



**Exploring the use of state of matter PhET simulation on learners'
conceptual understanding of phase changes of matter**

By

LANDIWE BEAUTY NKOSI

Submitted in fulfilment of the requirements for the degree

MASTER OF EDUCATION: SCIENCE EDUCATION

In the

Department of Mathematics, Science and Technology Education

FACULTY OF EDUCATION

UNIVERSITY OF ZULULAND

Supervisor: Dr T. W. Chinaka

Co-Supervisor: Dr A. Sondlo

January 2023

DECLARATION

I hereby declare that the thesis submitted for the degree of Master of Education (M.Ed), at University of Zululand, is my own, and all sources quoted have been acknowledged by means of references. I also declare that I have not previously submitted this thesis to any other institution of higher education.

Signature: _____  _____ Date: 30/01/2023 _____

(LANDIWE BEAUTY NKOSI)

DEDICATION

To the almighty God and Creator, for his love for Israel endures forever, and the Lord Jesus Christ, the shepherd of Israel, our rock and fortress: I will forever be grateful to the Lord for granting me time to accomplish this thesis.

This thesis is dedicated to my family and friends for their support and words of encouragement. A special feeling of gratitude to my best friends, Awande and Libongwe, for encouraging me to strive for a better life.

I also dedicate this thesis to my beloved people who have meant and continue to mean so much to me. Although they are no longer of this world, their memories continue to regulate my life.

ACKNOWLEDGEMENTS

I wish to thank the Lord Almighty for granting me an opportunity to conduct my Master's studies and sustaining me throughout the process.

A special thanks to Dr T. W. Chinaka for his countless hours of undying support, reading, encouragement and, most of all, patience throughout the entire process. His guidance, expertise, and invaluable support made this thesis a success. Thanks again to Dr A. Sondlo for his constructive and inspirational criticism throughout.

I am grateful to Mr T. Diwa for capturing and analysing the quantitative data. To the editor, Khumalo Nontobeko, thank you for your support.

I wish to thank the KwaZulu-Natal Department of Education and the uMkhanyakude District for allowing me to conduct research in their schools. Finally, I would like to thank principals, teachers, learners, and parents in schools. Learners' excitement and willingness to provide feedback made the completion of this research an enjoyable experience.

ABSTRACT

Many scientific concepts (such as elements, molecules, and energy changes) are not tangible. The scientific concepts are beyond our senses and learners often have little or no experience in constructing such concepts. The aim of this study was to investigate the effects of states of matter (SOM) Physics education technology (PhET) simulation on Grade 6 learners's conceptual understanding and retention of phase changes of states of matter. A purposive sampling technique was used to sample participants from the accessible population in uMkhanyakude District KwaZulu-Natal in South Africa. The sample consisted of 64 Grade 6 Natural Sciences and Technology (NS/Tech) from four primary schools. A mixed-method explanatory sequential design involving (non-equivalent pre-test, post-test, delayed post-test, and interviews) was adopted for this study. A validated two-tier diagnostic questionnaire and semi-structured interviews were used to collect data. A phase change of matter test (PCMT) was used for data collection as pre-test, post-test and delayed post-test. The reliability coefficient of 0.75 was established using Cronbach's alpha reliability coefficient. The participants in the control group were taught using the traditional teacher-centred approach, while the experimental group was exposed to the SOM PhET simulation. The same diagnostic questionnaire was administered as a post-test to establish the effectiveness of the intervention in enhancing conceptual understanding, and as a delayed post-test after a month to establish the retention of phase change of matter concepts. The quantitative data were analysed using the Social Statistical Package for Social Sciences (SPSS) version 25 and the qualitative used idiographic and nomothetic methods. The Johnstone triangle and the cognitive load theory (CLT) were employed as the theoretical framework to the study. The findings indicated that using a SOM PhET as an intervention effectively enhanced conceptual understanding. There was a statistically significant difference in the retention ability after treatment with a PhET simulation, compared to the control group. The findings indicate that an instructional method, based on PhET simulation, enhances conceptual understanding and retention phase change of matter concepts. Further studies are needed to determine the effect of PhET simulation on retention in long-term memory after a year.

Keywords: Conceptual understanding, cognitive load theory, Johnstone triangle, phase change of matter, retention.

LIST OF ABBREVIATIONS AND ACRONYMS

CAPS:	Curriculum and Assessment Policy Statement
CLT:	Cognitive load theory
CTML:	Cognitive theory of multimedia learning
CCMIS:	Concept mapping instructional strategy
ICU:	Incorrect conceptual understanding
IQR:	Interquartile range
IPT	Information processing theory
KZN:	KwaZulu-Natal
NCS:	National Curriculum Statement
NS/Tech:	Natural Science and Technology
PCMT:	Phase change of matter test
PCU:	Partial conceptual understanding
PhET	Physics education technology
PNM:	Particulate nature of matter
SCU:	Sound conceptual understanding
SOM:	States of matter
SOM PhET:	States of matter PhET simulation
STEM:	Science, Technology, Engineering and Mathematics
2TMC:	Two-tier multiple choice

TABLE OF CONTENTS

DECLARATION	II
DEDICATION	III
ACKNOWLEDGEMENTS	IV
ABSTRACT	V
LIST OF ABBREVIATIONS AND ACRONYMS	VI
TABLE OF CONTENTS	VII
LIST OF FIGURES	XII
LIST OF TABLES	XIII
CHAPTER 1 INTRODUCTION AND ORIENTATION TO THE STUDY	1
1.1 OVERVIEW	1
1.2 BACKGROUND TO THE STUDY	1
1.3 STATEMENT OF THE PROBLEM	4
1.4 AIMS AND OBJECTIVES OF THE STUDY	6
1.5 RESEARCH QUESTIONS	7
1.5.1 Research Questions	7
1.6 NULL HYPOTHESES	7
1.7 SIGNIFICANCE OF THE STUDY	7
1.8 METHODS OF STUDY	8
1.8.1 Research Paradigm	8
1.8.2 Research Design	8
1.8.3 Research Instruments	9
1.8.4 Data Analysis and Interpretation	9
1.9 ETHICAL CONSIDERATIONS	9
1.10 DEMARCATION OF THE FIELD OF STUDY	10

1.11 LIMITATIONS AND ASSUMPTIONS OF THE STUDY	10
1.11.1 Limitations	10
1.12 ASSUMPTIONS	10
1.13 DEFINITIONS OF TERMS	10
1.13.1 Conceptual Understanding	10
1.14 OUTLINE OF THE PLAN OF STUDY	12
CHAPTER 2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK	13
2.1 INTRODUCTION	13
2.2 THEORETICAL FRAMEWORK	13
2.2.1 The Johnstone Triangle	14
2.2.2 Cognitive Load Theory	17
2.2.3 Information Processing Theory	19
2.2.4 Cognitive Theory of Multimedia Learning	21
2.3 SIMULATION-BASED LEARNING SYSTEM	22
2.3.1 The Use of Computer Simulations in Teaching	23
2.4 COMPUTER SIMULATIONS IN CONCEPTUAL UNDERSTANDING OF SCIENCE TOPIC	24
2.5 LEARNERS' CONCEPTIONS OF PHASE CHANGE	27
2.6 INSTRUCTIONAL APPROACHES AND RETENTION IN SCIENCE EDUCATION	28
2.7 SUMMARY AND CONCLUSION	32
CHAPTER 3 RESEARCH METHODOLOGY	33
3.1 INTRODUCTION	33
3.2 RESEARCH PARADIGM	33
3.3 RESEARCH DESIGN	34
3.3.1 Characteristics of Mixed Method Design	34
3.3.2 Explanatory Sequential Research Design	35

3.3.3 Non-Equivalent Pre-Test Post-Test, Delayed Post-Test Control Group Design	36
3.4 POPULATION AND SAMPLING.....	37
3.5 VARIABLES.....	37
3.5.1. Instruments.....	37
3.5.2 The Phase Change of Matter Test (PCMT)	38
3.5.3 Reliability and Validity of PCMT.....	39
3.6 INTERVIEWS.....	40
3.7 INTERVIEW SCHEDULE	41
3.8 TRUSTWORTHINESS OF THE INTERVIEW DATA	41
3.9 PILOT STUDY	42
3.10 ADMINISTERING OF THE PRE-TEST.....	43
3.11 ADMINISTERING INTERVENTION.....	44
3.12 ADMINISTERING POST-TEST	45
3.13 ADMINISTERING A DELAYED POST-TEST	45
3.14 METHODS OF DATA ANALYSIS	46
3.15 ETHICAL CONSIDERATIONS.....	46
3.15.1 Protection	47
3.15.2 Confidentiality	47
3.15.3 Choice and Participation.....	47
3.15.4 Informed Consent.....	47
3.15.5 Provision.....	48
3.15.6 Researcher Avoiding Bias	48
3.15.7 The Role of the Researcher.....	48
3.16 SUMMARY AND OUTLINE OF THIS STUDY'S RESEARCH DESIGN.....	49
3.17 SUMMARY	49

CHAPTER 4 DATA ANALYSIS AND INTERPRETATION	51
4.1 INTRODUCTION	51
4.2 BIOGRAPHICAL CHARACTERISTICS OF PARTICIPANTS	51
4.2.1 Gender Distribution.....	51
4.2.2 Age Distribution	52
4.3 COMPARISON OF PERFORMANCE OF LEARNERS TAUGHT USING THE PHET SIMULATION VERSUS THE TRADITIONAL TEACHER-CENTRED METHOD	53
4.3.1 Descriptive Statistics of Pre-Test and Post-Test Scores	53
4.4 SKEWNESS AND KURTOSIS.....	55
4.5 SHAPIRO-WILK TEST (TEST OF NORMALITY)	55
4.6 PAIRED SAMPLE T-TEST	56
4.7 INFERENTIAL STATISTICS ANALYSES	57
4.8 THE EFFECTIVENESS OF THE PHET SIMULATION VERSUS THE TRADITIONAL-BASED INTERVENTION	58
4.9 QUALITATIVE DATA ON THE LEARNERS CONCEPTUAL UNDERSTANDING OF PHASE CHANGES OF MATTER	59
4.10 EXCERPTS FROM INTERVIEWS.....	62
4.11 THE EFFECT OF THE PHET SIMULATION VERSUS TEACHER-CENTRED APPROACH ON RETENTION OF STATES OF MATTER CONCEPTS	65
CHAPTER 5 DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS	67
5.1 INTRODUCTION	67
5.2 DISCUSSION.....	67
5.3 IS THERE A STATISTICALLY DIFFERENCE BETWEEN PRE-TEST AND POST-TEST MEAN SCORES OF THE GRADE 6 LEARNER TAUGHT WITH A SOM PHET SIMULATION VERSUS TRADITIONAL INSTRUCTION?.....	68

5.4 TO DETERMINE HOW A SOM PHET SIMULATION ENHANCES GRADE 6 LEARNERS' CONCEPTUAL UNDERSTANDING OF PHASE CHANGES OF MATTER.....	69
5.5 TO DETERMINE HOW THE USE OF SOM PHET SIMULATION AFFECTS THE RETENTION ABILITY OF THE GRADE 6 LEARNERS ON PHASE CHANGES OF MATTER.....	71
5.6 SUMMARY	73
5.7 LIMITATIONS	74
5.8 RECOMMENDATIONS FOR FURTHER RESEARCH	74
5.8.1 Recommendations for Instruction	75
REFERENCES.....	76
ANNEXURES.....	86
ANNEXURE A: UNIVERSITY ETHICAL CLEARANCE	87
ANNEXURE B: DBE PERMISSION FOR RESEARCH	88
ANNEXURE C: PARTICIPANT INFORMED CONSENT DECLARATION.....	89
ANNEXURE D: PARENT AND GUARDIAN'S INFORMED CONSENT DECLARATION	91
ANNEXURE E: CHILD PARTICIPANT'S CONSENT FORM	93
ANNEXURE F: TRANSLATED PARENT /GUARDIAN'S INFORMED CONSENT	94
ANNEXURE G: LETTER TO SCHOOL PRINCIPALS	96
ANNEXURE H: PRE-TEST AND POST TEST	97
ANNEXURE I: INTERVIEW SCHEDULE.....	100

LIST OF FIGURES

Figure 1.1: Outline of study	12
Figure 2.1: Johnstone triangle (adapted from (Popova & Jones, 2021)	14
Figure 2.2: The symbolic domain as providing resources for representation and communication of chemical concepts (adapted from (Taber, 2013).....	16
Figure 2.3: Cognitive load theory (adapted from (Albus et al., 2021)	18
Figure 2.4: Information processing theory (adapted from Pratiwi et al., 2019)	20
Figure 2.5: Dual-channel assumption (Mayer, 2011)	21
Figure 3.1: Explanatory sequential research design	35
Figure 3.2: Explanatory design (quan / qual) (adapted from (Creswell & Clark, 2017)	36
Figure 3.3: States of matter: Basic PhET simulation	45
Figure 3.4: Outline of the research design	49
Figure 4.1: Age Distribution of the participants (n = 64)	52
Figure 4.2: Histogram of the participants' post-test scores.....	56
Figure 4.3: Analysis of interview responses	61
Figure 4.4: Analysis of interview responses	62
Figure 4.5: Condensation process	65

LIST OF TABLES

Table 2.1: Learners' alternative conceptions of phase change in the literature.....	28
Table 3.1: Non-equivalent control group design.....	36
Table 4.1: Gender distribution of the participants (n=64)	52
Table 4.2: Descriptive statistics of pre-test and post-test scores.....	54
Table 4.3: Test of normality.....	56
Table 4.4: Paired samples test.....	57
Table 4.5: Testing the effectiveness of the PhET simulation versus the traditional teacher-centred intervention.....	59
Table 4.6: Delayed-post-test mean scores of the control and experimental groups .	66

CHAPTER 1 INTRODUCTION AND ORIENTATION TO THE STUDY

1.1 OVERVIEW

This study explored the use of simulations on South African Grade 6 Natural Science learners' conceptual understanding of phase changes of matter. It also determined how the states of matter PhET simulations enhance the retention of phase change of matter concepts.

1.2 BACKGROUND TO THE STUDY

There is a general agreement that the quality of Science teaching and mastery at the primary school level is crucial for learner success and development in life (Halverson, 2007). The particulate nature of matter (PNM) is a concept that has become more important with the development of Natural Science and Technology (NS/Tech). The fundamental of the PNM lies in the atom concept and atom models. In most countries, the topic spans from primary, high school, and university levels. The PNM plays a major role in chemistry and physics and is essential in understanding some basic concepts in everyday life such as the structure of matter, the states of matter, osmosis, diffusion, solution, and solubility, as well as chemical reactions (Türkoguz, 2020) .

Numerous studies show that learners from primary school to tertiary levels have difficulty understanding the PNM concept (Adadan et al., 2009; Aydeniz et al., 2017; Stojanovska et al., 2012). NS/Tech is a subject that has concepts that can be difficult for learners to comprehend. One of the topics, phase change of matter, involves visualisation and abstract thinking and is taught using a language different from everyday life (Hejnová & Králík, 2019).

The Department of Basic Education in South Africa introduced the Curriculum and Assessment Policy Assessment Statement (CAPS) in 2012, which was designed to motivate the engagement of learners in gaining knowledge conceptually across different grades and learning areas (Moodley, 2013). However, in rural schools in the province of KwaZulu-Natal (KZN), instructional approaches remain largely teacher-centred. Most teachers working in public primary schools use chalkboards and charts to teach about the phase changes of matter .

Fitzgerald and Smith (2016) posited that most South African teachers, especially in primary schools, depend only on textbooks. It is also difficult to grasp the concept because the PNM is presented in classrooms and books in simple representations and analogies based on the historical process, and motion positions cannot be given in these expressions (Yaseen & Akaygun, 2016). Conceptual understanding of NS/Tech in primary schools also depends on three levels of representation, namely macroscopic, symbolic, and sub-microscopic (Nyachwaya & Gillaspie, 2016).

The macroscopic refers to the visible and tangible; symbolic refers to mathematical interpretations and formulas; and sub-microscopic represent atoms, molecules, ions and structures (Gilbert & Treagust, 2009). Learners live in the macroscopic world, and they must create their own representation to gain some understanding about the dynamic nature of particles at a sub-microscopic level. The dynamic motion of particles at sub-microscopic level, resulting in energy changes and phase changes, is abstract and cannot be explained using books and charts.

Learners come to school having abundant first-hand experience with change of state. The reciprocal processes of evaporation and condensation have been central to many studies on learners conceptual understanding (Smith, 2016). Aydeniz and Kotowski (2012) reported that Grade 5 students attributed the condensation on a glass of cold water to seepage of water through the glass. Furthermore, some thought that the cold surface reacted with the dry air to form water by allowing oxygen and hydrogen to react. In a similar study, Durmuş and Bayraktar (2010) discussed that some learners thought that evaporation occurs only at very high temperatures, whereas others believed that evaporation occurs only when liquids boil. Savasci-Acikalin (2019) reported Grade 6 learners' conceptual understanding of phase change of matter using textbook representations. The learners' representations of phase change did not match the scientific notions. Furthermore, the textbook representations did not help learners to understand the particle dynamics at sub-microscopic level during phase changes. One of the recommendations was to provide more guidance, discussions and change instructional approaches.

In South Africa, learners start to learn about the states of matter (SOM) in NS/Tech from Grade 4, where they use physical properties to describe a state of matter. It is essential for students to understand that matter exists in all phases and that matter can also change its states, by either absorbing or releasing energy. Several studies

have explored learners' conceptions of matter and found that learners, at all grade levels, struggle to understand the sub-microscopic nature of matter (Nakhleh et al., 2005; Othman et al., 2008; Singer et al., 2003; Taber & García-Franco, 2010). The researcher explored the use of simulations on learners conceptual understanding of phase changes of states of matter in Grade 6 learners since such studies has rarely been done in South Africa.

Research on the learning effects of computer simulations in Science education has shown that interactive simulation can improve the effectiveness of instruction (Yaseen & Akaygun, 2016). A simulation is a simplified version of the natural world, and it has the potential to clarify learners' conceptual understanding on targeted chemical phenomena. Physics education technology (PhET) simulations have been instrumental in improving students conceptual understanding of abstract concepts in Science education (Inayah & Masruroh, 2021).

One of the advantage of simulations is "the multi-representational visualizations of imperceptible objects and phenomena make explicit the information embedded in external representations with interactive visual displays, thus helping learners perceive the relationship between the representing and represented world" (Taibu et al., 2021). Thus, PhET simulations allow learners to connect to the real world and allow student interaction and inquiry. Simulations are also cost effective and they can be useful in schools situated in rural areas. According to Wilcox and Lewandowski (2017), learners from primary schools are more likely to construct new knowledge through multimedia presentations, such as the use of simulations. There are few studies that have documented the teaching of Science in primary schools; more studies focus on the secondary school level, especially Grade 12 (Bantwini, 2017). The researcher, therefore, intends to explore the effectiveness of the use of the states of matter PhET simulations on Grade 6 learners of selected primary schools of uMkhanyakude District, in KZN, South Africa.

In a study involving the effect of using the Virtual Laboratory on Grade 10 learners conceptual understanding and their attitudes towards Science, Abou Faour and Ayoubi (2017) found that most learners relied on rote skills and lacked a recall of important concepts learnt the previous term. Knowledge retention is mainly influenced by memory and classroom activities. Science as a discipline risks being a mnemonic exercise if learners fail to retain core knowledge concepts that drive phase changes.

