causes the anthills to lean towards the west, in this nature reserve?

A. Anthills are made by termites.
B. Anthills lean in the direction in which the wind blows.
C. Anthills lean towards the west to avoid the sun and the rain.
D. The distribution of anthills depends on the direction of the wind.

17. The graph below shows the changes in human population from the year 1950 to 2000.

Graph 1.2



Which of the following statements best describes the graph?

A. The human population increases as the number of years increase.
B. The human population first increases, then it reduces and increases again as the number of years increase.
C. The human population first increases, then it remains the same and increases again as the number of years increase.
D. The human population first increases then it remains the same as the number of years increase.

18. Mulai wants to find out the amount of water contained in meat, cucumber, cabbage and maize grains. She finely chopped each of the foods and carefully measured 10 grams of each. She then put each food in a dish and left all the dishes in an oven set at 100°C. After every 30 minutes interval, she measured the mass of each food, until the mass of the food did not change in two consecutive measurements. She then determined the amount of water contained in each of the foods.

How is the amount of water contained in each food measured in this experiment?

A. By heating the samples at a temperature of 100°C and evaporating the water.
B. By measuring the mass of the foods every 30 minutes and determining the final mass.
C. By finely chopping each food and measuring 10 grams of it, at the beginning of the investigation.
D. By finding the difference between the original and the final mass of each food.

19. In a radio advertisement, it is claimed that Surf produces more foam than other types of powdered soap. Chudwa wanted to confirm this claim. He put the same amount of water in four basins, and added 1 cup of a different type of powdered soap (including surf) to each basin. He vigorously stirred the water in each basin, and observed the one that produced more foam.

Which of the factors below is **NOT** likely to affect the production of foam by powdered soap?

A. The amount of time used to stir the water.
B. The amount of stirring done.
C. The type of basin used.
D. The type of powered soap used.

20 Monde noticed that the steel wool that she uses to clean her pots rusts quickly if exposed to air after using it. She also noticed that it takes a longer time for it to rust if it is left in water. She wondered whether it is the water or the air that causes the wet exposed steel wool to rust.

Which of the following statements could be tested to answer Monde's concern?

A. Steel wool cleans pots better if it is exposed to air.
B. Steel wool takes a longer time to rust if it is left in water.
C. Water is necessary for steel wool to rust.
D. Oxygen can react with steel wool.

21. A science teacher wants to demonstrate the lifting ability of magnets to his learners. He uses many magnets of different sizes and shapes. He weighs the amount of iron filings picked by each magnet.

How is the lifting ability of magnets defined in this investigation?

A. The weight of the iron filings picked up by the magnets.
B. The size of the magnet used.
C. The weight of the magnet used to pick up the iron filings.
D. The shape of the magnet used.

22. Thabo wanted to show his friend that the size of a container affects the rate of water loss, when water is boiled. He poured the same amount of water in containers of different sizes but made of the same material. He applied the same amount of heat to all the containers. After 30 minutes, he measured the amount of water remaining in each container.

How was the rate of water loss measured in this investigation?

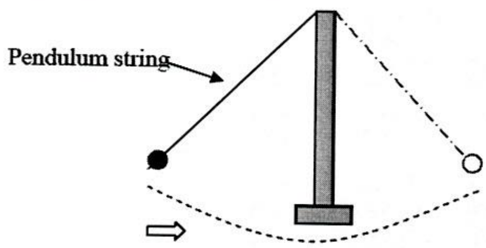
A. By measuring the amount of water in each container after heating it.
B. By using different sizes of the containers to boil the water for 30 minutes.
C. By determining the time taken for the water to boil in each of the containers.
D. By determining the difference between the initial and the final amounts of water, in a given time.

23. A school gardener cuts grass from 7 different football fields. Each week, he cuts a different field. The grass is usually taller in some fields than in others. He makes some guesses about why the height of the grass is different. Which of the following is a suitable testable explanation for the difference in the height of grass.

A. The fields that receive more water have longer grass.
B. Fields that have shorter grass are more suitable for playing football.
C. The more stones there are in the field, the more difficult it is to cut the grass.
D. The fields that absorb more carbon dioxide have longer grass.