The retention of core knowledge concepts by learners may be a research niche in Science-education that has the potential to inform instructional practices in primary schools.

According to Lysne and Miller (2017), retention is the ability of a learner to remember what has been learned over time and it is influenced by instructional approaches. Furthermore, retention is the extent to which learners can successfully retrieve core knowledge concepts from long-term memory. Instructional methods play an important role in the retention ability of learners. Inappropriate instructional approaches in Science invariably translate to learners' inability to retain core knowledge concepts (Ajayi & Angura, 2017). In South Africa, NS/Tech lessons are usually large classes. The traditional teacher-centred approach is the *modus operandi*. The researcher considered the idea of a PhET simulation, which involve the active participation of the students, would improve the retention of phase change concepts.

1.3 STATEMENT OF THE PROBLEM

The researcher postulates that Grade 6 learners experience difficulties in grasping and understanding many topics and concepts in NS/Tech. One of these topics is states of matter (SOM). The topic is important and it is the foundation of many Science, Technology, Engineering and Mathematics (STEM) disciplines (Council, 2012). The SOM is fundamental in NS/Tech and is used to explain the behaviour of matter and the complex arrangement of the materials that make up objects. The configuration and behaviour of the particles in materials and their interaction with energy at sub-microscopic level is abstract. The abstract nature of matter and its phase changes are beyond the conceptual understanding of primary and secondary learner if improper instructional approaches are used (Popova & Jones, 2021).

Several studies (Adadan et al., 2009; Aydeniz & Kotowski, 2012; BADRIAN et al., 2011; Hejnová & Králík, 2019; Othman et al., 2008) have found that learners from primary school to university have difficulty understanding particle nature of matter which is central to understanding the phase changes. Hejnová and Králík (2019) suggested that the particle nature of the matter concept is abstract and difficult to visualise. In addition, it is taught in a language different from everyday life in schools. There are other learning obstacles to the concept, including the simple representations and analogies in lessons and books based on the historical process, and the inability

to specify motion positions in these expressions (Türkoguz & Ercan, 2022). According to (Talanquer, 2018), learners' conceptual understanding in SOM requires versatility among macroscopic and microscopic, and their symbolic representations. The traditional instructional approach of SOM involves the use of charts, chalkboard and textbooks (Özmen, 2013a).

The 'chalk and talk' teacher-centred approach is the prevalent instruction in most rural primary schools. Khumalo and Maphalala (2018) acknowledged that schools situated in rural areas in South Africa lack the proper study materials that enhance learning. Most teachers in these places rely mostly on textbooks. Textbooks are one of the teaching tools frequently used in schools. In addition, textbooks are also a major source of representation that learners encounter in Sciences classes. Popova and Jones (2021) discussed that textbooks do not provide the dynamic nature of particles when matter change phase.

There is great consensus among researchers that high-quality Science education teaching and learning at primary school level is fundamental for learner success (Popova & Bretz, 2018; Popova et al., 2020). Many countries have adopted the use of simulations in Science education among primary learners as fundamental to enhance success in STEM. Despite various countries focussing on primary school Science education, such attention has not been evident in South Africa (Set et al. (2017), especially in NS/Tech (grades 4–6). There has been a paucity in research related to the SOM and conceptual understanding of phase change of matter related to the South African context. In the present study, the researcher sought to investigate the Grade 6 NS/Tech learners' conceptual understanding of phase change of matter and retention on the topic SOM.

Research in primary school Science education shows there is a lack of the conceptual understanding of Science concepts. Set et al. (2017) contended that NS/Tech teaching hardly supports conceptual understanding. The researcher believes that active learning, involving learners' PhET simulations, rather than relying on traditional instructional approaches, would enhance their conceptual understanding of abstract and complex concepts of the phases changes of SOM. Phase changes of matter are considered to be abstract in nature. Its abstract in nature results in poor performance and retention of concepts among Grade 6 learners. Knowledge retention is mostly influenced by classroom activities as well as memory. The reliance of learners on rote

skills risks NS/Tech becoming just a mnemonic exercise. Educators should strive to teach for conceptual understanding that may lead to better retention. The use of simulations is expected to promote learner engagement and improve conceptual understanding and retention of states of matter concepts among primary school learners.

In summary, learners of all ages can have a lack of knowledge on the particle nature of matter and can incompletely explain the dynamic nature of particles at microscopic level especially during phase changes. Phase change of matter is an abstract concept that requires a microscopic explanation due to its invisible nature. The imperfect-teaching methods and insufficient explanations in scientific language may cause this lack of conceptual understanding and retention of concepts. Popova and Bretz (2018) advocated that multiple representations such as the modelling, simulations and animation if designed well may bridge macroscopic and microscopic levels. One of the promising strategies that can enhance learners learning and retention of information is the integration of emerging technologies into instruction

1.4 AIMS AND OBJECTIVES OF THE STUDY

The aim of this study was to investigate the effects of SOM PhET simulation on Grade 6 learners conceptual understanding and retention of phase changes of states of matter. The following research objectives were set to guide this study:

1. To investigate the effects of SOM PhET simulation on Grade 6 learners conceptual understanding of phase change of states of matter.
2. To determine how a SOM PhET simulation enhance Grade 6 learners conceptual understanding of phase changes of matter.
3. Determine the effects of SOM PhET simulation on the retention ability of the Grade 6 learners on phase changes of matter.

1.5 RESEARCH QUESTIONS

1.5.1 Research Questions

1. Is there a statistically difference between pre-test and post-test mean scores of the Grade 6 learner taught with a SOM PhET simulation versus traditional instruction?
2. How does a SOM PhET simulation enhance a conceptual understanding of phase change of matter among Grade 6 learners?
3. What are the effects of SOM PhET simulation on Grade 6 learners retention?

1.6 NULL HYPOTHESES

To answer research questions 1 and 3, the following two hypotheses were tested:

H₀ 1: There is no significant difference in the performance of learners taught using the PhET Simulation versus those taught by the traditional method.

H₀ 2: There is no statistically significant difference in the learners' retention ability on phase changes of matter between learners taught by PhET simulation versus the traditional method.

1.7 SIGNIFICANCE OF THE STUDY

The findings of this study will enhance the level of interest in learning Science and improve learners performance in Science as well. The results obtained from the present study are capable of identifying the challenges learners face when learning about phase change of matter. Thus, the results can contribute towards the interventions used by teachers when teaching the states of matter. These interventions can take the form of tutorials as well as extra time being spent focusing on problematic areas during lesson presentations. The results of this study could also inform curriculum developers in Science education about the conceptual understanding levels of Natural Science and Technology (NS/Tech) learners.

1.8 METHODS OF STUDY

1.8.1 Research Paradigm

The researcher utilised a mixed method methodology and a pragmatism paradigm was adopted. A research paradigm is defined as “a way of seeing the world that frames a research topic” and impact the researcher’s view about the topic (Hughes, 2020). Pragmatism paradigm is not committed to any one system of philosophy or reality. It focuses on what works best and can result in using both quantitative and qualitative approaches to address the research questions (Creswell & Clark, 2017). Since the research questions of the present study are multifaceted, a pragmatism paradigm was adopted because it enables data collection and analysis methods that bring insights into the research problem, without restriction to any alternative paradigm. Creswell and Clark (2017) suggested that the advantages of combining qualitative and quantitative approaches are twofold: augment experimental data with qualitative data and to draw strengths of both qualitative and quantitative approaches and minimises the weakness of one approach within a single study.

1.8.2 Research Design

The present study was conducted based on a quasi-experimental research design, referred to as the non-equivalent control group design, as well as interviews in a manner of a sequential explanatory design. In a sequential explanatory design, quantitative and qualitative data collection is implemented in two phases with primary emphasis on quantitative methods (Cohen et al., 2018). The non-equivalent control group design was chosen because it has minimal internal validity. The goal of the body of quasi-experimental design is an attempt to answer questions such as: “Does a treatment or intervention have an impact?” (Mills & Gay, 2019). It appropriately tests the effect of the independent variable SOM PhET simulation on the dependent variable (conceptual understanding). This means that the design is able to determine whether the PhET simulation is responsible for the observed statistical change in the learners’ scores in phase change of matter. In this study, instruction using the PhET simulation was the treatment and interviews allowed the researcher to probe learners’ conceptual understanding.

1.8.3 Research Instruments

A two-tier diagnostic test was issued as a pre-test, post-test, and a delayed post-test. The pre-test was used as a baseline assessment to check learners' conceptual understanding of phase changes of states of matter. After baseline assessment of pre-test, PhET simulations was used as an intervention to assist learners. The procedure carried on for a week. A post-test and delayed post-test were administered to determine the effects of PhET simulations on learners' conceptual understanding of phase changes of states of matter. An interview schedule was utilised to interview learners to get an insight of the effectiveness of the PhET simulations.

1.8.4 Data Analysis and Interpretation

In this study, data analysis transpired in two phases. Quantitative data were analysed using SPSS (Statistical package for social Sciences). Qualitative data that was collected through interviews were analysed using a three-stage technique which entailed transcribing, coding and classification of information as well as representing data.

1.9 ETHICAL CONSIDERATIONS

The university research committee granted a clearance letter for this study. There were three ethical considerations that guided this study namely confidentiality of data, deception of the participants as well as protection of the participants from any forms of harm. Consent forms were filled, and the benefits of the study were clarified to the learners. Participants were assigned numerical codes to retain confidentiality. Participation in the study was completely voluntary and none of the participants were obligated to participate in pre-test, post-test, delayed post-tests as well as interviews. Since research design of this study was a sequential explanatory, the researcher used a quasi-experiment to obtain quantitative data. Quasi-experimental utilises intact classes, hence participants appear to have no alternative class to join should they have decided not to participate. However, participants were completely permitted not to partake in writing pre-test and post-tests, as well as interviews

1.10 DEMARCATION OF THE FIELD OF STUDY

The study focused on exploring the use of simulation on Grade 6 learners' conceptual understanding of phase changes of states of matter. A total of 64 learners completed this study, with 32 in the comparison group and 32 in the experimental group. This study involved a total of 64 (n=64) Grade 6 learners enrolled at public primary school of South Africa.

1.11 DELIMITATIONS AND ASSUMPTIONS OF THE STUDY

1.11.1 Delimitations

- 1 The study was restricted to Grade 6 learners at a public primary school in uMkhanyakude District in KwaZulu-Natal. The sample size might not be big enough to represent the whole population of Grade 6 learners in public primary schools in South Africa.
- 2 The interview sample of eight learners drawn from both experimental group and control group might have been small.

1.12 ASSUMPTIONS

1. During the one week–study, there was no interaction between learners in both experimental group and control group.
2. Pre-tests, post-tests, and delayed post-tests were administered to learners in both experimental group and control group under the standard primary school's examination conditions.
3. All learners honestly completed the three tests they were given.
4. Learners' interviews were conducted under the standard conditions and interview questions were answered truthfully.

1.13 DEFINITIONS OF TERMS

1.13.1 Conceptual Understanding

In Science education, conceptual understanding is the primary goal (Konicek-Moran & Keeley, 2015), and a complex phenomenon (Nieswandt, 2007). In conceptual understanding, learners develop generalisations about what a concept is about or about its properties based on what they know about the concept (Mills & Gay, 2019).

A conceptual understanding of a subject does not require memorisation, but rather formulates ideas as they learn; asks questions continuously based on their current understanding; and transforms and reconstructs knowledge structures. Learning NS/Tech conceptually is of utmost importance for a variety of reasons. The first step towards developing conceptual understanding among learners is to help them connect knowledge across contexts and not isolate facts and procedures. The present study adopted Mills and Gay (2019) definition of conceptual understanding as a process whereby learners can comprehend ideas in a transferrable way and help them use what they learn in schools and apply it in across domains.

Phase change of matter

A phase change is a physical process in which a substance goes from one phase to another. The nature of the phase change depends on the direction of the heat transfer. When heat is added to a substance, it changes from a solid to a liquid or from a liquid to a gas. Gases become liquids and liquids become solids when heat is removed.

PhET simulation

According to Winsberg (2013), the term computer simulation is used in both a narrow and a broad sense. Some may want to grasp the term from more than one sentiment. Parker (2013) described computer simulations as an inventive way to transfer scientific ideas and unite learners in educational activities. Research on the learning effects of computer simulations in chemical education has shown that interactive simulation can improve the effectiveness of instruction (Taibu et al., 2021). A simulation is a simplified version of the natural world, and it has the potential to clarify learners' conceptual understanding on targeted chemical phenomena. Physics education technology (PhET) simulations have been instrumental in improving students conceptual understanding of abstract concepts in Science education (Wilcox & Lewandowski, 2017).

Retention

The term *retention*, as used in the present study, relies on the definition of Sousa (2016) who viewed retention as a measure of how well a learner remembers the material over time. In addition, it refers to the extent to which a learner can successfully retrieve information from long-term memory. Retention of introductory NS/Tech course material is vital for learner success in future Science related courses. Retention can

be fostered by internal and external factors such as comprehension of phase change of matter concepts as well as by external factors such as teaching methods (Engelbrecht et al., 2007).

1.14 OUTLINE OF THE PLAN OF STUDY

The outline of this study from Chapter 2 to the end is envisaged as follows:

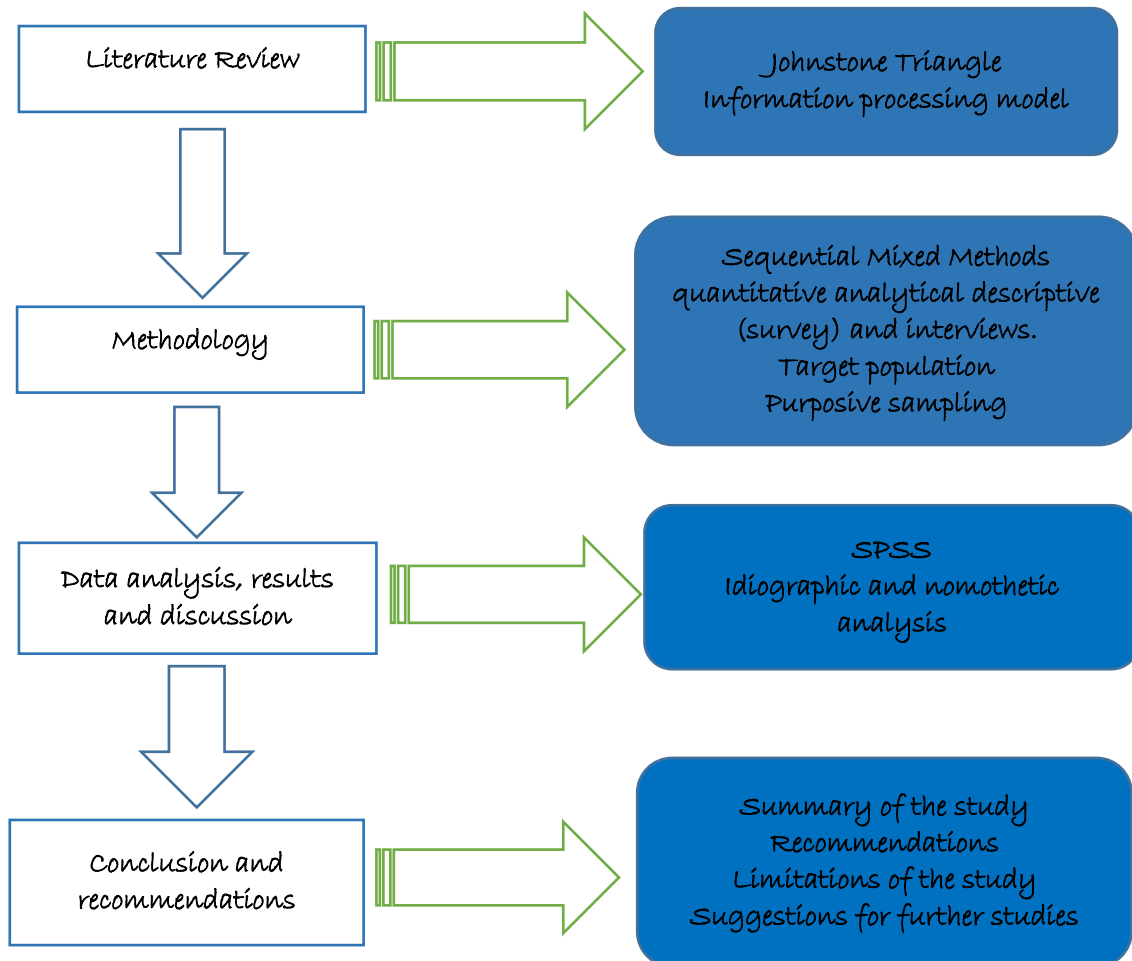


Figure 1.1: Outline of study

CHAPTER 2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 INTRODUCTION

The background for the present study is provided in Chapter 1. The statement of the problem and the objectives of the study were also discussed. The research design, including the research methods, selection of the participants, and data collection and analysis methods were then explained. Lastly, Ethical considerations and chapter-by-chapter organisation pertaining to the current study were also provided. This chapter provides literature on theories selected to support this study. According to Fairbanks (2021), a theory or theories are formulated to explain, predict, and understand phenomena and in many cases to challenge and extend existing knowledge within the limits of critical bounding assumptions. One of the main objectives of the current study is to determine the effects of PhET simulation on learners' conceptual understanding and retention of phase change of matter concepts. Two theories were selected, as theoretical frameworks to support this study namely: cognitive load theory (CLT) and the Johnstone triangle. This chapter entails a comprehensive review of the literature of this study. This chapter will begin with a brief discussion of the two theoretical frameworks underpinning this research study. Thereafter, a review of the scope of the literature review.

2.2 THEORETICAL FRAMEWORK

Theoretical framework refers to a set of concepts or understanding of the world in the field of research or empirical work and is also the basis of one's research problem (Kumar, 2018). The theoretical framework demonstrates an understanding of theories and concepts that are relevant to the topic of the study and relate to the broader areas of knowledge being considered. Different philosophies underpin various research studies. These philosophies are regarded as theoretical frameworks; they are the parameters upon which this study is discussed. In this study, the researcher briefly explains the key elements of the theories that underpin this study and also provides a rationale for adopting the theories in relation to conceptual understanding and retention of phase change of matter concepts. Since conceptual understanding and

retention are formed during formal and informal learning experiences, this study adopted the cognitive load theory and Johnstone's triangle.

2.2.1 The Johnstone Triangle

This study is grounded by the Johnstone triangle (Johnstone, 2010; Taber, 2013) developed by Alex Johnstone. This theory acknowledges that chemistry knowledge can be understood on three fundamental 'levels' or 'representations' or 'domains' as suggested by Alex Johnstone (Figure 2.1), the macroscopic, the symbolic, and the sub-microscopic. The macroscopic level includes all that learners can see, smell, and feel with their sensory organs (such as water in the liquid phase). The sub-microscopic levels are the atoms and molecules that are dynamic when matter changes phases. It is also unseen and consists of explanatory models such as the PNM. The representational level includes symbols, equations, mathematical formulae, graphs, and diagrams. In the present study, the representation level consists of the shapes (PNM) of solids, liquids, and gases. The use of chemistry visualisations by chemists in communicating chemical phenomena is one of the reasons why chemistry can be challenging for learners.

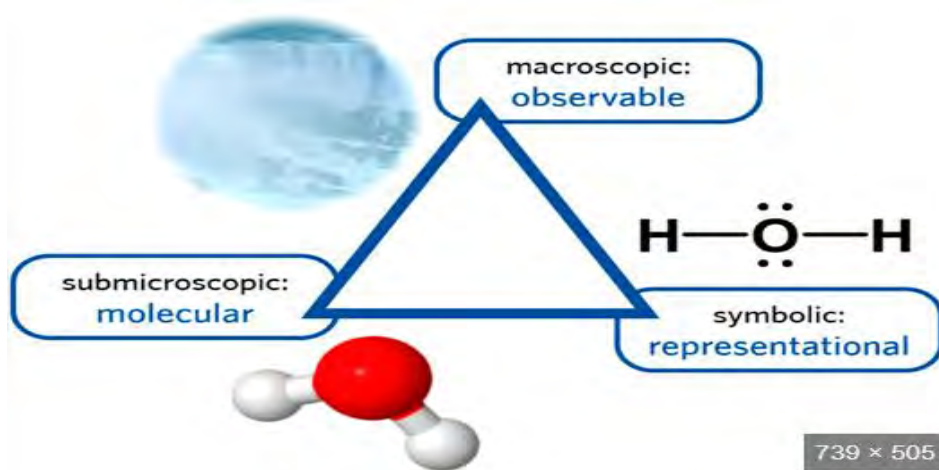


Figure 2.1: Johnstone triangle (adapted from (Popova & Jones, 2021))

Furthermore, Popova and Jones (2021) argued that there are many representations to describe chemical phenomena such as two-dimensional graphs and diagrams, concrete ball-and-stick models, symbolic representations such as chemical symbols, formulas, and equations. Learners need to be able to understand phenomena across multiple distinct domains/levels in addition to the sheer number of representations in chemistry. To enhance conceptual understanding the learners be able to translate

among the three levels: macroscopic phenomena (visible and tangible phenomena), and symbolic phenomena (symbols and characters used to represent macroscopic and sub-microscopic phenomena). In the present study, Grade 6 learners must be able to translate from macroscopic (water, ice), symbolic (representation of the phases using the PNM), and sub-micro (energy changes leading to phase change).

Johnstone (2010) stated that expert chemists/teachers can operate at all three levels with ease. He postulates that experts in chemistry view any subject topic at three levels, and “jump freely from level to level in a series of mental gymnastics”. However, learners may struggle to translate with ease at all three levels, and as a result, they face difficulties with conceptual understanding. Nevertheless, learners often find the interplay of the levels difficult both to conceptual understand and retain the concepts. Taber (2013) suggested that a lack of sub-micro-level experience is one problem that arises from such interplay. Consequently, learners face the difficult task of learning chemical representations’ ‘language’ when studying NS/Tech.

A chemical symbol can resemble a letter from the alphabet, a chemical formula resembles a word, and a reaction equation resembles a sentence in which invisible dynamic interactions between sub-microscopic particles are conveyed. For example, proficiency in using symbolic representations alone can be compared to learning a foreign language. Popova and Bretz (2018) argued that learning chemistry requires both the mastery of complicated abstract concepts and the development of representational abilities. Though learners live in a macroscopic world, the phase changes of states of matter require them to be versatile in all three levels microscopic, symbolic, and sub-micro. The utility of Johnstone’s triangle framework is not restricted to chemistry alone. Wright et al. (2014) used the framework to study how learners interpreted catalysis graphs. According to Baldwin and Orgill (2019), Johnstone’s triangle outlines the way to describe various components found in chemistry’s three levels. Teaching using three levels assists learners to develop a deeper understanding of Science concepts.

Berg and Nyachwaya (2019) stated that learners seem to have a greater understanding of the physical properties of matter at a macroscopic level but are unable to explain the particle arrangements when the phase changes. The capacity to be capable to work with the three levels of Johnstone’s triangle, and to move mentally in between them, leads to the full comprehension of the explanations that Science

gives on a given phenomenon (Berg & Nyachwaya, 2019). The Johnstone triangle was adopted in this study as the researcher believed that if learners can move in all three levels it enhances conceptual understanding. In a similar study, Petillion and McNeil (2020) used Johnstone's triangle as a framework for their flipped class in instructional videos in introductory chemistry study. They reported that the video segments associated with Johnstone's triangle theory contributed positively to learners' conceptual understanding and promoted both learners' engagement and trust in the instructional material. However, Taber (2013) asserted that the symbolic or representational level is the language for communicating and representing chemical concepts. It should not be treated as a discrete 'level' of chemical knowledge that is one element of an ontological triad of macroscopic-sub-microscopic-symbolic. Taber (2013) argued that two levels (Figure 2.2), the macroscopic and sub-microscopic, are of vital importance when learning chemistry, and the representation or symbolic level facilitates the shift. Thus, representations such as the particle nature of matter are treated as facilitators that enable learners to shift between the macro and sub-microscopic levels.

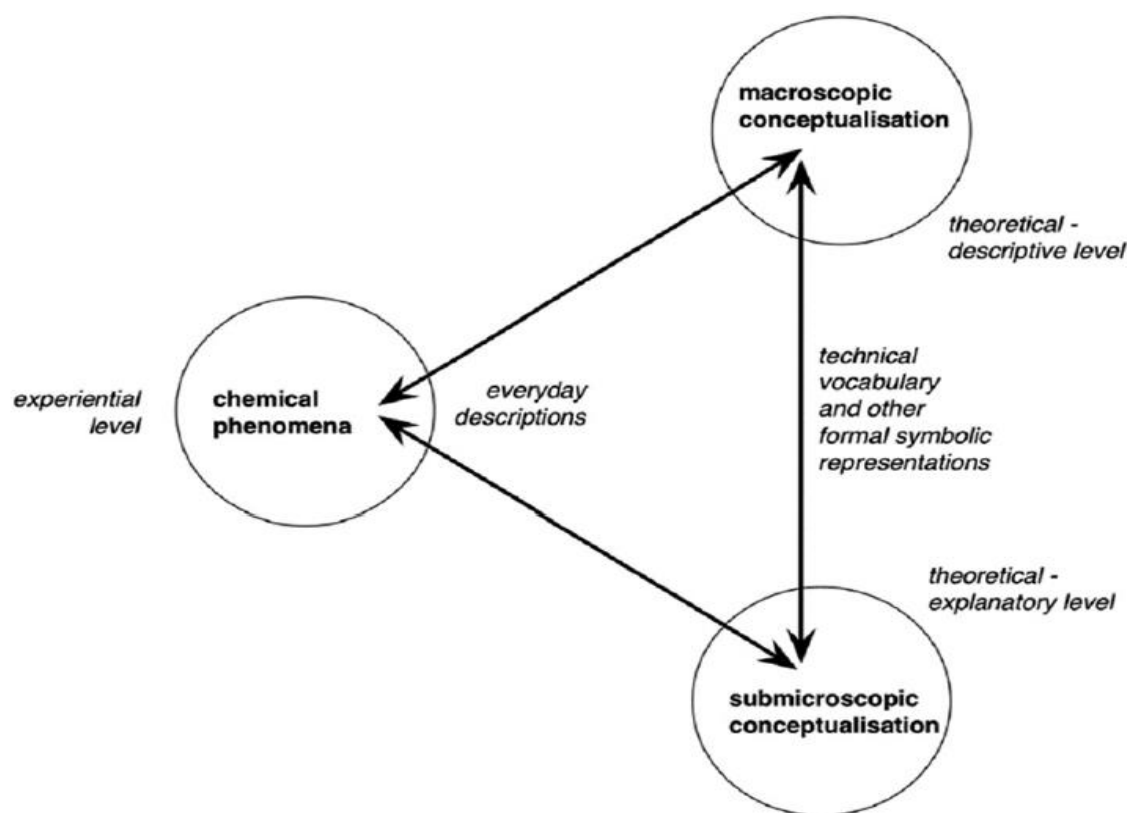


Figure 2.2: The symbolic domain as providing resources for representation and communication of chemical concepts (adapted from (Taber, 2013))

For the purposes of this study, an effective framework should then be one that is consistently applied in analysing learners' conceptual understanding. Johnstone's triangle is preferred as a guiding tool for the development of the framework and analysis of the learner's conceptual understanding in general. Numerous research (Gess-Newsome, 2015; Gibbons et al., 2018; Irby et al., 2016; Popova et al., 2020) in Chemistry, Physics, and Mathematics education have used the Johnstone triangle as a theoretical lens to identify learners' conceptual understanding difficulties when learning Sciences. One of the most widely adopted and applied ideas in chemistry education is Johnstone's triangle. It advocates for teachers and learners to deal with three distinct levels to understand chemical phenomena.

Chemistry education has many representations which learners must translate with ease to enhance conceptual understanding. One limitation of the Johnstone triangle was suggested by (Taber, 2013), who argued that the macroscopic apex of Johnstone's triangle also brings challenges. Chemistry is primarily about substances, and substances are already a major abstraction from real-life experience (Taber, 2013). Furthermore, the relationship between the nature of Science and the Science of learning is blurry. Taber (2013) suggested that novice learners find difficulties even in the macroscopic level of chemistry. Science at primary and high school is primarily about pure substances elements and compounds which learners seldom meet in everyday life. Thus, macroscopic level must be reconceptualised and matched to the corresponding formal descriptions, despite the shortcomings raised by (Taber, 2013).

In conclusion, subjects like NS/Tech are highly abstract and theoretical, learning is especially difficult. The nature of Science concepts requires multilevel thought. In contrast to other concepts in school, many scientific concepts are not tangible (such as energy, molecules, and bond energy). Learners often lacks the experience to construct scientific concepts that are beyond their senses.

2.2.2 Cognitive Load Theory

The cognitive load theory (CLT) builds on the premise that working (short-term) memory has a limited capacity and that overloading reduces the effectiveness of teaching (Sweller, 2003). The CLT, developed by (Chandler & Sweller, 1991; Paas & Ayres, 2014), is that working memory should not be overloaded during the learning process. It is based on a number of widely accepted cognitive theories about how

human brains process and store information. Essentially, the CLT states that working memory is limited and can only process a few items at a time (Cook, 2006). The theory is an analogy of how a computer processes information, which is that the opening of many programs on the computer slows the processing speed of the computer.

The CLT suggests that instructional materials and environments should be designed to reduce the load on working memory and long-term memory in order to facilitate the transfer of new information from working memory to long-term memory. Thus, eliminating distractions allows learning to move more efficiently from working memory to long-term memory. The CLT (Figure 2.3) has shaped modern-day instructional methods by advising instructors to teach using methods that reduce the learners' working memory. The environment represents classroom activities that go into the working memory first. Educators are, therefore, advised to avoid using many activities that overload learners' working memory during lessons. As a rule of thumb, learners should not attend to more than seven concepts at a time, to avoid cognitive overload. Later, the information is transferred to long-term memory. Information stored in the working memory is easily forgotten, while in the long-term memory, information can be remembered and easily retained.

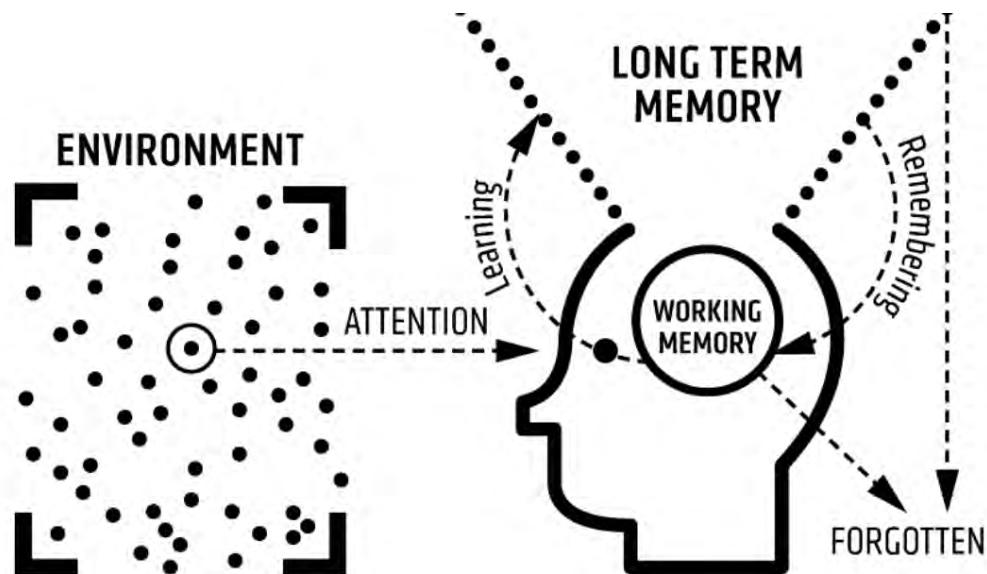


Figure 2.3: Cognitive load theory (adapted from (Albus et al., 2021)

Nyachwaya and Gillaspie (2016) defined that there are three types of cognitive load namely: intrinsic, extraneous and germane. The first two directly affect the working memory. The intrinsic cognitive load is related to the innate difficulty of the task (phase change of matter). Educators should strive to match the intrinsic load of phase change

of matter to the learners' experience to reduce the complexity of the concepts. Extraneous cognitive load is educator dependent. The way the educator structures and presents his or her lessons affects both the extraneous and intrinsic loads (Bussey & Orgill, 2019). Essentially, germane load refers to the capacity of the working memory to link new ideas with long-term memory information. The present study used the CLT to ensure the efficient learning of the phase change of matter by breaking the topic down into parts reducing the load.

2.2.3 Information Processing Theory

Information processing theory (IPT) is part of the CLT of learning that entails the processing, retrieval and retention of knowledge from the brain as well as storage (Jawad et al., 2021). This theory clarifies how an individual grasp information and can recall it for a long time (Pratiwi et al., 2019). The information acquired is much easier to process if that information is well structured and organised especially for primary school learners. (Mayer, 2012) argued that well-structured and organised information can improve memory because the information items are systematically well connected to one another. According to Clewett et al. (2019), it is easier to remember the information if it is presented in an organised manner. If the information has been well received, it is then encoded and stored in memory. Norris (2017) argued that the storage encompasses how information is sustained over a period of time and information is organised in memory.

The perception filter (Figure 2.4) involves the ability of a learner to select important information from the topic phase change of matter. According to Klahr and Wallace (2022), the perception filter is directly proportional to academic performance. Instructional implications of the perception filter require educators to focus on important points during lessons and avoid irrelevant information. The present study did not follow the full spectrum of CLT and IPT.

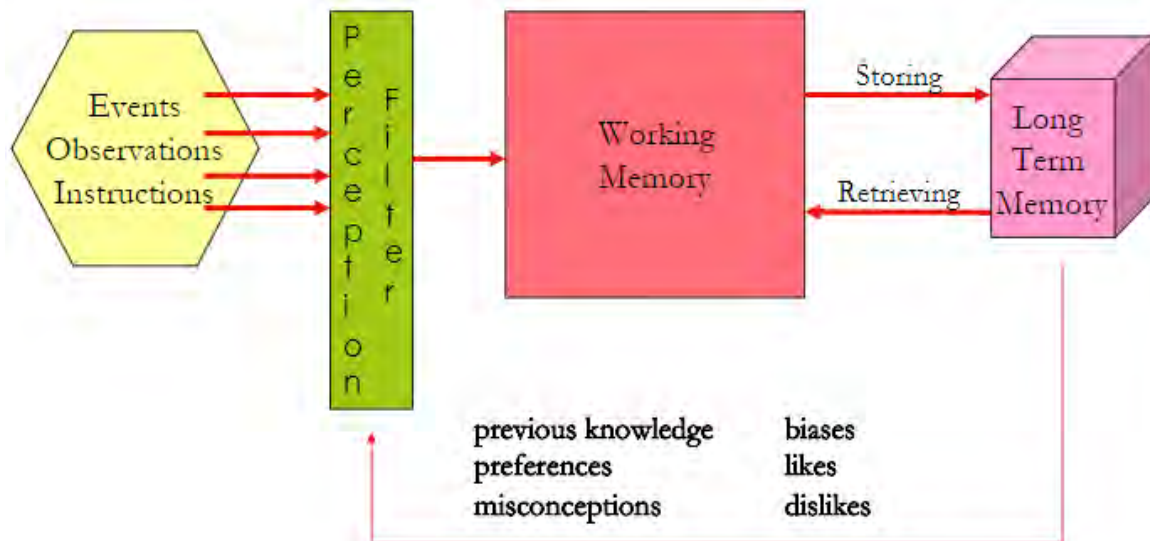


Figure 2.4: Information processing theory (adapted from Pratiwi et al., 2019)

Information processing begins when an external stimulus is related to one or more of the following: hearing, sight, and touch. Adequate sensory memory takes in external stimuli and stores them in sensory records for a period. Information enters the system via sensory memory but is only stored for a limited period. To stay in the system, information entered into short-term memory is combined with information in long-term memory. Essentially, germane load refers to the capacity of the working memory to link new ideas with long-term memory information Pratiwi et al., 2019) .

New information is classified by the brain and stored in the long-term memory when a learner is exposed to it. This classification is known as a schema. Schemas are like folders in the memory where information is stored and retained. The weakness of long-term memory is that it is very difficult to access the information stored in it. Learners have difficulty accessing information because accessing information that is tempered is imperfect. However, critics of the CLT and IPT have argued that other factors, such as motivation (Lepper et al., 2005), learners' attitude towards Science (phase change of matter), and metacognition (Langer et al., 2017), influence learner's educational attainment. In summary, in order to learn and retain instructional materials effectively, the long-term memory is a crucial component. During classroom instruction information is stored in the short-term memory before being transferred to the long-term memory. Data from the observations of the macroscopic domain are collected through perception filters and processed through comparing with prior experiences in

the working memory and finally meshed into new knowledge and stored in the long-term memory.

2.2.4 Cognitive Theory of Multimedia Learning

Mayer (2014) stated that cognitive theory of multimedia learning (CTML) also relies heavily on the CLT. Mayer (2019) defined meaningful learning as a process of deeply understanding the material, mentally organising it into a coherent cognitive structure, and integrating it with existing knowledge. Multimedia learning refers to ‘learning from words and pictures, and multimedia instruction refers to presenting words and pictures that are intended to foster learning. The main tenets of CTML are similar to those of simulations, which makes them effective tools for learning. The basic premise of multimedia learning, as discussed by Mayer (2002), is that words and pictures together can allow learners to learn more deeply than words alone. In order to explain how multimedia learning works and how it can be used most effectively, Mayer (2002) developed the CTML. There are three assumptions that (Mayer, 2002) makes about how humans process information in his CTML. They are the dual-channel assumption, the limited capacity assumption, and the active processing assumption. According to Mayer (2019), the dual-channel assumption (Figure 2.5) suggests that “humans possess separate channels for processing visual and auditory information”.