24. James wanted to know the relationship between the length of a pendulum string and the time it takes for a pendulum to make a complete swing. He adjusted the pendulum string to different lengths and recorded the time it took the pendulum to make a complete swing.

Diagram 1.2 A pendulum.

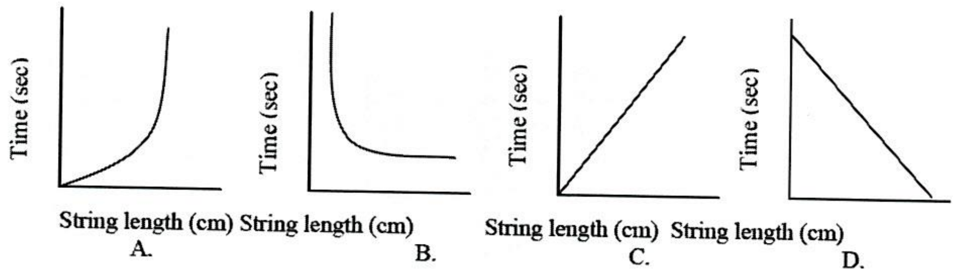


He obtained the following results from an investigation.

Length of string (cm)	80.0	100.0	120.0	140.0	160.0	180.0
Time taken (seconds)	1.80	2.02	2.21	2.39	2.55	2.71

Table 1.4. The relationship between the lengths of a pendulum string and the time the pendulum takes to make a complete swing.

Which of the following graphs represent the above information correctly?



25. A farmer raises chickens in cages. He noticed that some chickens lay more eggs than others. Another farmer tells him that, the amount of food and water given to chicken, and the weight of chicken, affect the number of eggs they lay.

Which of the following is **NOT** likely to be a factor that affects the number of eggs laid by the chickens?

A. The size of the cage where the eggs are laid.
B. The weight of the chickens.
C. The amount of food given to the chickens.
D. The amount of water given to the chickens.

26. A science class wanted to test the factors that might affect plant height. They felt that the following is a list of factors that could be tested: the amount of light, amount of moisture, soil type, and change in temperature.

Which of the statements below could be tested to determine the factor that might affect plant height?

A. An increase in temperature will cause an increase in plant height.
B. An increase in sunlight will cause a decrease in plant moisture.
C. A plant left in light will be greener than one left in the dark.
D. A plant in sand soil loses more water than one in clay soil.

27. A Biology teacher wanted to show her class the relationship between light intensity and the rate of plant growth. She carried out an investigation and got the following results.

Light intensity (Candela)	**Plant growth rate (cm)**
250	2
800	5
1000	9
1200	11
1800	12
2000	15
2400	13
2800	10
3100	5

Table 1.5. Shows the relationship between light intensity and the growth rate of a plant.

Which of the following statements correctly describes what these results show?

A. As light intensity increases, plant growth also increases.
B. As plant growth increases, light intensity decreases.
C. As plant growth increases, light intensity increases then decreases.
D. As light intensity increases, plant growth increases then decreases.

Questions 28, 29 and 30 refer to the investigation below.

Thabiso is worried about how the cold winter will affect the growth of his tomatoes. He decided to investigate the effect of temperature on the growth rate of tomato plants. He planted tomato seedlings in four identical pots with the same type of soil and the same amount of water. The pots were put in different glass boxes with different temperatures: One at 0°C, the other at 10°C, and another at room temperature and the fourth at 50°C. The growth rates of the tomato plants were recorded at the end of 14 days.

28. What effect does the differences in temperature have in this investigation?

A. The difference in the seasons.
B. The difference in the amount of water used.
C. The difference in growth rates of the tomato plants.
D. The difference in the types of soil used in the different pots.

29. The factor(s) that were being investigated in the above experiment are:

A. Change in temperature and the type of soil used.
B. Change in temperature and the growth rate of the tomato plants.
C. The growth rate of tomato plants and the amount of water used.
D. The type of soil used and the growth rate of the tomato plants.

30. Which of the following factors were kept constant in this investigation?

A. The time and growth rate of tomato plant.
B. The growth rate of tomato plants and the amount of water used.
C. The type of soil and the amount of water used.
D. The temperature and type of soil used.