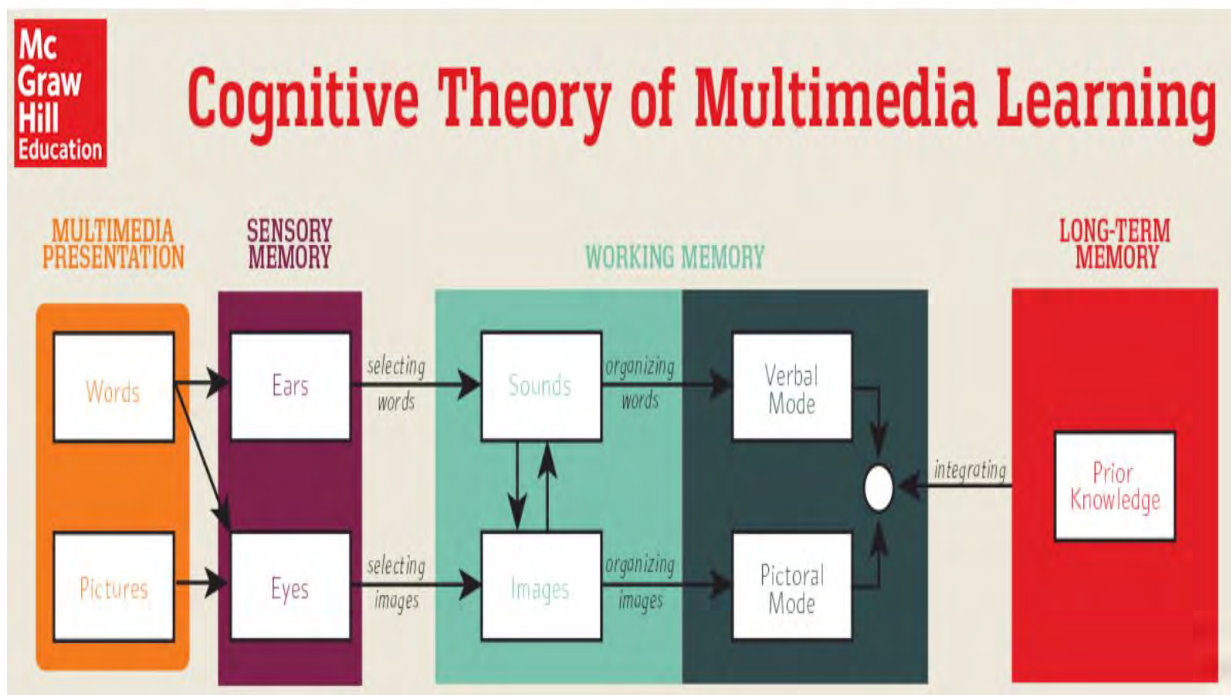


Figure 2.5: Dual-channel assumption (Mayer, 2011)

In the visual-pictorial channel, images are processed through the eyes (including words displayed on a screen). The information is processed through the sensory memory (ears and eyes) into the working memory. In working memory, the information integrates with prior knowledge from long-term memory. Additionally, there is the auditory-verbal channel, which processes spoken language. In the present study, the PhET simulation was a balanced presentation of words and pictures to assist learners to better engage in conceptual understanding of concepts. Therefore, the inclusion of the PhET simulation was expected to promote conceptual understanding of phase change of matter concepts.

2.3 SIMULATION-BASED LEARNING SYSTEM

The PhET project is a set of interactive, research-based Science and Mathematics online simulations. A multimedia software designed as a computer-assisted scaffolding system to teach Science and Mathematics. The PhET simulations can be used online or offline. Simulations are computer-based representations of natural phenomena that display the outputs of changes in input variables (Correia et al., 2019). A simulation is a software program that allows students to explore complex interactions among dynamic variables that model real-life situations. Learning NS/Tech is difficult for many learners due to their inability to visualise molecular structures and processes. Correia et al. (2019) recommended that using simulations builds learners' understanding at a sub-microscopic level first to allow them to gradually refine their ideas that can be applied to a larger variety of novel situations in the future. One advantage of simulation-based learning is the enhancement of learners' conceptual understanding of scientific phenomena (Quellmalz et al., 2012). Interactivity is another important feature of simulations that allows learners to design and test hypotheses.

Quellmalz et al. (2012) posited that "simulations are interactive, students can demonstrate their abilities to apply the active inquiry practices of Science by designing investigations, conducting iterative trials, predicting, observing, and explaining findings, and critiquing the investigations of others". Thus, simulations encourage inquiry learning of scientific phenomena and improve Science process skills. However, in the present study, due to a lack of computers and necessary hardware, the simulation was used by the teacher. Less developed countries have significant

challenges when it comes to teaching and learning Science and Mathematics. The literature shows that most Science teachers adopt chalk-and-talk methods that are limited and challenging. In addition to ill-equipped laboratories and a lack of laboratory consumables, teachers face challenges when it comes to implementing experiments. As a result, NS/Tech topics, such as phase change of matter, become very challenging to both educators and learners. There is limited research on simulations' actual use and empirical effects in classrooms, particularly those that focus on the particle nature of matter and phase change of matter. Simulations can be applied in a variety of fields, including education, aviation, and health care. Their aim is to enable participants to grow their skills without exposing them to situations that might result in severe consequences or necessitate high expenses otherwise. Through multiple representations, computer simulations facilitate learners' understanding of real-life data (Almasri, 2022; Rooney et al., 2018; Tho & Yeung, 2016). A computer simulation is a way of simultaneously representing the real and theoretical behaviour of a phenomenon and of visualising the effects of the choices made. The present study was guided by Lee et al. (2021) who suggested that PhET simulations are very flexible tools that can be used in a variety of ways.

2.3.1 The Use of Computer Simulations in Teaching

The use of computer simulations encourages learners to be active agents in their own learning. Incorporating them into authentic inquiry practices facilitates question formulation, hypothesis formulation, data analysis, and theory revision (Rutten et al., 2012). A simulation allows learners to manipulate objects effortlessly (virtual manipulatives), generate new representations, and conduct experiments to test hypotheses and tentative ideas without exerting much effort. According to Vlachopoulos and Makri (2017), simulations have a constructive influence on learning goals. Through simulation-based learning, learners are not only motivated to construct new knowledge, but they also gain a better understanding of the topics being taught. Simulations enhance cognitive affordances by allowing learners to make connections to existing knowledge and new knowledge.

Computer simulations when they are used in the classroom for teaching are perceived by educators as useful and easy to use, which contributes to the cognitive dimension (Lee et al., 2021). Simulations also encourage learners to apply their knowledge to

real-world problems using a scenario-based technique. Sanina et al. (2020) also acknowledged that simulation-based teaching helps develop learners' analytical, critical thinking, strategic, and problem-solving skills. Although using simulations in Science education is not a new concept, there is not enough literature on using simulations for Science teaching in sub-Saharan African countries (Lee et al., 2021). Several studies (Lee et al., 2021; Lindgren et al., 2016; Robertson et al., 2009) have adequately investigated the efficacy of simulations for teaching scientific concepts. Based on an experimental study involving primary school learners in New Zealand, Falloon (2019) concluded simulations can be valuable for teaching simple physical Science concepts and improves higher order thinking skills.

2.4 COMPUTER SIMULATIONS IN CONCEPTUAL UNDERSTANDING OF SCIENCE TOPIC

Several researchers (Almasri et al., 2021; Huang et al., 2018; Khlaif et al., 2021) have reported mixed results regarding the effectiveness of simulations in enhancing learners' academic performance and conceptual understanding. Compared to the traditional teacher-centred approach some studies (Bond, 2020; Falloon, 2019; Farrell & Brunton, 2020) reported that simulations improved performance and laboratory skills. In order to teach conceptual understanding of Science concepts, computer simulations are increasingly being used by educators around the world as a part of technology integration practices in education. Learners can visualise Natural Science representations and understand Science concepts through computer-based simulations, but their effectiveness may vary depending on the level of representation (Tang & Abraham, 2016).

There are studies (Ndiokubwayo et al., 2020; Sorden, 2012) that have shown improved academic performance when simulations are used to teach and learn stoichiometry concepts in high schools. Their studies found that learners exposed to simulations achieved outstanding results in chemical equation balancing and interpretation. These studies were conducted with high school learners and there is a need to establish the effect of simulations on learners' conceptual understanding and retention of phase change of matter concepts under NS/Tech classroom settings in primary schools. In South Africa, available studies on Science teaching focused on areas such as the potential of integration technologies and improving teaching and

learning of NS/Tech. There is a dearth of studies on the actual use and empirical effects of simulations in primary school classrooms particularly those focusing on phase change of matter.

Due to the abstract nature of atoms and molecules, the particulate theory of matter proves one of the most challenging topics for students to understand (Özmen, 2011). The topic requires learners to logically operate on information and symbols beyond personal experience and concrete cases in the real world especially the sub-micro level which involves the phase change of matter. The Piagetian theory of cognitive development suggests that primary school learners operate between concrete and formal stages. In order for these learners to comprehend abstract concepts, they often need concrete experiences when performing mental operations.

Ndihokubwayo et al. (2020) investigated the effectiveness of teaching optics using well-designed and diversified instructional tools such as multimedia throughout the teaching and learning process. The multimedia involved YouTube videos and PhET simulations. The purpose of the study was to explore how PhET simulations and YouTube videos improve the conceptual understanding of optics concepts. The study was framed by the CTML. The instrument was the geometric optics conceptual understanding test which was administered to experimental and control groups. The findings revealed that learners taught using PhET simulations and YouTube videos achieved significantly more gains on the post-test compared with the control groups that were taught using a traditional teacher-centred approach. The findings also showed that PhET simulations without learners' manipulation (non-interactive) were equally effective. In the present study, the teacher manipulated the simulation, and the same theoretical framework was used. Since (Ndihokubwayo et al., 2020) was based on physics, and on high school learners, this study focused on primary school learners.

Natural Science and Technology have always been considered an abstract subject with some of the concepts isolated from learners' everyday life (Ramma et al., 2018). Therefore, educators must strive to introduce various engaging instructional tools to improve learners' conceptual understanding and retention of such abstract Natural Science topics. Several researchers (Kunnath & Kriek, 2018; Stott & Case, 2014) suggested that teachers must help learners develop Natural Science competencies and conceptual understanding through the use of multimedia tools. According to Kunnath and Kriek (2018), multimedia tools can be grouped into audio, visual and

audio-visual, and can be used to supplement verbal explanations of concepts to clarify and concretise the lesson for learners. This study relied on the use of the simulation through visual-audio to enhance the conceptual understanding and retention of the phase change of matter.

Kunnath and Kriek (2018) also reported that Grade 12 physical Sciences learners who were exposed to the PhET photoelectric effect simulation performed better as compared to the ones exposed to the teacher-centred approach. The implication to instruction was that the photoelectric PhET simulation improved the learner's visualisation of something that is otherwise not visible. Kotoka and Kriek (2014) stated that computer simulations improved the conceptual understanding of key concepts in electromagnetism. Furthermore, they argued that simulations enable learners to view Science concepts in a virtual environment. Ndiokubwayo et al. (2020) concurred that simulations show what could be similarly visualised in a conventional laboratory. Therefore, PhET simulations have the potential to promote conceptual understanding of difficult topics. As a result, explicit and shared understanding can be developed that overcomes a non-scientific conception.

Mohafa et al. (2022) investigated the effect of computer simulations on Grade 12 learners' performance and retention of stoichiometry concepts. A quasi-experiment was used to compare the performance between experimental and control groups. The experimental group recorded higher mean scores in the post-test and retention mean scores. Therefore, they concluded that simulations improved learners' performance and retention of stoichiometry concepts. The reported study did not investigate the conceptual understanding of the stoichiometry concepts. Thus, the present study primary school learners. Therefore, there is a need to establish the effect of simulations on learners' conceptual understanding and retention in NS/Tech classroom settings. Mohafa et al. (2022) recommended that simulations be used to supplement the teaching and learning of Science, in particular chemistry.

The literature provides insights into the effectiveness of simulations in teaching and learning Science. Attempts have been made to explore the potential benefits of PhET simulations for teaching and learning. Simulations address economic and safety challenges of real experiments and infrastructure shortages, as well as help to visualise unobservable phenomena. It is argued that meaningful learning occurs when words and pictures scaffold assimilation and accommodation in studies of multimedia

tools. Mayer's CTML proposes that meaningful learning occurs when words and pictures scaffold assimilation and accommodation in multimedia tools.

The sub-micro level of the phase change of matter includes molecules, atoms, energy, and heat as well as the dynamic movement of the particles. Tang and Abraham (2016) suggested that learning at the particulate level often requires aid of models and imagination. Simulations and animations can provide learners with visual representations of particle structures and processes that may aid them in building mental models or imaginations. Several research studies (Robertson et al., 2009); Rooney et al. (2018) discuss the efficacy of computer simulations in Science education. Learners' learning outcomes and attitudes were measured using a variety of methods, such as word problems, open-ended questions, interviews, and field observations. It was concluded that simulations help learners visualise abstract Science models, translate the three levels of the Johnstone triangle and develop conceptual understanding at sub-micro level.

The literature reviewed has shown that simulations have the potential to improve the learner's conceptual understanding and retention of phase change of matter. The simulations also enhance the visualisation of abstract concepts in Science. Most of the studies focused on high school and tertiary learners and there is a paucity of studies done at primary schools.

2.5 LEARNERS' CONCEPTIONS OF PHASE CHANGE

Scientists have studied matter extensively over the past 30 years, as it is one of the fundamental concepts in Science (Özmen, 2013b). There have been numerous studies that have examined learners' conceptions of matter, and all levels have difficulties comprehending matter's particulate nature. Learners' understanding of matter as continuous contradicts the PNM, which has been attributed to this problem (Savasci-Acikalin, 2021). Approximately one-third of students in (Sujak & Daniel, 2018) study had macroscopic views of matter, while others had sub microscopic views with significant alternative conceptions of matter. They indicated that learners in their study held non-scientific conceptions regarding the relative size of atoms and molecules. Zajkov et al. (2017) reported that Grade 12 learners thought that the size of molecules changed across different phase changes and had difficulty understanding empty space among particles. Several alternative conceptions were associated with

an understanding of the sub microscopic level and dynamic nature, size, and arrangements of particles during phase changes. Several researchers agree that there can be various sources of learners' alternative conceptions, including their educators (Calik & Ayas (2005), textbooks (Zajkov et al. (2017), and ineffective instructional approaches (Savasci-Acikalın, 2019). Table 2.1 shows some of the alternative conceptions that have been recorded in Science education about the phase change of matter and the particle nature of matter.

Table 2.1: Learners' alternative conceptions of phase change in the literature

Bubbles in boiling water are made up of heat, air, or hydrogen and oxygen	(Johnson, 1998)
When the matter is heated, the number of particles changes	(Özmen, 2013b)
When the matter is heated, its molecules expand	(Stojanovska et al., 2012)
Water droplets on a cold coke come through the metal of the can	(Kapıcı & Akcay, 2016)
Gas particles are weightless or weigh less than liquid particles	(Ayas et al., 2010)
When ice changes to water, the water weighs less because ice has more stuff in it than water	(Özmen, 2011)

2.6 INSTRUCTIONAL APPROACHES AND RETENTION IN SCIENCE EDUCATION

The term *retention* as used in the present study relies on the definition of Sousa (2016) who viewed retention as a measure of how well a learner remembers the material over time. In addition, it refers to the extent to which a learner can successfully retrieve information from long-term memory. Similarly, Kara (2008) defined retention as the extent a learner can successfully access and use information from the long-term memory. Cued recall and recognition are two methods that are commonly used in Science education to measure knowledge retention. Souza and Oberauer (2017), claimed that retention measures how well a learner remembers material over time and is enhanced by instruction methods which support the encoding of information in the long term memory. Retention can be fostered by internal and external factors such as comprehension of phase change of matter concepts as well as by external factors such as teaching methods (Engelbrecht et al., 2007).

The retention of phase change of matter concepts is vital for learners' success in future Science and STEM related fields. Instructional methods play an important role in the retention ability of learners and inappropriate teaching methods in Science invariably translate into learners' inability to retain the concepts (Ajayi & Angura, 2017).

In South Africa, the learning environment in rural areas lessons are largely teacher-centred and large classes (Khumalo & Maphalala, 2018). In general, large classes have less than favorable outcomes, including increased reliance on traditional teaching approach, less active learner engagement, and fewer interactions between teachers and learners. Educators have encouraged to adopted a variety of teaching strategies both inside and outside of the classroom in order to minimise the unwanted results of teaching large classes and to increase learner long-term retention. One of the promising instructional method is technology integration such as simulations that can enhance learning and retention of concepts (Schrader & Bastiaens, 2012).

With many Science education studies focusing on knowledge retention, retention is treated as one section of a dynamic model of the learning process (Gkitzia et al., 2020). These authors claimed that concepts are not immediately or completely forgotten once learned. Moreover, retention decreases over time. Engelbrecht et al. (2007) defined the retention interval as a period between the test of the original learning which proceeds after classroom instruction and the delayed post-test retention test. Khishfe (2015) differentiated short-term and long-term retention according to days, weeks, and months. Short-term retention refers to the post-test that is taken after some days and weeks and long-term starts from a month to years. In this study, the delayed post-test was administered after a month, and it fits under long-term retention. Retention over a month was chosen because Sendur et al. (2017) contended that longer interval retention is harder to assess.

In an investigation to establish long term retention of genetics' concepts among first year university students, Crossgrove and Curran (2008) administered tests four months after students had been exposed to activity-based and traditional methods of teaching. The results from the study indicated that activity-based instruction significantly improved the students' retention ability. Students taught using activity-based instruction had statistically significant higher retention scores as compared to those taught using the traditional teacher-centred approach.

In a similar study, Ajayi and Angura (2017) investigated the students' retention in electrolysis using collaborative concept mapping instructional strategy (CCMIS). The two instructional methods of CCMIS and discussions were compared. The results of the study revealed that students who were taught using CCMIS had higher statistically significant mean retention scores as compared to those exposed to the other instructional method. Furthermore, the retention ability of the students was not influenced by gender. Thus, it can be concluded that retention is influenced by the instructional approach.

Nigerian high school students' performance and retention of concepts after instructing the experimental group using an analogy and traditional teacher-centred approach were reported by (Owobi, 2018). The findings of the study revealed that analogy-based instruction aroused students' interest and imagination and therefore led to sound conceptual understanding and retention of concepts. This study also sought to investigate whether the use of the PhET simulation would also enhance the retention of phase change of matter concepts better than the traditional teacher-centred approach.

In a similar study, high school learners' retention of redox reactions concepts using advance organisers was tested by (Ekenobi et al., 2016). The research design was a quasi-experiment pre-test and post-test control group design (n= 220). A post-post-test was administered three weeks after intervention. The findings of the study revealed that the learners taught using advance organisers obtained higher retention mean gains as compared to the control group taught using a traditional teacher-centred method. Thus, the retention of concepts is influenced by the instruction approach.

The effects of the activities, based on a four-step constructivist approach, on learners' achievement on rates of reaction was investigated by (Kurt & Ayas, 2012). The research methodology employed a mixed method sequential research design, quantitative (experimental group design) and qualitative (interviews). A quasi-experiment research design was the first phase and two intact classes were randomly assigned into experimental and control groups. The experimental group was taught using a four-step constructivist approach and control group was taught using the teacher-centred approach. A real-life relating test was administered as a pre-test and post-test. Learners in the experimental group performed better in the post-test as compared to

the control group. Interviews were conducted a month later after instruction and it was found that the learners taught by the traditional teacher-centred approach relied heavily on rote learning. They failed to explain the underlying concepts on rates of reaction. Furthermore, some of the learners had alternative conceptions about the topic.

In a related study, Supasorn and Promarak (2015) investigated the effects of 5E inquiry with an analogy on learner's conceptual understanding in chemical kinetics. The participants were 44 high school students in Turkey. Intervention in the experimental group consisted of 5E inquiry activities blended with analogies. The same conceptual test was administered twice to both groups as a pre-test and post-test. The findings revealed that 5E inquiry was an effective instruction method which enhanced student's conceptual understanding and retention ability of chemical kinetics concepts.

In Denmark, second year physical Sciences students were given a delayed post-test after 14 months (Jukić Matić & Dahl, 2014). The results showed that despite being provided with hints the students had low levels of retention. It should be noted that this study lacked activities that would have assisted the long-term memory of the students. Engelbrecht et al. (2007) studied the retention of first year Engineering students at a public university in South Africa. The retention of basic calculus techniques and rote skills acquired in the first year were studied over a period of two years. A mixed methods approach, involving questionnaires and interviews, was used to collect data. Students were taught using the lecture-centred approach. The findings of the study showed a rapid decline in retention over a two-year period.

The literature reviewed on retention in Science education has shown that there is no unique way to measure retention of concepts. Activities and analogies improve and enhance the retention of Science concepts. Low retention levels are associated with low conceptual knowledge. Most of the research has been done with high school and university chemistry students and there is a paucity of research among primary school learners in South Africa. Enhancing the retention of learned information lies at the heart of all educational systems. The retention of Science concepts is directly proportional to the instruction approach.

2.7 SUMMARY AND CONCLUSION

This chapter discussed the literature review which was related to the conceptual understanding and retention of phase change of matter. Mayer (2002) cognitive theory, cognitive load theory of graphical interpretation and IPT constituted the theoretical framework of this study. Conceptual understanding requires a learner to translate among the three domains, which are macro, representation and sub-microscopic. Conceptual understanding is directly related to the instructional approaches. Simulations have the potential to increase visualisation of abstract concepts in Science. The researcher further reviewed the relevant literature on learners' conceptions about phase change of matter and retention of the concepts. The literature reviewed concurred that both primary school and high school learners face similar challenges. In the next chapter the research design, research population and sample, research instrument, research methodology, and ethical considerations will be discussed.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter entails and outlines the research methodologies compiled in this study. According to Dawson (2019), research methodology is regarded as the fundamental principle that guides any research study. Creswell (2015) ideas about the construction of a research study were used to guide the research design and methodology. The ideas associate the research design with the blueprint of the house and the research methodology with the construction process. The researcher's beliefs about the knowledge to be constructed should start before the research design and methodology. The construction process involved the research methodology (construction process), data collection (collection of construction materials) and data analysis. This chapter describes the research paradigm and design, sampling, and the two-phase processes that were implemented in collecting data to address the research questions of the study. Measures of trustworthiness, ethical and safety issues are also presented in this chapter

3.2 RESEARCH PARADIGM

Paradigm is a procedure to present a world view that is enlighten by philosophical assumptions with reference to the nature of social reality (ontology), methods of knowing (epistemology) and principles and values system (axiology) (Chilisa & Kawulich, 2012). Research processes are guided by three considerable philosophical dimensions namely ontology, epistemology, and methodology. A paradigm guides the researcher to inquire about certain questions and utilise appropriate techniques to systematic inquiry referred to as the methodology. The word paradigm is derived from Greek which means patterns. Hughes (2020) suggested that patterns can be selected as a way in which the researcher chooses to view the world that influences researcher's topic. Since the research objectives, research problem and research questions of this study are multifaceted in nature, the merging of qualitative and quantitative approaches was purposefully selected and the pragmatism perspective were adopted (Saunders, 2015). Pragmatism was chosen because it's not "committed to any one system of philosophy or reality" (Creswell, 2014). Cohen et al. (2018) claimed that pragmatism provides the underlying philosophical framework for mixed

methods research. The pragmatic paradigm places the research problem at a pinnacle and applies all approaches to understand the research problem (Creswell & Creswell, 2017). The idea of using many approaches to a research problem is the gist of mixed methods research. Pragmatism allows data collection and analysis methods that provide insights into the research problem without restrictions to any alternative paradigm. Pragmatist researchers seek to find answers to the 'what' and 'how' of the research problem (Cohen et al., 2018). Many researchers (Creswell & Clark, 2017) Morse and Maddox (2014); (Yin et al., 2018), now view the two approaches (i.e. qualitative and quantitative) as complementary and that a researcher should use both in an investigation. Thus, the methodology of this study relied on the mixed-methods research paradigm where data were collected using pre, post, delayed post-tests and interviews. The advantage of pragmatism is that it is based on the fundamental belief that qualitative and quantitative methods can complement one another by relying on the strengths of these two approaches.

3.3 RESEARCH DESIGN

According to (Creswell & Clark, 2017), research design is regarded as the overall techniques that are chosen to merge the various components of the research in a coherent and rational way, where the researcher successfully addresses the research problem. Research design also represent the blueprint for data collection, measurement as well as analysis of data. However, Akhtar (2016) viewed research design as a blueprint of the proposed research study that holds together all the elements of the research study. This study employed an experimental mixed method research design.

3.3.1 Characteristics of Mixed Method Design

(Creswell & Creswell, 2018) determined the couple of factors that regulate the characteristics of an experimental mixed method research design:

Priority

The qualitative and quantitative approaches can be assigned equal or unequal weight in a mixed-method study. Molina-Azorin and Fetters (2016) concurred with the view regarding priority that in the mixed method the researcher can decide to emphasise qualitative more or emphasise quantitative more. In this study, the different weight

design (quan-qual) was used by giving greater weight to quantitative methods (non-equivalent-group pre-test and post-test research design) and less weight to qualitative methods (interviews).

Implementation of data collection

The order of collecting data between the quantitative and qualitative approaches is crucial in the implementation stage. If data are collected at the same time, it is called a simultaneous, concurrent, or parallel design. In a sequential design data is collected at different times. A sequential design was used in this study, whereby quantitative data were collected first, followed by qualitative data. Kumar (2018) posited that in a sequential design, the abbreviations quan and qual are used to represent the quantitative and qualitative data collection parts and weights. The mixed-method methodology comprised of explanatory sequential design (Figure 3.1) quantitative phase followed by the qualitative phase. The quantitative phase (quan) was heavily weighed compared to the qualitative phase (qual). The qualitative phase was used to corroborate the statistical results of the quantitative phase.



Figure 3.1: Explanatory sequential research design

3.3.2 Explanatory Sequential Research Design

This study used a pre-experimental control group, a non-equivalent pre-test post-test, a delayed post-test control group (Figure 3.2), and interviews in the sequential design. The rationale for this approach was two pronged that the quantitative approach provides a general understanding of the research problem, and the qualitative approach complements the quantitative approach to refine and explain in depth the statistical results (Creswell & Clark, 2017).

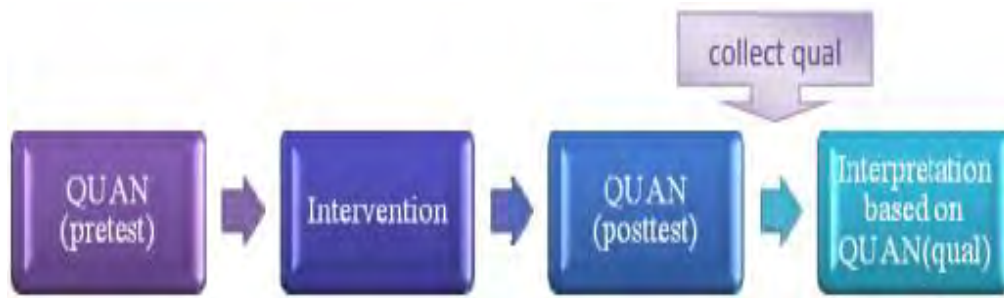


Figure 3.2: Explanatory design (quan / qual) (adapted from (Creswell & Clark, 2017)

The pre-experimental design was quasi, and it lacked randomisation of members into experimental and control groups. The motive of a quasi-experimental layout is to decide the purpose and impact of an intervention using intact classes (Mills & Gay, 2019). The objective of this sequential design is to determine the cause and effect of the intervention regulated by experiment. This study compared the intervention of using simulations-based instruction with the traditional method in improving learner’s conceptual understanding of phase change of states of matter.

3.3.3 Non-Equivalent Pre-Test Post-Test, Delayed Post-Test Control Group Design

It encompasses studying the same participants before and after the intervention. This design can be utilised in a nearly infinite number of ways, on condition that the participants are examined prior to the intervention and that the participants are required to be examined after the intervention to check if it was effective or not. This design was preferred as it was the most appropriate design to measure the effect, the intervention had on the Grade 6 learners’ conceptual understanding.

Table 3.1: Non-equivalent control group design

Group	Pre-test	Intervention	Post-test	Delayed post-test
Group A	→ O ₁	→ X ₁	→ O ₂	→ O ₃
Group B	→ O ₁	→ X ₂	→ O ₂	→ O ₃
Group C	→ O ₁	→ X ₁	→ O ₂	→ O ₃
Group D	→ O ₁	→ X ₂	→ O ₂	→ O ₃
Time	Three weeks			After four weeks

Key: Group A: Experimental group 1

Group B: Control 1

Group C: Experimental group 2

Group D: Experimental group 2

X₁: Treatment (SOM PhET simulation)

X₂: Treatment (traditional teacher-centred)

3.4 POPULATION AND SAMPLING

The target population of this study was all Grade 6 NS/Tech learners in primary schools of South Africa. The accessible population were 64 Grade 6 learners of four public primary schools in uMkhanyakude District in the KZN, South Africa. According to Etikan et al. (2016), an accessible population comprises of sub-population of the target population which is close enough to the researcher. Four public primary schools where the research was conducted were selected mostly for convenience purposes since the researcher has a direct access to primary schools as she is a primary school teacher. Since this study used a quasi-experimental design, four primary schools were purposively selected and assigned to two experimental and two control groups. The experimental groups were taught using a SOM PhET phase simulation and the control group were taught using traditional teacher-centred instruction approach. A purposive sample of eight learners (four females and four males) were selected from the control and experimental groups for interviewing after the completion of the post-test. The interviewees were selected according to their high, medium and low scores in both pre-test and post-test. The time frame for each interview session ranged from 15–20 minutes. Due to the global pandemic, Covid-19, all necessary health protocols were observed such as maintaining social distancing, using face masks throughout the sessions, and sanitizing regularly. Interviews were conducted face to face and all Covid-19 safety majors were observed. The study was conducted for four weeks during the April–June 2022 second term.

3.5 VARIABLES

Two sets of variables were involved in this study. The dependent variable and independent variable. An independent variable can be manipulated by the researcher. A dependent variable is one that can be measured, and the changes are caused by the independent variable. The dependent variable were learners test scores from pre-test, post-test, and delayed post-tests. All dependent variables were handled as continuous variables. The independent variable was the use of a PhET simulation.

3.5.1. Instruments

This study used an interview schedule and three tests (diagnostic questionnaire) as instruments. According to Cohen et al. (2018, p. 456), “in tests, researchers have at their disposal a powerful method of data collection and an impressive array for

gathering numerical rather than verbal data". Diagnostic questionnaires are instruments that are used in educational research to fulfil, three purposes of assessment namely: reveal the misconceptions learners bring as prior knowledge to a class; measure the conceptual gains of a class as a whole; and identify concepts that are weak areas of understanding for the individual learner or as a class/grade (Cohen et al., 2018). A two-tier multiple choice (2TMC) diagnostic instrument on phase change of matter was developed using the procedures outlined (Yan & Subramaniam, 2018) (Türkoguz & Ercan, 2022). Three stages were followed in the developmental process of the diagnostic instrument: i) defining the content area boundaries, ii) literature review of alternative conceptions in chemical kinetics and iii) validation of the instrument followed by a pilot study.

3.5.2 The Phase Change of Matter Test (PCMT)

The PCMT was developed by the researcher to illicit students' conceptual understanding of phase changes of matter (Appendix H). The test consisted of 10 2TMC questions. The phase change of matter concepts covered in the PCMT was evaporation, melting, and condensation. The 2TMC questions were made up of content-based questions (first tier), and interpretation/justification (second tier). The development of the (PCMT) was further guided by (Yan & Subramaniam, 2018), who suggested that students' responses in the normal multiple-choice test do not ordinarily show the interpretation of the questions. Kelly and Hansen (2017) claimed that in multiple-choice questions students tend to guess and overestimate their knowledge. In a 2TMC, the first tier examines factual knowledge, and the second tier justifies the reason behind the first-tier choice, thus collecting more information on the students' choices – thereby determining the nature of their knowledge and understanding. The 2TMC questions overcome the limitations of one-tier multiple-choice questions. In one tier, it is difficult to tell whether a correct response reflects a good understanding or is based on guesswork (Blown & Bryce, 2017).

In recent literature, Ozmen (2011) used a 2TMC test for conceptual understanding of chemical kinetics. One disadvantage of the 2TMC was reported by Kelly and Hansen (2017), who argued that a correct answer accompanied by a wrong explanation could either mean a lack of conceptual knowledge or guessing. It is not possible to differentiate between the two; two marks were allocated if a learner got both tiers correct.

The first stage of the instrument development involved defining the content boundaries of phase change of matter. South Africa's primary school National Curriculum Statement (NCS) for NS/Tech was used to define the content scope of the study, encompassing matter & materials, solids, liquids, and gases. The second stage involved reviewing the literature and identifying alternative conceptions that were used as distractors in the first tier of the multiple choice. The distractors were based on studies (Adadan et al., 2009; Ayas et al., 2010; Aydeniz & Kotowski, 2012). Questions 1–10 were based on phase change of matter which included evaporation, melting, condensation (Question 3.0), and freezing.

- 3.0 You find the inside of the car window getting foggy in winter.
This is because of:



- A. Condensation
- B. Freezing
- C. Melting
- D. Evaporation



Answer:

.....
.....

3.5.3 Reliability and Validity of PCMT

Reliability and validity measure the quality of the research instruments. Reliability is concerned with the degree of consistency, stability, and repeatability of the attributes to be measured (Cohen et al., 2018). The validity of a diagnostic questionnaire can be described as the extent to which the instrument measures what it is supposed to measure (Creswell & Creswell, 2018). In this study, content validity was viewed as the degree to which the content (phase changes of matter) of the diagnostic questionnaire covers the extent and depth of the topic. To check the content validity, PCMT was

examined by six primary school NS/Tech educators. Content validity was established by presenting the test and the CAPS NS/Tech policy document outlines objectives to educators to ensure that the content of the test falls within the scope. Furthermore, the face and construct validity were checked by the educators. The educators evaluated the 10 PCMT items based on their suitability for primary school learners and the NCS Natural Science curriculum and rated them either 'suitable', 'not suitable, should be corrected', or 'not suitable'. Teachers were requested to fill out a checklist (yes or no) followed by remarks on each question. The checklist was modelled along factors that affect the validity of a measuring instrument (Yan & Subramaniam, 2018):

- The questions tested learners' understanding of phase changes in matter.
- The use of ambiguous and confusing test items was reduced to ensure that the questions would not be misinterpreted.
- Test takers would use vocabulary at the right level of difficulty.
- Ensuring that each question had only one unequivocal intended response in each tier.

The test was adjusted after considering the suggestion of the primary school teachers. The feedback from the reviewers indicated that the diagnostic instrument could effectively assess the learners' conceptual understanding of phase changes of matter. The same test was administered as a pre-test, post-test, and post-post-test. According to Creswell (2018), the reliability of the instrument is ensured when it consistently yields the same results when the characteristics being measured remain the same. Cronbach's alpha reliability of the pilot test was found to be 0.75 which is acceptable for group measurements (Zhao & Gallant, 2012). The reliability coefficient was consistent with other two-tier tests in the literature (Kelly, 2014; Tsui & Treagust, 2010).

3.6 INTERVIEWS

Semi-structured interviews were used in this study. The interviews allowed the researcher to investigate the use of PhET simulations on learners' conceptual understanding of phase changes of matter. The interviews enabled the researcher to address specific topics of interest that might lead to constructive suggestions. Paper-and pencil -pre-test, post-test, and delayed post-tests have constraints, because they are not open-ended enough and do not establish a friendly dialogue that allows for

investigation for clarification or probing (Cohen et al., 2018). An interview programme is a qualitative tool that attempts to explain an interviewee's imagination (Creswell, 2015).

This study opted for semi-structured questions, and to ensure consistency across participants, the researcher utilised a set of pre-planned questions on phase changes of states of matter (Annexure G). The analysis of the interview feedback was compared with the test data and precise conclusions were drawn about the learners under study. Kumar (2018) suggested that interviews are advantageous because it is only through direct contact between participants and the researcher that precise and optimistic suggestions can be generated, in-depth probing can provide detailed records and to collect rich and precise data, and only a few participants are required. Numerous researchers have widely used interviews in probing learners' conceptual understanding' (Bain & Towns, 2016; Talanquer, 2007). Interviews can be an effective method of eliciting detailed information about learners' interpretations if they are conducted skilfully. Although interviews are beneficial, Kumar (2018) noted that data analysis can be cumbersome and time consuming.

3.7 INTERVIEW SCHEDULE

To engage the participants and establish the narrative terrain, interview schedules are developed to guide interviews and provide answers predetermined by the interviewer (Kumar, 2018). By using a semi structured interview schedule, the researcher could probe for insufficient detail, depth, or clarity in answers. The researcher devised the interview schedule to obtain more detailed information about learners' conceptual understanding of phase change of matter. A total of four questions were used in a semi-structured interview. The interview questions were based on phase changes of matter. Interviews were recorded on a tape recorder and each interview lasted for 15-20 minutes.

3.8 TRUSTWORTHINESS OF THE INTERVIEW DATA

In a qualitative study, Kumar (2018) contended that trustworthiness is the degree to which a review merits focusing on, worth observing, together with the degree to which others are persuaded that the discoveries can be relied upon. In the qualitative approach, internal and external validity and reliability are replaced by the criteria of

trustworthiness and authenticity. Qualitative research is trustworthy when it accurately represents the experiences of the participants in the study. To ensure trustworthiness, the researcher personally directed interviews where all the participants were recorded accurately, and the recorded data were interpreted fairly. The trustworthiness of qualitative research can be confirmed by attending to four strategies, namely, credibility, confirmability, dependability, and transferability. Credibility refers to the truthfulness and accuracy of results; transferability is the extent to which results can be transferred to other contexts. Dependability is the extent to which similar findings would be obtained if a similar study was undertaken at a different location or time using participants who have similar characteristics. Confirmability is the extent to which the results are free from bias so that findings can be replicated by other researchers (Cohen et al., 2017). The conceptual understanding interpretations done by the researcher. The interpretations done by the researcher were based on contextual detail and patterns that emerged from the phase change of matter interpretations. A probing and iterative approach was used to ensure credibility of the research findings. Also, learners were asked to verify that the transcripts accurately reflected their comments to add credibility to the study. As part of the validation process, the researcher also examined previous findings of research to ensure the credibility of the current findings.

3.9 PILOT STUDY

Studies conducted in preparation for major studies are known as pilot studies (Creswell & Creswell, 2018). Studying feasibility, establishing baselines, or running trials are all terms used to describe pilot studies. Tests of the diagnostic questionnaire and interview schedule were conducted in this study as a pilot study. The instruments were piloted on twenty-five learners in the population but outside the sample space of the study. It is advantageous to conduct a pilot study to identify any potential pitfalls, protocol problems, or unsuitable methods and instruments that may arise in the main study. Feedback from the respondents was used to assess the feasibility of the study, to check statistical and analytical procedures, and to assess the adequacy of the research instruments.