SCORING KEY FOR THE DEVELOPED TEST INSTRUMENT

Item #	Correct option	Item #	Correct option	Item #	Correct option
1	D	11	A	21	A
2	B	12	C	22	D
3	D	13	B	23	A
4	D	14	D	24	C
5	A	15	D	25	A
6	C	16	C	26	A
7	B	17	C	27	D
8	B	18	D	28	C
9	A	19	C	29	B
10	B	20	C	30	C

Appendix 2. The hands–on practical task guideline

Grade Ten Physical Sciences; Term one

Practical Investigation: Determining the heating and curve of a pure substance; water

Learners' worksheet

Information for the learner

In this investigation you will investigate the phase change and determine the heating and cooling curve of water. You are given a set of guideline to follow in this investigation and the materials in the list are provided to you.

Safety Alert

I. Fire can be dangerous, keep your hair and clothes away from the open flame.

II. Do not temper wit gas taps

III. Report any accident to the teacher immediately

Materials

- Ice cubes
- 250ml beaker
- Tap water
- Bunsen burner and matches
- Gauze wire
- Tripod stand
- Laboratory thermometer
- Stop watch

Method

1. Draw up a suitable table to record the results of your investigation.
2. Place the tripod and the gauze wire over the Bunsen burner.
3. Add crushed ice to the beaker till it is three quarters full.
4. Stir the ice with the thermometer, taking care not to break the thermometer.
5. Record the initial temperature of the water
6. Light the Bunsen burner
7. Place the beaker on the tripod over the burner and start the stop watch.
8. Gently stir the contents of the beaker all the time.
9. Take a temperature reading every one minute, record the readings in the table.
10. Continue taking readings until the water is boiling.
11. Take two more temperature readings while the water is boiling.
12. Remove the beaker of water from the burner
13. Continue to record the temperature of water for the next ten minutes.
14. Write a scientific report for your investigation.

Figure 2 Apparatus used to determine the heating curve of water.

Scientific report

Write up the scientific report in the form of a scientific report. The report should include the following

The investigation title

The investigation question

The hypothesis

The aim of the investigation

The variables (independent variable, dependent variable, fixed/constants)

Apparatus and materials

Method

Results. Table of results, graph from the results

Conclusion

Discussion

You will be provided with a scientific report guideline to use.

Appendix 3. The virtual practical task guideline

Grade Ten Physical Sciences: Term one

Practical Investigation: Determining the heating and curve of a pure substance; water

Learners' worksheet **(Virtual practical investigation)**

Information for the learner

In this investigation you will investigate the phase change and determine the heating and cooling curve of water. You are given a set of guideline to follow in this investigation and the virtual materials in the list are provided to you on the websites below.

http://www.physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/boiling_pure_substance_water_from_liquid_to_gas_vaporization.htm (for heating curve)

http://www.physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/boiling_pure_substance_water_from_liquid_to_gas_vaporization.htm (for heating curve)

go to the website and follow the instructions given.

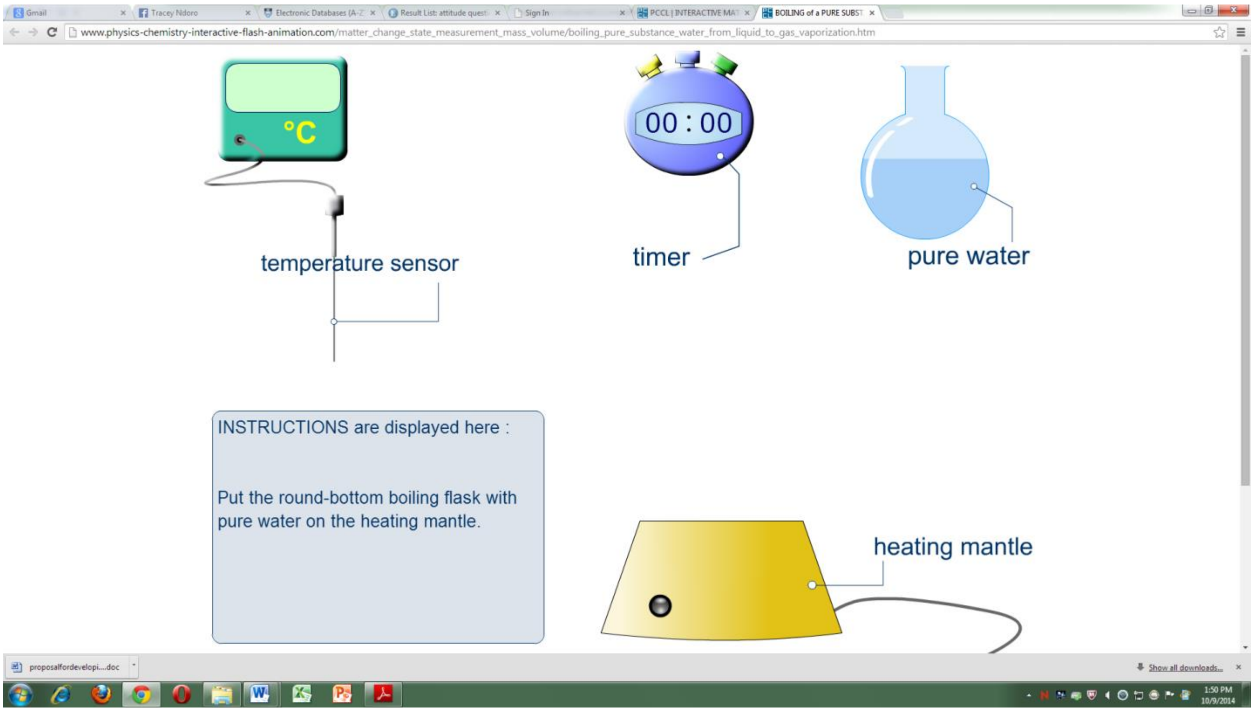
transition from a liquid to a gaseous state

VAPORIZATION OF A PURE SUBSTANCE

p u r e w a t e r

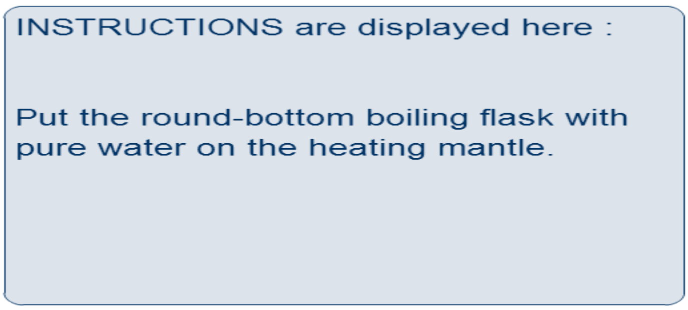
What happens after the boiling point ?

Materials

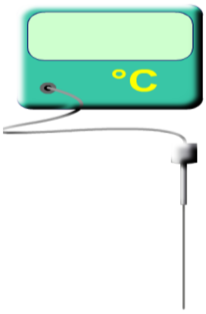

°C
00 : 00
temperature sensor
timer
pure water
INSTRUCTIONS are displayed here :
Put the round-bottom boiling flask with pure water on the heating mantle.
heating mantle

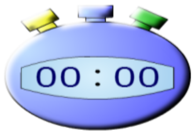
Method

1.

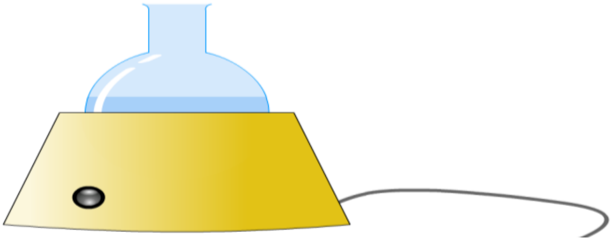

INSTRUCTIONS are displayed here :
Put the round-bottom boiling flask with pure water on the heating mantle.

2.