The item content validity rate (**CVR_i**) and the test content validity index (**CVI**) for all 10 items of the PCMT were calculated using (Lawshe, 1975) formulae:

$$\text{Item content validity ratio, } CVR_i = \frac{(2 \times N_u - N)}{N}$$

$$\text{Test content validity index, } CVI = \frac{\sum_{i=1}^n CVR_i}{n}$$

Key:

Nu: number of teachers approving the test item

N: number of all experts

i: item code

n: item number

The calculated CVI and CVRi of the PCMT was 0.89 and 0.79 respectively. Ayre and Scally (2014) suggested that the threshold value of the content validity should lie between 0,7-1.0. As a result of feedback from pilot participants who expressed concern about not having enough time to proofread and complete the diagnostic questionnaire, the time for the test was extended to 40 minutes. Participants in the pilot study took the PCMT the same way as those in the main study. After interviewing six students, adjustments were made based on the feedback and observations. The time was decreased from 25 to 15 minutes for each interview.

A pilot study was conducted in October 2020 in preparation for a full-scale study. Pilot testing was an important aspect of the research study because it ensured the reliability of the research instruments, the feasibility of the study protocol, and the acceptability of the intervention. The pilot exercise was helpful in preparing the researcher for actual study. During pilot testing, the Covid-19 protocols were followed.

3.10 ADMINISTERING OF THE PRE-TEST

The PCMT was administered to all 64 Grade 6 Natural Science learners as a pre-test prior to the teaching of phase change of matter. The purpose of the pre-test was to elicit the learners conceptual understanding of the phase changes of matter. To maintain validity and reliability, the pre-test was written under supervised school examination conditions. The teaching assistants invigilated the pre-test. The learners were not informed about the date of writing the pre-test to avoid studying before the test. The PCMT was written at the same date and time by the experimental and control

groups. All the completed and spare PCMT copies were collected by the researcher after the test.

3.11 ADMINISTERING INTERVENTION

The study was conducted at four public primary schools in uMkhanyakude District KZN in South Africa at the start of the term three. The researcher and three teachers revised the lesson plans during the one week of the school holiday. The researcher prepared a lesson plan for each subtopic. Demonstrations and activities were revisited to match the target concepts. The researcher has more than six years' teaching experience in primary schools, teaching NS/Tech, which had a regular timetable of four one-hour long periods per week.

This stage entailed incorporating two instructional approaches as an intervention strategy into the teaching of phase change of matter. Experimental and control groups were randomly selected from the four schools. Before the intervention phase, both groups were given pre-tests one week before the study. In the present study, the experimental group was taught with states of matter basics PhET simulation and the control group was the traditional approach which included teacher explanations, demonstrations and examples. In the control group, it was a more teacher-centred approach that involved explanations, demonstrations, examples, and illustrations from the teacher in a 'talk-and-chalk' type of lesson". The educators also showed charts, pictures, and power point figures to the learners without allowing the students to actively use them. As part of the instruction, the teachers did not discuss or consider the learners' alternative conceptions. A passive teaching approach in control group generally required learners to sit passively, and the learners were only encouraged to raise their hands when they had questions and to answer questions. When learners are instructed in this manner, they become listeners, the teacher gives the facts and defines the key ideas, and the learners' participation is usually limited to listening.

Alternatively, the experimental group received the PhET (Figure 3.3) instruction used as a demonstration. The PhET simulation can be found on the internet for free. The teachers manipulated the simulation and projected on the screen. The learners were passive, and the teacher demonstrated using the simulation.



Figure 3.3: States of matter: Basic PhET simulation

3.12 ADMINISTERING POST-TEST

The purpose of the post-test was to explore the effects of the use of PhET simulations on learners' conceptual understanding of phase changes of states of matter. The test was administered on the same day. The students were not informed of the date to avoid prior study. This stage's goal was to determine whether the intervention (usage of PhET simulations) had any impact on the learners' conceptual understanding of how states of matter change over time. The same process that was used for the pre-test was repeated. The four schools received the test that day in a sealed envelope. Once more, the learners were not informed of the test date in order to keep them from preparing for it. The questionnaire was distributed on the same date and at the same time each time, preserving the validity and reliability of the data. All completed and spare copies of PCMT were collected by the researcher.

3.13 ADMINISTERING A DELAYED POST-TEST

The delayed post-test was conducted four weeks after the post-test. The aim of the delayed post-test was to determine the retention of the learners' phase changes of

states of matter after treatment using the PhET simulations and the traditional teaching-oriented approach. Learners were not informed of the date to avoid studying for the exam. The PCMT was written on the same date.

3.14 METHODS OF DATA ANALYSIS

The completed pre-test, post-test and delayed post-test PCMT were submitted to a statistician for data to be captured and coded. Descriptive and inferential statistics were used to analyse quantitative data. Descriptive statistics included finding the mean, standard deviation, skewness, kurtosis, range, minimum and maximum score values, and constructing charts. Some of the data were analysed using the Statistical Package for Social Sciences (SPSS) version 25 and Microsoft Excel. To address the research question concerning the effectiveness of the PhET simulation in enhancing conceptual understanding and retention, samples t-tests and analysis of covariance (ANCOVA) were performed to ascertain the statistical significance of the pre-, post-test and delayed post-tests means. Qualitative data from interviews were tape recorded and transcribed. All the recorded audio files were transcribed verbatim. Learners' responses were analysed using scientifically completed response (nomothetic) and classification of explanations (ideographic). Triangulation was then achieved by matching interview transcript responses with pre-test and post-test written responses. Yu et al. (2019) suggested that interview transcript shed light on the sequencing and evolution of students' ideas.

3.15 ETHICAL CONSIDERATIONS

The study was approved by a letter of approval from the University's higher degrees Committee and an ethical clearance letter was granted from Faculty Ethics Committee. Any deception of participants, protection of participants from any forms of harm, provision, choice of participation, and confidentiality of data are five important issues related to ethics in research (Mills & Gay, 2019). No one except the researcher had access to the data collected in this study. Learners and parents completed an informed consent form, and the purpose and objective of the study were explained. This study was conducted in public schools and therefore all necessary ethical considerations were met. The following considerations and approvals were requested:

- A research permit letter was sent to the Provincial Head of the KwaZulu-Natal Department of Basic Education requesting permission to conduct research at selected schools (see Annexure D).
- A letter was also sent to the public primary school principal of uMkhanyakude District requesting permission to conduct research at primary schools within the intermediate and senior band in the district (see Annexure E).
- Approval was obtained from the University of Zululand Ethics Committee who issued a Clearance Certificate (see Annexure H).

The study was also governed by the following six ethical considerations:

3.15.1 Protection

Learners were informed that test results would not be utilised by the schools for assessment purposes. To ease the anxiety of writing the pre-test, post-test, and delayed post-test under examination conditions, learners were informed not to study before-hand.

3.15.2 Confidentiality

Confidentiality of the research data was ensured by assigning a number to the pre-tests and post-tests. The learners were informed that their personal information such as names were not required, and that any data collected would be kept confidential.

3.15.3 Choice and Participation

Participation in the study was voluntary. Learners were informed that they were free to withdraw from this study at any time without sanction or pressure from the researcher or teachers to provide reasons.

3.15.4 Informed Consent

One of the most frequently reported major ethical issues is that of informed consent. According to (McMillan & Schumacher, 2010), “informed consent is a process of informing the subject of their rights, the purpose of the study, the procedures to be followed and the potential risks and benefits of their participation”. The informed consent process was explained to learners for the sole purpose of ensuring that participants make an informed decision about whether to enrol in the study or discontinue participation.

3.15.5 Provision

The learners were informed that the research had the capability to discover awareness about their conceptual understanding of phase changes of states of matter.

3.15.6 Researcher Avoiding Bias

Dual roles in a research study can lead to conflicts of interest and biases. According to Ketokivi (2019), bias on the part of the researcher is not ethical. Bias is completely different from subjectivity. Bias is a deliberate attempt either to hide what you found in your study or to highlight something out of proportion to its true existence. To avoid biases, the researcher did not influence or alter the results of this study in any way.

3.15.7 The Role of the Researcher

An investigator is ethically obligated to make sure that he or she is competent and adequately trained to undertake the research process. This research study was conducted as a comparatively requirement for my degree to obtained in Maths, Science and Technology. I acquired proper guidance from my supervisor and my co-supervisor. I undertook an extensive engagement in literature review (Chapter 2) to empower me with relevant knowledge related to research topic, research questions as well as associated problem statement.

3.16 SUMMARY AND OUTLINE OF THIS STUDY'S RESEARCH DESIGN

The summary of the research design of this study is outlined in Figure 3.4.

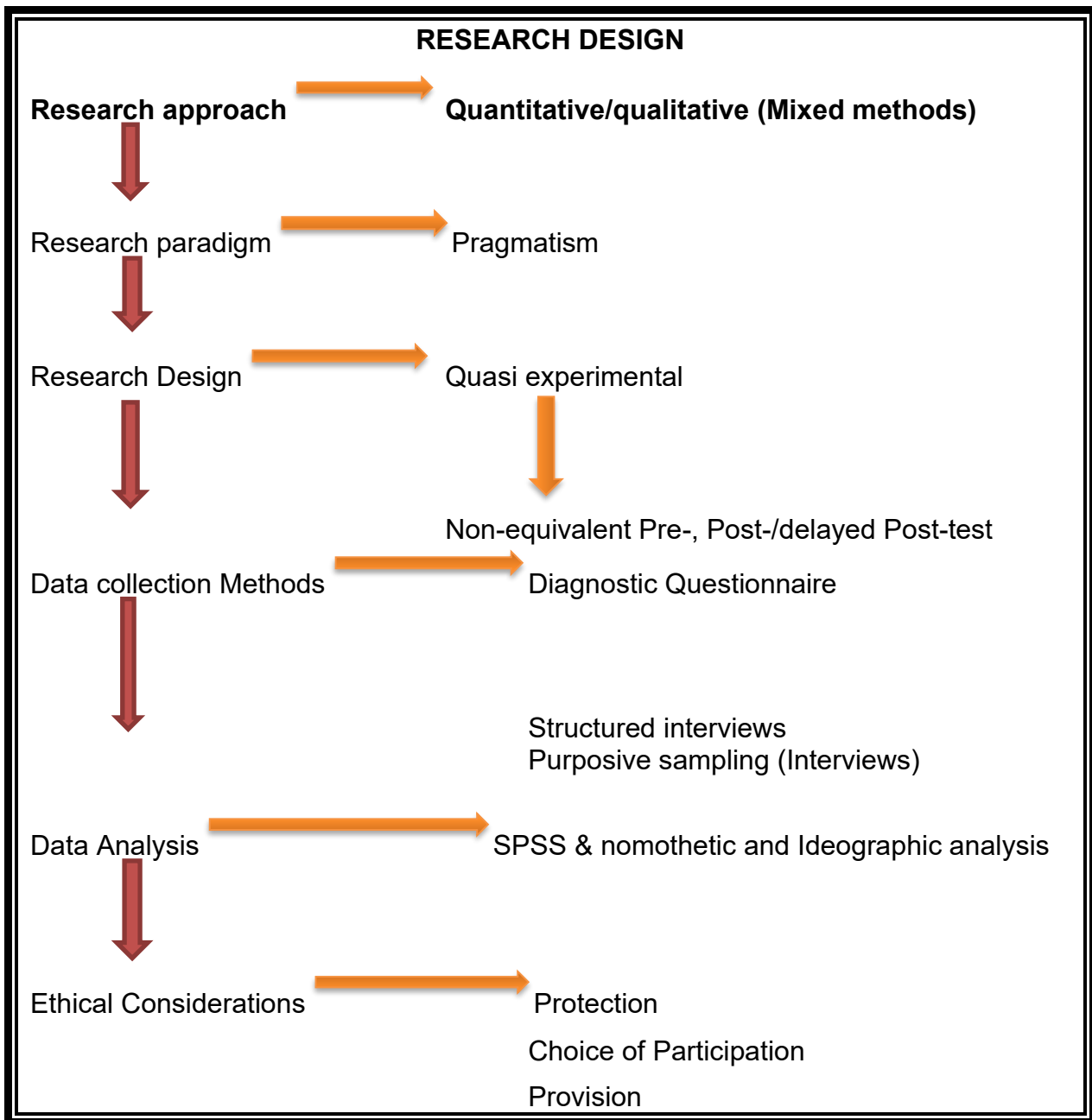


Figure 3.4: Outline of the research design

3.17 SUMMARY

In this chapter, the study design and rationale for the mixed methods research paradigm was presented as a technique to explore the use of simulations on learners' conceptual understanding of phase changes of states of matter. The intervention comprised of the PhET simulations and the traditional teaching method in teaching

phase changes of states of matter. Statistical analysis using SPSS as well as interviews were utilised to measure the effectiveness of intervention. Finally, ethical considerations were discussed and presented. The findings of the study are outlined in Chapter 4.

CHAPTER 4 DATA ANALYSIS AND INTERPRETATION

4.1 INTRODUCTION

This study sought to investigate the effect of the PhET simulation states of matter on conceptual understanding of phase changes of matter among Grade 6 learners. This chapter commences by a comparison of the academic performance and retention. The Statistical Package for Social Science Version 25 (SPSS) was used to analyse quantitative data and the level of significance adopted for rejecting or retaining the stated hypotheses was $p \leq 0.05$. Qualitative data (semi-structured interviews) were analysed using nomothetic and ideographic methods.

The chapter is structured in sections to answer the research questions as shown below:

Section 4.3 presents and analyses the data relating to the three research objectives:

1. To investigate the effects of SOM PhET simulation on Grade 6 learners conceptual understanding of phase change of states of matter.
2. To determine how a SOM PhET simulation enhance Grade 6 learners conceptual understanding of phase changes of matter.
3. Determine the effects of SOM PhET simulation on the retention ability of the Grade 6 learners on phase changes of matter.

4.2 BIOGRAPHICAL CHARACTERISTICS OF PARTICIPANTS

Sixty-four learners completed this study, with 32 in the comparison group and 32 in the experimental group. The age of the participants ranged from 10 to 15 years. The modal age was 12, with a total of 64 participants. The total number of females and males were 38 and 26 respectively.

4.2.1 Gender Distribution

The gender distribution of the research sample ($n = 64$) of Grade 6 Natural Sciences participants (59% females and 41% males) is presented in Table 4.1. A total number of 38 females and 26 males took part in this study. This gives us a good gender equity, which generated rich information.

Table 4.1: Gender distribution of the participants (n=64)

Gender	Number of students	Percentage (%)
Females	38	59
Males	26	41
Total	64	100

4.2.2 Age Distribution

The age distribution of the participants (Figure 4.1) ranged from 10–15 years. The modal age was 12 years, which was 58% of the research sample (n= 64). The median age after arranging the ages in ascending order was 12 years.

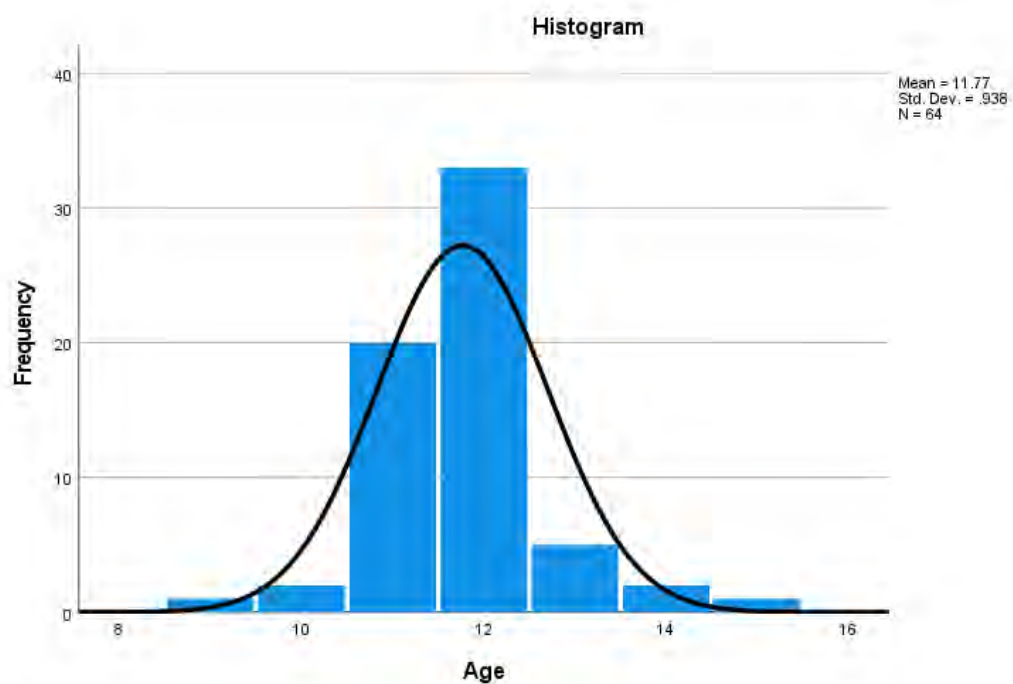


Figure 4.1: Age Distribution of the participants (n = 64)

4.3 COMPARISON OF PERFORMANCE OF LEARNERS TAUGHT USING THE PHET SIMULATION VERSUS THE TRADITIONAL TEACHER-CENTRED METHOD

4.3.1 Descriptive Statistics of Pre-Test and Post-Test Scores

The first research objective was to determine whether there would be a statistically significant difference in the performance of learners taught using the PhET simulation versus learners taught using the traditional method. In addressing this research objective descriptive data was first presented, before presenting inferential statistics which was used to test the hypothesis for the second research objective. The descriptive statistics were analysed using the measures of central tendency, measures of dispersion, skewness, and Kurtosis. The purpose of the comparison between pre-test and post-test scores was to establish the statistical significance of the two instruction methods. Measures of central tendency, which include the mean, revealed how the pre-test and post-test scores were grouped.

Table 4.2 shows that the mean score of the pre-test for both control and experimental groups were 53.43 and 54.84, respectively. Mean scores for both control (62.95) and PhET (70.12) groups increased indicating that learners performed better in the post-test, as compared to the pre-test. A variation of the mean, the trimmed mean, which drops 5% of the highest and lowest scores was calculated. A trimmed mean, unlike the arithmetic mean, is resistant, and is not affected by extreme values. The trimmed means were almost the same for both the pre-test and post-test respectively. This implies that the test scores were not affected by the extreme values. Therefore, the extreme scores had no significant influence on the mean.

The standard deviation (SD) is the square root of the variance and is a measure of the spread of the scores (Kumar, 2018). It is also a measure of how individual scores deviate or vary from the mean. (Hayley et al., 2014) posited that a higher standard deviation indicates that scores are scattered around the mean and a lower one the scores are close to the mean. The value for the standard deviation for the pre-test was calculated as 6.132, while the standard deviation for the post-test is 6.884. There was a slight increase in the standard deviation from the pre-test to the post-test. From the descriptive statistics, it can be concluded that learners performed slightly better in the post-test than in the pre-test.