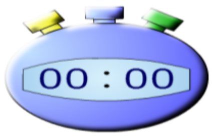


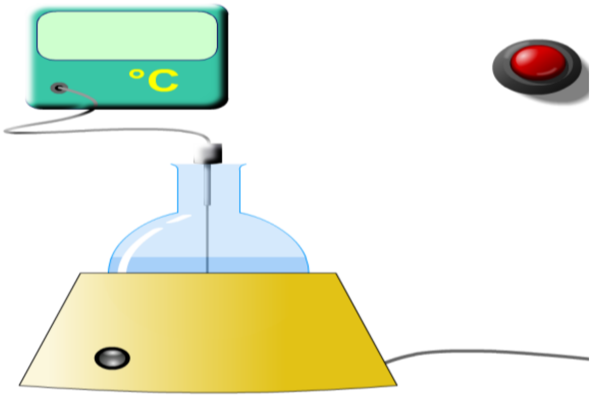
Put the thermometer in pure water.



3.

t (min)	0	1	2	3	4	5	6	7	8	9	10
θ (°C)	16										
state	L										



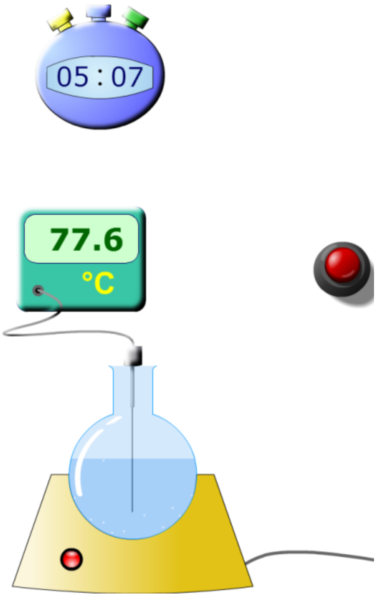


Complete the array by :
1. Clicking on the red button to activate the stopwatch and thermometer.
2. Clicking again on the same red button once every minute.

Note : - You must be careful to be precise.
 - The process was accelerated !

4.

t (min)	0	1	2	3	4	5	6	7	8	9	10
θ (°C)	16	28.3	40.2	52.1	64.3	76.3					
state	L	L	L	L	L	L					



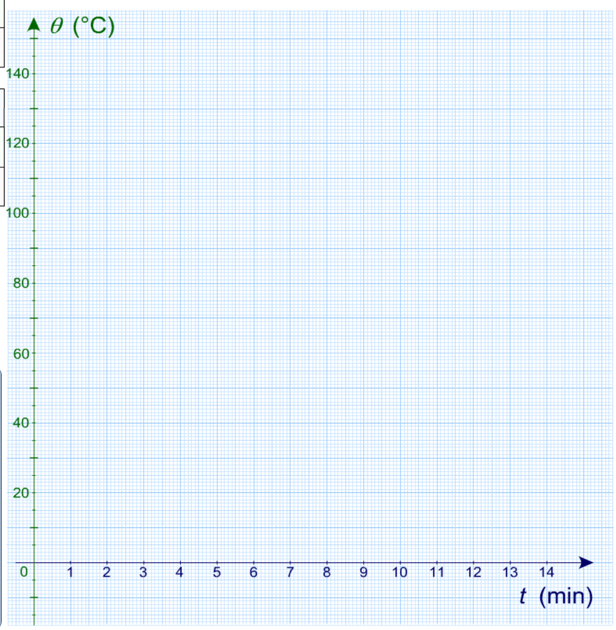
5.

t (min)	0	1	2	3	4	5	6	7	8	9	10
θ (°C)	16	28.3	40.2	52.1	64.3	76.3	88.2	97.3	100	100	100
state	L	L	L	L	L	L	L	L	L+G	L+G	L+G

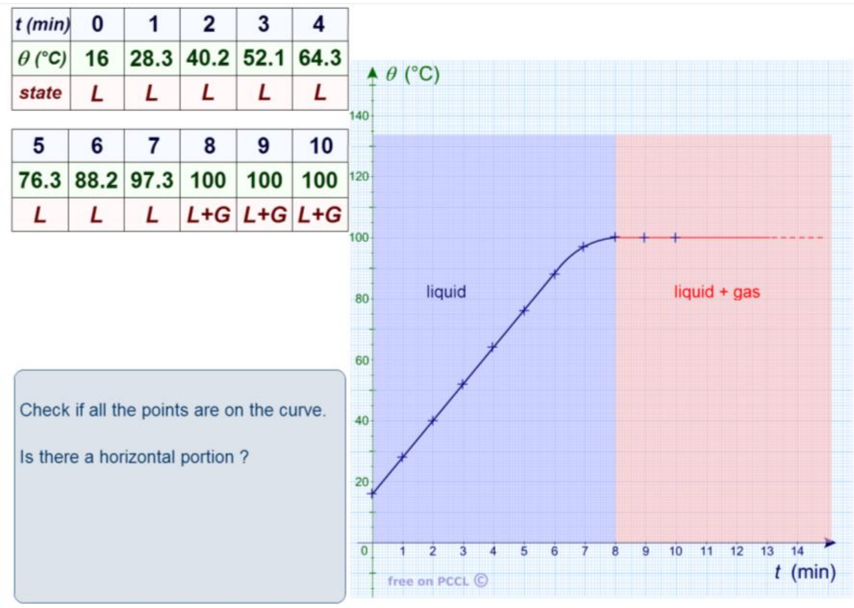
Click on the grid to place each point on the curve.

To delete a point, click it.

Placing the last point launches verification.



Data presentation



6. Go to the website and follow the instructions to determine the cooling curve of water.

7. http://www.physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/solidification_pure_substance_ice_water.htm (for cooling curve)

Scientific report

Write up the scientific report in the form of a scientific report. The report should include the following

The investigation title

The investigation question

The hypothesis

The aim of the investigation

The variables (independent variable, dependent variable, fixed/constants)

Apparatus and materials

Method

Results. Table of results, graph from the results

Conclusion

Discussion (*You will be provided with a scientific report guideline to use.)*

Appendix 4. Scientific report and marking memorandum

A. <u>Scientific report for the practical investigation</u> *Total 30 marks*

Name ______________________ Class ________________________________ Date ________

Investigation title ---

What is the aim of your investigation?--

------ (2)

State the **variables** of the investigation you carried out.

Independent ---

Dependent ---

Controlled/fixed --

---------------- (3)

Write down your investigating question --
--

---------------- (2)

State the hypothesis for this investigation ---

------- (2)

Write a description of how you carried out the investigation ---------------------------------------

----

---------------- (4)

Results

Present the results of your investigation in a table.

-------------- (4)

Present the results in the table in an appropriate graph.

---------------- (6)

Interpret and evaluate your results.

(3)

Identify the melting and boiling points.

Identify the plateaus of phase change and name them (areas of constant temperature).

State the different phases of water at each stage on the graph.

Conclusion

Draw a conclusion from the results of your investigation--

--- (2)

Verify hypothesis.

Use relationship between independent and dependent variables.

--------------- (2)

Discussion

Discuss significance of investigation.

Discuss possible sources of error.

Discuss limitation.

Discuss ways to improve the investigation.

-------------------------- (2)

[Total=30]

A. <u>Scientific report for the practical investigation</u> *Total 30 marks*

Marking Memorandum

Investigation title

Phase changes and heating and cooling curves of water

Identifying the problem

What is the aim of your investigation?

To investigate✓ *phase changes of water and determine*✓*the heating and cooling curve of water*. (2)

Identifying and controlling variables

State the variables of the investigation you carried out.

Independent: *time* ✓

Dependent: *temperature*✓

Controlled/fixed: *heat source, time interval*✓

(3)

Stating the hypothesis

Write down your investigating question?

What happens to the temperature✓*of ice/water if it is heated over a period of time?*

(2)

State the hypothesis for this investigation

When ice/water is heated over a period of time, its temperature changes✓✓

(2)

Experimental Design

Write a description of how you carried out the investigation

Step by step procedure-logical✓

Measurements of variables (temperature and time) identified, quantities specified ✓

Method of recording data specified✓

Diagrams

Adequate/ complete instruction, using instructive language✓

(4)

Results

Present the results of your investigation in the a table

Independent variable indicator column with heading✓

Dependent variable indicator column with heading✓

Correct units given next to each heading✓

Measurement recorded correctly and neatly✓ (4)

Present the results in the table in an appropriate graph

Title of graph✓

X-axis and Y-axis labelled correctly (independent variable –X-axis)✓ ✓

Appropriate scale for Y-axis and for X-axis✓✓

Points plotted correctly as per table of results✓

Line and shape of graph✓

(6)

Data interpretation

Interpret and evaluate your results.