Table 4.2: Descriptive statistics of pre-test and post-test scores

Group		Pre-test		Post-test		
		Statistic	Std. Error	Statistic	Std. Error	
Control	Mean	54.37	.538	62.73	.536	
	95% Confidence Interval for Mean	Lower Bound	55.33		63.87	
		Upper Bound	57.41		65.63	
	5% Trimmed Mean	53.43		62.95		
	Median	57.00		60.00		
	Variance	37.714		39.132		
	Std. Deviation	6.134		6.882		
	Minimum	46		44		
	Maximum	72		76		
	Range	26		32		
	Interquartile Range	5		6		
	Skewness	-.115	.243	-.064	.216	
	Kurtosis	1.264	.467	1.132	.413	
PhET	Mean	55.86	.589	70.30	.539	
	95% Confidence Interval for Mean	Lower Bound	53.69		71.04	
		Upper Bound	55.02		70.17	
	5% Trimmed Mean	54.84		70.12		
	Median	54.00		64.00		
	Variance	43.948		48.212		
	Std. Deviation	6.033		7.025		
	Minimum	40		45		
	Maximum	75		80		
	Range	35		25		
	Interquartile Range	7		9		
	Skewness	.041	.235	.068	.230	
	Kurtosis	.368	.438	.701	.473	

The measure of dispersion that was used to analyse the data was the range. Arithmetically the range is the difference between the largest and smallest scores. However, in descriptive statistics, the range provides an indication of the variability of the data called the interquartile range (IQR). The IQR is a measure which shows where most scores lie from the median. The IQR for both groups increased from 5–6 control group and 7–9 experimental group in the pre-test and post-test, respectively. An increase in IQR shows that students who had lower scores in the pre-test performed better in the post-test, especially the experimental group.

The data was subjected for further testing. These tests include Skewness and Kurtosis, Shapiro-Wilk test, Kolmogorov-Smirnov and a paired sample-t-test. These tests help to establish if the treatment administered was effective.

4.4 SKEWNESS AND KURTOSIS

Skewness is a measure of symmetry; it measures the deviation of the given distribution of a random variable from a symmetric distribution (like normal distribution). Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. Skewness was used to study the direction of variation of the data in this study. Skewness is a measure of the asymmetry of a distribution (George & Mallery, 2010). The range for kurtosis and asymmetry z- values should fall between +/-1.96 in order to prove normal univariate distribution. If the values of kurtosis and skewness are close to 0, the distribution of the scores is close to the Gaussian distribution. Positive skewness occurs if most of the scores are at the low end of the distribution, accompanied by few high scores. Negative skewness occurs when most scores are located at the high end of the distribution. The calculated skewness of the pre-test and post-test of the experimental group were 0.068 (SE 0.215) and 0.701 (SE 0.215), respectively, which means the scores were symmetrical around the mean.

The skewness of the post-test and pre-test of the control group were -0.115 (SE 0.243) and 1.264 (SE 1.132), which implies that the scores were skewed to the right, or negatively skewed. Thus, learners performed better in the post-test as compared to the pre-test. Kurtosis measures the flatness of the normal curve. In both groups, the pre-test and post-test kurtosis were greater than zero, implying leptokurtic. It can be concluded that the scores for both pre-test and post-test scores were a little skewed and kurtotic, but do not differ significantly from normality. Thus, the scores are approximately normally distributed in terms of skewness and kurtosis.

4.5 SHAPIRO-WILK TEST (TEST OF NORMALITY)

The Shapiro-Wilk test was calculated to test for normality. The null hypothesis for this test of normality is that the pre-test and post-test scores are normally distributed. A null hypothesis is rejected if the significant level $p < 0.05$. Normality tests are important since all statistical tests rely on an assumption of the normality of the scores. Figure

4.3 and Figure 4.2 shows pre-test and post-test histograms respectively. Histograms below show that the scores were normally distributed. The probabilities levels for both tests $p > 0.05$ are evident in Table 4.3, and thus the null hypothesis is accepted.

Table 4.3: Test of normality

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test score	.124	64	.055	.962	64	.054
Post-test	.155	64	.051	.934	64	.058

a. Lilliefors Significance Correction

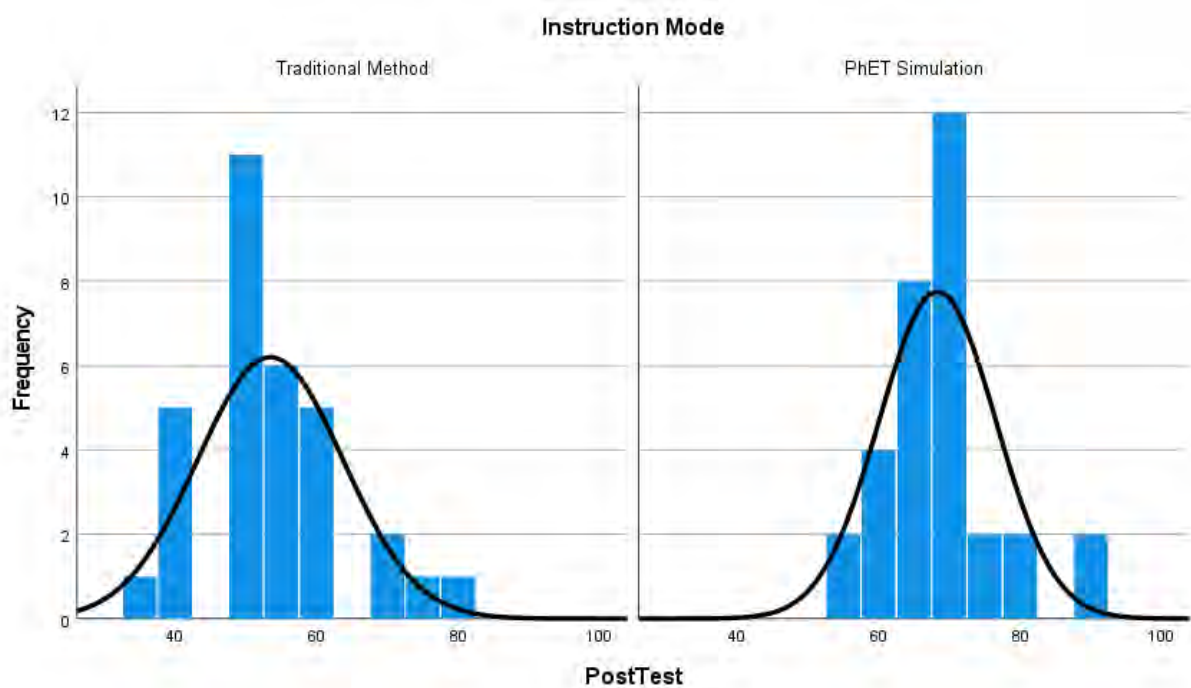


Figure 4.2: Histogram of the participants' post-test scores

4.6 PAIRED SAMPLE T-TEST

The paired sample test is used to test the difference between two variables for the same subjects. It is considered powerful to use paired t-tests because they use the same participants or items, thereby eliminating variation between samples that could be attributed to anything else but the test (Kumar, 2018). Also known as the dependent

or correlated t-test it is a statistical test that is used to compare the statistically significant difference between the means and standard deviations between two groups. A significant difference occurs when the differences between groups are unlikely to be due to sampling error or chance. In the present study, a quasi-experimental design was used, and the same pre-test and post-tests were administered to the same sample learners before and after treatment. The paired sample t-test was used to test the statistically significant difference between the pre-test and post-test mean scores at the probability value of ($p < 0.05$). Table 4.4 shows the standard deviation and significance which was below ($p < 0.05$).

Table 4.4: Paired samples test

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-test Score – Post-Test	-7.734	21.449	2.681	-13.092	-2.377	-2.885	63	.005

The t-value of -2,885 from a sample size of 64, with 63 ($n - 1 = 64 - 1$). The significant value (2-tailed) was 0,005 which is less than 0.05 ($p < 0,05$). It can be concluded that there was a significant difference between pre-and post-test. This is an indication that the treatment administered was effective and the post-test mean scores were higher than pre-test.

4.7 INFERENCE STATISTICS ANALYSES

The results from the testing of the two null hypotheses stated in Chapter 1 are presented in this section. The hypotheses were tested by using the SPSS Analysis of covariance (ANCOVA) and an independent t-test at the 95% level of significance of $p < 0.05$. (Kumar, 2018) claimed that as ANCOVA is a powerful tool that is used to analyse quasi-experimental design. It considers the lack of randomisation by adjusting initial differences between groups. This study used non-equivalent intact groups.

ANCOVA is powerful and versatile in situations where basic ANOVA assumptions, particularly randomisation, are violated (Campbell & Stanley, 2015).

(Kumar, 2018) suggested three assumptions before conducting ANCOVA:

1. Initial homogeneity or equality of variance. The Levene's test was carried out assuming equal variances between the groups. This is the test of homoscedasticity.
2. Normality of the scores.
3. No interaction between the covariate and the independent variable.

To cater for the first assumption, an independent samples t-test was performed to check whether there was a statistically significant mean difference between the experimental and the control group scores obtained in the pre-test. The result revealed that there was no a statistically significant difference between the two groups' pre-test scores ($t_0 = -0.643$, $p = 0.523$). Thus, the Levene's test, yielded $p > 0.05$, thereby proving homoscedasticity, which was a very important step in the analysis of the results. The normality check (Shapiro-Wilk test) was carried out and the assumptions were met.

4.8 THE EFFECTIVENESS OF THE PHET SIMULATION VERSUS THE TRADITIONAL-BASED INTERVENTION

Table 4.5 reports the findings of the ANCOVA, in which the post-test scores were the dependent variable, and the pre-test scores which were a covariate to correct for any differences in the control or comparison and experimental groups. The group (control or experimental) was entered as fixed factor to determine the statistical significance of the treatment. This test gave the answer to the first research question of this study. The following hypotheses was tested at $\alpha = 0.05$ to give the answer to the second research question of this study:

H₀: There is no statistically significant difference between pre-test and post-test mean scores of the learners taught using the PhET simulation approach and those taught using a traditional teacher-centred instructional approach.

The alternative hypothesis was:

H₁: There is a statistically significant difference between pre-test and post-test mean scores of the students taught using the PhET approach and those taught using a traditional lecture centred instructional approach.

Table 4.5 shows a statistically significant result ($F= 2.696$; $p < .0001$). The value of p showed that there was a very small probability of this result occurring by chance, under the null hypothesis of no difference between pre-and post-test scores. Based on the results of the ANCOVA, the null hypothesis was rejected in favour of the alternative hypothesis, since $p < 0.05$. This is an indication that the PhET simulation intervention was more effective, resulting in higher post-test scores, in comparison to the traditional teacher-centred group.

Table 4.5: Testing the effectiveness of the PhET simulation versus the traditional teacher-centred intervention.

ANOVA						
		Sum of Square	df	Mean Square	F	Sig.
Post-test	Between groups	8812.516	1	8812.516	46.197	.000
	Within groups	11827.094	62	190.760		
	Total	20639.609	63			
Pre-test score	Between groups	126.563	1	126.563	.413	.523
	Within groups	18984.375	62	306.200		
	Total	19110.937	63			

4.9 QUALITATIVE DATA ON THE LEARNERS CONCEPTUAL UNDERSTANDING OF PHASE CHANGES OF MATTER

In order to identify learners for the interviews, pre-test and post-test scores were grouped into three groups, namely low, middle and high achievers. Purposive sampling was done, bearing in mind gender balance to select four male and female learners. Of the eight learners who were chosen, four were from each group. To maintain anonymity, the learners were assigned alphabetic letters from A to H. The

interview questions were prepared to determine learners conceptual understanding after the two interventions. Semi-structured interviews were conducted, and an interview schedule was used to maintain uniformity on the questions asked of each learner. The learners were interviewed a week after they had completed the post-test. As part of the interviews, the researcher strived to create an environment that is comfortable and natural. All the interviews were recorded with the consent of the guardian and learner and were later transcribed verbatim.

The purposes of the interview were three-fold. First, it was necessary to find out the conceptual understanding of the learners after treatment with the two interventions, the PhET simulation and the traditional teacher-centred approach. Currently, there is a dearth of educational research in the use of simulations and learners' retention of phase changes of matter in primary schools (Bain & Towns, 2016). Second, the researcher sought to find out whether the qualitative data would complement the quantitative data. Kumar (2018) suggested that the use of multiple sources of data is important as it helps to triangulate and ensure the credibility of the research data. Third, semi-structured interviews were conducted in order to gain insight into the depth and details of learners' conceptual understanding of phase change of matter.

After the transcription of the recorded data, the responses that learners gave were analysed using nomothetic and ideographic methods, as suggested by (Küçüközer, 2004). Idiographic and nomothetic methods are two different approaches used to understand social life in the social Sciences. A nomothetic method is used to produce "general statements that account for larger social patterns, which form the context of single events, individual behaviours, and experience" (Lyon et al., 2017).

In Science education, a nomothetic approach is used to assess definitions of scientifically complete responses by (Ahmad et al., 2019). Fundamentally, the nomothetic approach concerns the assessment of learners' response based on ideas accepted by the scientific community. Alternatively, an ideographic approach "explores learners' understanding in its own terms without assessment against established scientific ideas (i.e., normative Science)" (Cakmakci et al., 2006). An ideographic approach was used to classify explanations in four categories.

Responses were grouped into three groups after responding to the fixed alternative of the question, namely correct answer, no answer and incorrect answer. The responses

were then coded into a fourth category, after classifying explanations as scientifically correct or scientifically unacceptable. Learners' interview responses were classified into four different categories, as suggested by (Kala et al., 2013). Further, Kala et al. (2013) classified learners' responses into three different categories, namely sound understanding, partial understanding, and no understanding. Substantially, the results from their analysis of the interview data corroborated the quantitative data.

The use of structured interviews in this study led to interesting findings which could not be obtained by the quantitative approach alone. The results of the interview process including some comments and the excerpts are presented below for each question. The categories that were used to analyse interview responses and classifying conceptual understanding are shown in Figure 4.3:

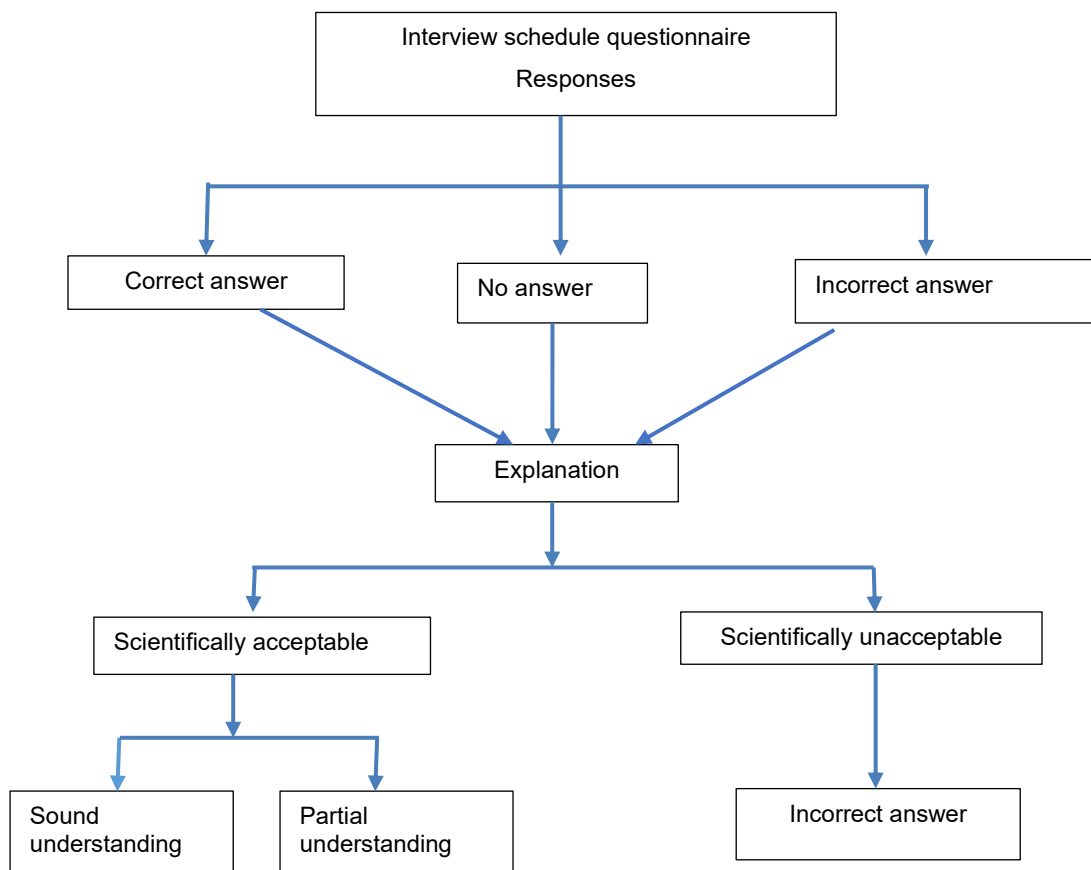


Figure 4.3: Analysis of interview responses

Key:

Sound conceptual understanding (SCU): The response included a correct answer and scientifically accepted explanation.

Partial conceptual understanding (PCU): Response included at least a correct answer or scientifically acceptable explanation correct but not both.

Incorrect conceptual understanding (ICU): A response that consisted of an incorrect answer and illogical explanation.

The results of semi-structured interviews are presented in Figure 4.4. For learners in the PhET simulation group, their responses were mainly in the scientifically conceptual acceptable category (SCU and PCU). Incorrect conceptual understanding (ICU) from the interview responses were 2 in the PhET group, as compared to 7 from the control group. The ICUs were like the ones reported from first phase which involved quantitative data analysis. In the experimental group, phase changes of water were explained well, and ICUs were greatly reduced. Thus, it may be concluded, as it was from the quantitative data, that the use of the PhET simulation greatly improved the sound conceptual understanding (8) of phase changes of matter as compared to (4) control.