On the graph

Identify the melting and boiling points ✓

Identify the plateaus of phase change and name them. (areas of constant temperature) ✓

State the different phases of water at each stage on the graph.✓

(3)

Conclusion

Conclusion

Verify hypothesis✓

Use relationship between independent and dependent variables✓

(2)

Discussion

Discuss significance of investigation

Discuss possible sources of error

Discuss limitation

Discuss ways to improve the investigation (any two) ✓✓ (2)

[Total =30]

Appendix 5a. Attitude questionnaire; the cover letter

Attitude Questionnaire

Attitude towards virtual practical task and hands-on practical work

Dear learner

Thank you very much for volunteering to participate in this research project.

The project has been approved by the Western Cape Education Department. This project seeks information on learner attitude and performance in virtualpractical work. As a participant you will perform a practical investigation on phase change of matter in two ways: using the real laboratory equipment and then using computer simulated objects. You are required to complete the attitude questionnaire by giving your opinion regarding the two ways of practical work.

You can be assured of complete confidentiality. The information you provide for this project will have your name removed. You are free to withdraw from this study at any time without obligation. If you have any questions about the project, you may ask the researcher:

MC Ndoro

Thank you for your assistance!

Appendix 5b. The Attitude Questionnaire

This questionnaire has questions that seek your opinion on virtual practical investigation and hands-on practical investigation in physical sciences. Please answer these questions as truthful as you can. This is not a test. There are no right or wrong answers. You will not be graded on these answers. Note that all your responses are important and appreciated.

This questionnaire has questions that seek your opinion on virtual practical investigation and hands-on practical investigation in physical sciences. Therefore, we would like you to answer some questions on this subject. Please answer these questions as truthful as you can. This is not a test. There are no right or wrong answers. You will not be graded on these answers. Do not take too much time for one question. You should only need 25 minutes for the whole questionnaire. The first set of questions are about you.

Instructions

Mark with an **x** in the box of your choice for the answer and write the explanation in the spaces provide for some questions.

Thank you for taking your time to participate in this questionnaire.

Question	**Your response**			
1. State your gender	Male		Female	
2. Did you participate in both the hands-on practical investigation and the virtual investigation on phase change?	Yes		No	
3. Which practical investigation did you enjoy the most?	Hands-on		Virtual	
What did you enjoy about the practical investigation you chose in question 3?____________________ ____ ________				

4. Which practical investigation was easy to learn and operate?	Hands-on		Virtual	
Explain ______________________________ ________				
5. Which practical investigation was difficult to learn and to operate?	Hands-on		Virtual	
6. The practical investigation which made understanding of concepts on 'phase change in matter' was …	Hands-on		Virtual	
7. Which practical gave you a better sense of the kind of problems to be encountered in real life?	Hands-on		Virtual	
8. The ------ practical investigation took less time to complete.	Hands-on		Virtual	
9. The practical investigation that helped me understand science better is the -----	Hands-on		Virtual	
10. State the practical investigation that you would prefer to use in future practical investigation.	Hands-on		Virtual	
11. Is there any difference in your understanding of practical investigation skills before and after the practical investigation?	Yes		No	
Explain your answer in question 11 - ______________________________				

____ ______
12. Is there anything else regarding the practical investigation that you would like share with us? ____ __

Appendix 6. Western Cape Department of Education consent

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20150629-837

ENQUIRIES: Dr A T Wyngaard

Ms Chawapiwa Ndoro

PO Box 76

Maitland

7404

Dear Ms Chawapiwa Ndoro

RESEARCH PROPOSAL: COMPARING LEARNER PERFORMANCE AND ATTITUDES TOWARDS TRADITIONAL REGULAR PRACTICAL WORK VERSUS COMPUTER SIMULATED PRACTICAL WORK

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **02 July 2015 till 30 September 2016**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services

Western Cape Education Department

Private Bag X9114

CAPE TOWN

8000

We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard

Directorate: Research

DATE: 30 June 2015

Appendix 7. School consent

PLUMSTEAD HIGH SCHOOL

BASIL ROAD
PLUMSTEAD 7800

TEL: 021 761 8066/7
FAX: 021 797 8494

NON NOBIS PLUMSTEAD

Headmaster
C. George, B.A., B.ED.

27 March 2015

Mrs M Ndoro
55 L 5th Avenue
Kensington
7405

Dear Mrs Ndoro

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT PLUMSTEAD HIGH SCHOOL

I hereby give my consent to allow you to use data from Plumstead High School's Grade 10 Physical Science learners' results, as well as their Grade 9 end of year (2014) results in Natural Science.

Wishing you well with this project.

Signed

MR C GEORGE

PRINCIPAL

Appendix 8. Learner informed consent

University of Cape Town: Faculty of Humanities: School of Education

Learners consent to participate in the learner's attitude towards virtual practical work and hands-on practical work questionnaire

---

Title of study: Learner performance and attitudes in hands-on practical work versus virtual practical work.

Purpose: You are being invited to participate in the above research study. The purpose of this study is to develop a better understanding of learners' experiences in science practical work using computer simulated materials and using real materials and objects.

Procedure: If you agree to participate in this study, you will be required to complete a questionnaire on your attitude on experiences with real materials practical work and simulated. The questionnaire will be completed during class time after your experience with the two kinds of practical work. The procedure will be explained to you when you do the exercise.

Risks: There are no risks to you for participating in this study.

Benefits: It is possible that you will not benefit directly by participating in this study. However, the study should provide you with valuable opportunity to think and reflect on your learning experiences. I addition to that the information gathered in this study will be presented to the school authorities and the Western Cape Department Authorities and it will help them in their efforts to provide better education programs.

Confidentiality: Absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena (summoned to testify). However, the confidentiality of the study records will be maintained to the best way possible. Your responses to the questionnaire will be coded to conceal identity. You will never be identified with any particular response, comments or material that you share with me.

Costs: There is no cost to you beyond the time and effort required to participate in the questionnaire described above.

Right to refuse or withdraw: you may refuse to participate in this study. Even if you agree, you may change your mind and quit at any point.

Questions: If you have any questions, please feel free to ask.

Consent:

I the undersigned confirm that (please tick as appropriate)

1.	I have read and understood the information about the project as provided in the information sheet added.	
2.	I have been given the opportunity to ask questions about the project and about my participation.	

3.	I voluntarily agree to participate in this project.	
4.	I understand I can withdraw at any time without giving reasons and that I will not be penalised for withdrawing neither will I be questioned for on why I have withdrawn.	
5.	The procedures about confidentiality have been clearly explained to me, (e.g. use of pseudonyms, codes, anonymization etc.)	
6.	The use of data in research publications, sharing and archiving has been explained to me.	
7.	If applicable separate consent for interviews, audio, video or other form of data collection has been explained to me.	
8.	I understand that other researchers will have access to this data only if they agree to confidentiality of the data and if they agree to the terms I have specified in this form.	
9.	Select one of the following: ☐ I would like my name used and I understand I have said or written. ☐ I do not want my name used in this research project	
10	I along with the researcher, agree to sign and date this informed consent	

PARTICIPANT

_____________________________ _________________ __________________

Name of Participant Signature Date

RESEARCHER

Name of Researcher Signature Date

Name of researcher: ***Ndoro CM*** Date : 18/ 05 / 2015

Signature of researcher 

Appendix 9. Faculty ethical clearance

Humanities Postgraduate and Research Office
University of Cape Town
Humanities Faculty Ethics in Research Committee

Room 104, Beattie
Private Bag X3 Rondebosch 7701
Tel: +27 (0) 21 650 3718
E-mail: Robyn.Udemans@uct.ac.za

Ref. No.: HUMREC201505-01

11th May 2015

Ms M.C. Ndoro
School of Education
Humanities Building
University of Cape Town

Dear Ms Ndoro,

RE: Ethical Clearance for Master's Project

I am pleased to inform you that ethical clearance has been granted by an Ethics Review Committee of the Faculty of Humanities for your Master's project entitled: *Learner performance and attitudes in regular traditional practical work versus computer simulated practical work.*
I wish you all the best with your study.

Yours sincerely,

Signed

Associate Professor M Prinsloo
Chair, Humanities Faculty Research Ethics Committee

Cc Associate Professor A Hattingh (Supervisor)