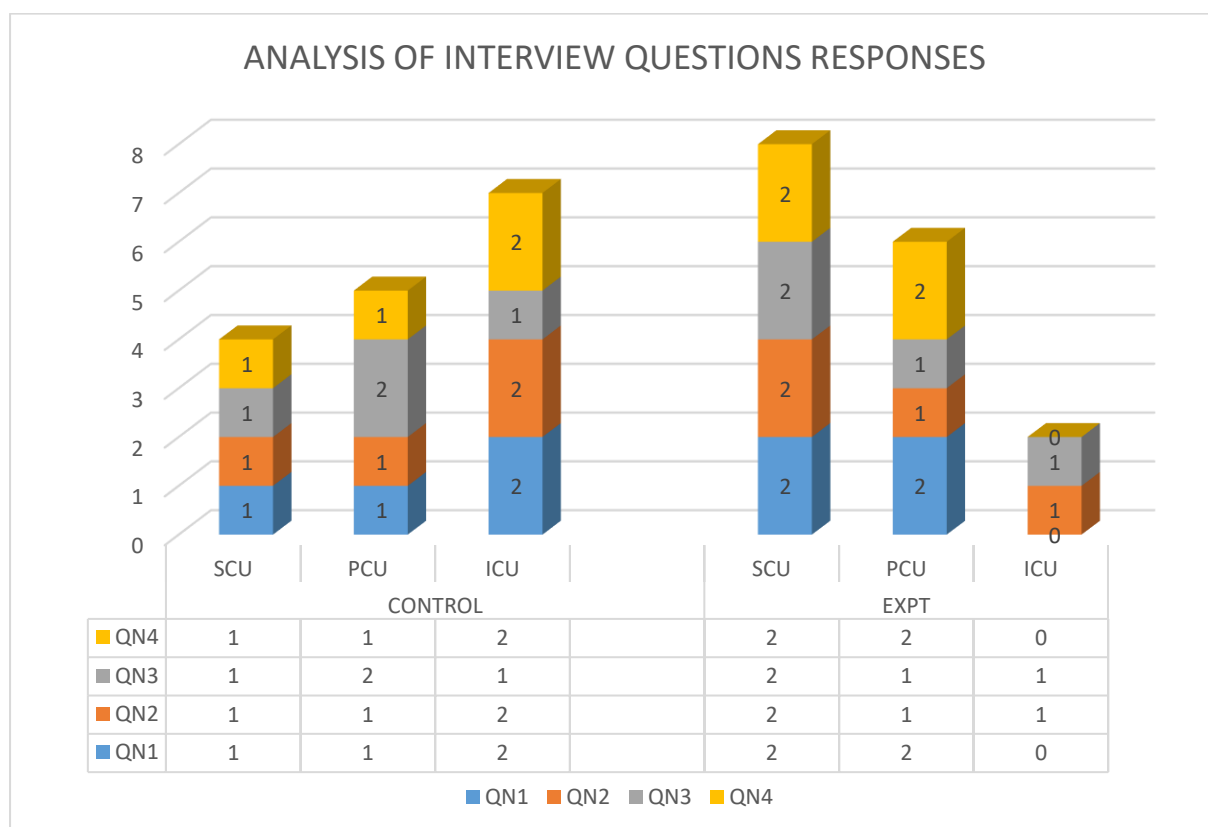


Figure 4.4: Analysis of interview responses

4.10 EXCERPTS FROM INTERVIEWS

Interview Questions 1: Explain what causes the changes in states of water.

One learner from the control group explained that it is caused by adding energy to water. In the experimental group, two learners explained that it is caused by the

addition and subtraction of water from the water molecules. The following excerpts are representative of the control and experimental groups on question 1.

Learner D: *The common phase change of water is brought about by boiling. If water is heated it evaporates. Using an electric kettle can bring about a phase change of water from liquid to gas the temperature increases.*

Researcher: *How about if we put water in the refrigerator?*

Learner D: *The water will freeze and turns into an ice block. In the fridge its cold and the temperature are low.*

The learners' response was based on Johnstone macroscopic level where phases changes were seen to be affected by temperature. Phase changes require learners to operate at both macroscopic and micro-level. The failure to link the unseen micro-level and qualitative sensory observations may lead to incorrect conceptual understanding.

Learner H: *Phase changes are caused by energy changes that leads to the change of temperature of the water molecules. If energy is taken out the water molecules, they come close together and form a solid. Freezing forming ice blocks. Taking in and out of the energy causes phase changes.*

Researcher: *How does the energy enter in and out of water?*

Learner H: *I saw on the simulation that energy changes from outside the water are the ones responsible for the phase changes. If an ice block is left on the sun, energy will be taken from the sun and changes the temperature which leads to melting.*

The learner's response shows that macroscopic and sub-were conceptual understood. Energy that moves in and out of the system is responsible for the phase changes in water. Thus, the use of the PhET simulation might have enhanced the conceptual understanding of the phase changes.

The second question was based on describing the process of melting.

Learner G: *Melting on the ice blocks occurs when energy is taken from outside into the ice block. This energy mainly comes from the sun. The energy will cause the temperature to increase inside, and the*

melting processes begins. If the temperature outside is greater than that of the ice block melting occurs.

Learner C: *Melting occurs when the temperature increases inside the ice block, and it melts. If it's placed where its hot it will melt. Temperature changes will lead the ice to melt.*

The two responses show that learner G has deep conceptual understanding of the melting process. Energy must be transferred into the system that will increase the temperature of the ice block. The surrounding energy mainly comes from the sun. Thus, melting occurs due to transference of energy from outside. Additionally, Learner C mentions temperature gradient to be behind the melting process. From these two responses, Learner G's conceptual understanding could reach both the macroscopic and sub-particle domains.

The third question was based on the freezing of water.

Learner D: *In the fridge the temperature is very low, and the water will turn into ice block. In the fridge low temperatures makes the liquid to go back to the solid phase.*

Researcher: *What happens to the arrangement of the particles as it changes phase?*

Learner D: *The particles will come close together and form a solid.*

Learner F: *Freezing occurs when the energy is taken out the water molecules, the particles come together to form a close pack. When energy is taken out the temperature drops.*

In the two responses the learner from the experimental group explains that it occurs when energy is taken out of the system which are the water molecules. There is a distinction between temperature and energy being taken out.

The last question was based on condensation of the water using the following diagram:



Figure 4.5: Condensation process

Learner A: *I have always wondered when you leave a cold bottle or water glass that droplets will form. I have no clear-cut explanation, but I think it's like morning dew. I think since the bottle is cold the air takes the cold and become water droplets, but I am not sure but guessing.*

Learner F: *The bottle is cold, when the air comes in contact with bottle it loses its energy due to temperature differences. The water particles in the gaseous phase come close together as they lose their energy forming water droplets.*

From the two responses it can be concluded that Learner F conceptual understood what happens at sub-particle level during the process of condensation. Overall, it be concluded that learners should develop an understanding of the distinction between energy and temperature in order to conceptually understand the phase changes of matter. The movement of energy in and out of the system is critical to the understanding of phase changes both at macro and micro levels.

4.11 THE EFFECT OF THE PHET SIMULATION VERSUS TEACHER-CENTRED APPROACH ON RETENTION OF STATES OF MATTER CONCEPTS

To provide the answer to the third research question, the following null hypothesis was tested:

H₀: There is no statistically significant difference in the retention ability of learners taught using the PhET simulation versus those using the teacher-centred method on states of matter concepts.

The alternative hypothesis was formulated as follows:

H₁: There is a statistically significant difference in the retention ability of students taught using a PhET simulation versus those taught using the teacher-centred approach on states of matter.

The delayed post-test mean scores of the control and experimental groups were subjected to independent t-test to test the above null hypothesis. The resulting p-value was 0.001, implying a statistically significant difference between the two groups mean scores (Table 4.6). Thus, the null hypothesis which stated that there would be no statistically significant difference in retention between the groups was rejected, in favour of its alternative.

Table 4.6: Delayed-post-test mean scores of the control and experimental groups

Test	Group	N	Mean	Std. Deviation	Std. Error Mean	Df	F	Sig
Delayed post-test	Control	32	53.91	6.558	.595	63	0.523	0.001
	Expt	32	60.39	6.369	.558			

The mean score obtained in Table 4.6 is 53.91 for the comparison group which was lower than the mean score for the experimental group (60.39). Thus, the retention ability of the students taught using the PhET simulation was significantly higher than those taught using the teacher-centred approach. The null hypothesis of no-significant difference was therefore rejected in favour of the alternative. This result indicates good retention of states of matter concepts by the experimental group. The results presented in Table 4.6 show that the PhET simulation improved learners' retention of phase change of states of matter.

CHAPTER 5 DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 INTRODUCTION

Chapter 4 presented the results of this study. This chapter concludes the study and presents recommendations, based on the findings. On that note, the following issues are highlighted: an overview of the study is presented, mainly highlighting the research questions. The main findings of the study are presented in line with the research objectives. This chapter presents the summary of the current study followed by a discussion of the main findings. The findings of the study are then supported by literature and a discussion of the study's contribution to knowledge. Recommendations are therefore made, based on the findings presented in the preceding chapter. Suggestions for future research, practice, and theory are also offered by the researcher. Finally, the limitations of the study are mentioned, and the chapter is concluded.

5.2 DISCUSSION

The aim of this study was to investigate the effects of States of Matter PhET simulation on Grade 6 learners' conceptual understanding of phase changes of states of matter. To this end, the findings of the study are discussed with regard to the research objectives of the study. The findings are presented as they relate to the three research questions as follows:

1. Is there a statistically difference between pre-test and post-test mean scores of the Grade 6 learner taught with a SOM PhET simulation versus traditional instruction?
2. How does a SOM PhET simulation enhance a conceptual understanding of phase change of matter among Grade 6 learners?
3. What are the effects of SOM PhET simulation on Grade 6 learners retention of phase changes of matter concepts?

5.3 IS THERE A STATISTICALLY DIFFERENCE BETWEEN PRE-TEST AND POST-TEST MEAN SCORES OF THE GRADE 6 LEARNER TAUGHT WITH A SOM PHET SIMULATION VERSUS TRADITIONAL INSTRUCTION?

The first research question was to determine whether or not there would be a statistically significant difference in the performance (pre-test and post-test mean scores) of Grade 6 learners taught with a SOM PhET simulation versus traditional instruction. In addition, research question one sought to better understand any differences in conceptual understanding that resulted between learners being taught with the simulation against the traditional teacher-centred approach. The comparison of pre-test scores in both experimental and control groups had similar mean scores. To cater to the first assumption, an independent samples t-test was performed in order to check whether there was a statistically significant mean difference between the experimental and the control group scores obtained in the pre-test. The result revealed that there was no statistically significant difference between the two groups' pre-test scores. The mean score of the pre-test for both the control and experimental groups was 53.43 and 54.84, respectively. Mean scores for both control (62.95) and PhET (70.12) groups increased indicating that learners performed better in the post-test, as compared to the pre-test. The post-test mean scores indicated that the SOM PhET simulation intervention was more effective, resulting in higher post-test scores than the control group. The result is consistent with a previous study by (Serevina & Raida, 2021), that simulations have been instrumental in improving learners' conceptual understanding of abstract concepts in Science education.

Furthermore, though the simulation was used as a demonstration by the teachers in the experimental groups instead of the learners' manipulation of the simulation the post-test mean score was high. The finding concurs with those reported by (Ndiokubwayo et al., 2020) who suggested that computer simulations in Science education have shown that using simulations interactively or as a demonstration can improve the effectiveness of instruction. Also, in general, having the learners, manipulate the simulation themselves or as a demonstration yields the same overall outcomes (Ndiokubwayo et al., 2020). The findings seem to suggest that the PhET simulation has the potential to clarify learners' conceptual understanding of targeted chemical phenomena such as phase change of matter. The finding also suggests that

conceptual understanding is one of the best predictors of academic success in Science education (Schwedler & Kaldewey, 2020).

The findings of this study have an impact on the modified Johnstone triangle by (Taber, 2013). Conceptual understanding of phase change of matter may shift among all the three levels macro, representation and sub-microscopic levels or domains. The finding on the high mean scores from the PhET groups confirmed the existence of some improvement in learners' conceptual understanding of the phase change of matter at large. The conceptual understanding impacts positively learners' constructing knowledge about phase changes. The results seem to suggest that learner performance is influenced by instructional approaches. Therefore, it was concluded that simulations enhanced learners' performance and could improve the retention of phase change of matter concepts. These findings support the argument that simulations can improve academic performance and help learners retain concepts in phase change of matter (Mohafa et al., 2022). The present study concurs with Mohafa et al. (2022), who recommended that simulations be used to supplement the teaching and learning of Science, to enhance performance.

5.4 TO DETERMINE HOW A SOM PHET SIMULATION ENHANCES GRADE 6 LEARNERS' CONCEPTUAL UNDERSTANDING OF PHASE CHANGES OF MATTER.

The findings showed that simulations enhanced learners' conceptual understanding as compared to traditional teacher centred approach. During interviews, learners from the experimental group had sound conceptual understanding. The participants explained that phase changes were caused by energy changes in and outside of the material. They could distinguish the difference between heat and temperature. The results seem to suggest instructional approaches play an important role in enhancing conceptual understanding. Physics education technology (PhET) simulations have been instrumental in improving students conceptual understanding of abstract concepts in Science education (Serevina & Raida, 2021; Stieff & Wilensky, 2003). Furthermore, Ajayi and Angura (2017) suggested that inappropriate instructional approaches in Science invariably translate to learners' inability to conceptually understand and retain core knowledge concepts. To improve conceptual understanding, the simulation might have allowed learners to visualise the

representational and submicroscopic levels. The findings are similar to those reported by Wilcox and Lewandowski (2017), that learners are more likely to construct new knowledge through multimedia presentations, such as the use of simulations. It was concluded in the present study that simulations help learners visualise abstract Science models. The CLT visualisation might have reduced the extraneous load allowing the working memory. The information was later transferred to the long-term memory where it was integrated in the with prior knowledge. The cognitive multimedia theory also suggest that words and pictures together can allow learners to learn more deeply than words alone. The PhET simulation allowed words and pictures that enhanced conceptual learning. The traditional teacher centred approach might have lacked the ability to show pictures about the dynamic nature of particles when they change phases. Chalk and talk method might have failed to reduce extraneous load, phase change of matter concepts can be challenging for teachers to simplify and make it comprehensible for learners. It is possible, however, that learners in the control groups were not exposed to dynamic pictorial representations, which could have hindered their ability to achieve deep conceptual understanding similar to the experimental group.

The visualisation the sub-micro and the representation levels might have enhanced conceptual understanding. Learners from the experimental group articulated that phase changes are brought about by adding energy or removing from the material. According to the Johnstone triangle conceptual understanding is enhanced when learners translate among the three domains. In the present study, the simulation used the representational and sub microscopic. The findings contradict the suggestion by Taber (2013) that learners moving from the macroscopic to microscopic and shifting using the representational. The simulations mainly used the representational level showing the particle nature of matter. Thus, the representational can also play a major role to enhance conceptual understanding. Mohafa et al. (2022) stated that the introduction of stoichiometry concepts has to start with sub-micro representations, to allow learners to concretise concepts.

The findings of the are similar to those reported by Ndiokubwayo et al. (2020) about using the simulation as a demonstration. The PhET simulation was not used interactively due to lack of resources. The results showed that the use of PhET simulations without learner manipulation is equally effective. Therefore, by its very

nature, the determination of explicit considerations of how deep learning or retention of concepts happened when learners were probed during interviews. There was strong evidence of mental models that were constructed when the simulation was used resulting in the information being retained in the long term memory.

5.5 TO DETERMINE HOW THE USE OF SOM PHET SIMULATION AFFECTS THE RETENTION ABILITY OF THE GRADE 6 LEARNERS ON PHASE CHANGES OF MATTER.

In order to provide the answer to the second research question, the following null hypothesis was tested:

H₀: There is no statistically significant difference in the retention ability of learners taught using the SOM PhET simulation versus those using the traditional teacher-centred approach in the phase change of matter.

The alternative hypothesis was formulated as follows:

H₁: There is a statistically significant difference in the retention ability of learners taught using the SOM PhET simulation versus those taught using the traditional teacher-centred in the phase change of matter.

The delayed post-test mean scores of the control and experimental groups were subjected to an independent t–test to test the above null hypothesis. The resulting p-value was 0.005, implying a statistically significant difference between the two groups. Thus, the null hypothesis which stated that there would be no statistically significant difference in retention between the groups was rejected, in favour of its alternative.

Thus, the retention ability of the learners taught using the SOM PhET simulation was significantly higher than those taught using the traditional teacher-centred approach. This result indicates good retention of phase change concepts by the experimental group. The delayed post-test performance of the experimental group increased as compared to the post-test. The possibility, therefore, exists that the PhET simulation instruction was effective in promoting the learners' conceptual understanding, resulting in the knowledge being stored in their long-term memories as advocated by the CLT. More specifically, D'Ottone and Ochonogor (2017) believed that the retention of concepts in chemistry is directly linked to the method of instruction. The findings of

this study show that the PhET simulation improved learners' knowledge retention of phase change of matter.

The finding corroborates the findings of (Ajayi & Angura, 2017), who reported that the teaching approaches in Natural Science are mainly qualitative macroscopic, resulting in low levels of conceptual understanding among students. It may seem to suggest that instructional methods play an important role in the retention ability of learners. Inappropriate teaching approaches in NS/Tech invariably translate to learners' inability to retain core knowledge concepts of phase changes of matter.

According to the CLT, the use of the SOM PhET simulation could have affected the germane cognitive loads that led to the automation of the right schemas. The finding on the use of the PhET simulation was similar to that by Didiş (2015), that learners enjoyed the simulation, and it improved the conceptual understanding and retention of quantum theory concepts. The traditional approach had the least retention, and it is concluded that the use of the PhET simulation lead to better retention of phase change of matter concepts. The findings of this study on the traditional approach are in agreement with several related research studies (Bruce et al., 2016; D'Ottone & Ochonogor, 2017; Taylor et al., 2017) that concluded teaching approaches have a direct effect on retention. According to the CTML, the use of the PhET simulation might have allowed new knowledge to be created when the prior knowledge interacted with information from the simulation in the long-term memory.

Mayer and Clark (2003) suggested that deeper learning occurs when information is presented in both text and graphics than by text alone. The results are in agreement with (Savasci-Acikalin, 2021), who suggested that simulations have the potential to improve visualisation of abstract concepts. The findings seem to suggest that improved visualisation tend to improve the retention of concepts. The findings of this study have an impact on the Johnstone triangle. Phase change of matter may require shifts from representational and sub-microscopic levels or domains. The findings on the phase change of matter revealed the existence of some difficulties affecting learners' retention when improper instructional are used. The findings are similar to Mohafa et al. (2022), that teaching and learning of Science and Mathematics in less developed countries face significant challenges. There are several limitations and challenges associated with the chalk and talk method used by most Science teachers.

One of the limitation is that chalk and talk methods do not enhance retention of phase change of matter concepts.

5.6 SUMMARY

The aim of the study was to explore the use of States of Matter PhET simulation on South African Grade 6 Natural Sciences learners' conceptual understanding of phase changes of matter. It also investigated how the simulation enhances the retention of phase change of matter concepts. A PhET simulation was used as the treatment to enhance learner performance and the retention of phase change of matter concepts. The study employed the Johnstone triangle and the CLT as the theoretical framework. The dynamic nature of matter during phase change makes the topic abstract and most learners fail to relate day-to-day macroscopic observations to what takes place at the molecular level. A PhET simulation provided a bridge and special learning environment for learners to enhance conceptual understanding. The simulation enabled learners to make translations among the three levels macroscopic, representational, and sub-micro which is abstract. The phase change of matter involves visualisation and abstract thinking and is taught using a language different from everyday life (Hejnová & Králík, 2019). Simulations can be used because they aid in meaningful learning since they are the art of scientific learning. The study was framed within the mixed methods (pragmatic) research paradigm. This study involved 64 (n = 64) NS/Tech Grade 6 learners enrolled at four public primary schools in uMkhanyakude District, KZN, South Africa. The research design utilised was a non-equivalent control group pre-test-post-test and delayed post-test. The phase change of matter concepts involved were evaporation, melting, and condensation. Two null hypotheses were stated and tested at $\alpha < 0.05$. A two-tier phase change of matter diagnostic questionnaire, or test, made up of fifteen multiple-choice questions, was used to measure performance and retention after treatment. The data collected from all the tests were analysed using descriptive and inferential statistics to test the stated hypotheses. The results, as discussed in Chapter 4, revealed that the PhET simulation is effective in enhancing conceptual understanding and retention among Grade 6 learners.

5.7 LIMITATIONS

This study had the following limitations which might have affected the outcome of this study:

1. The study was restricted to only Grade 6 Natural Science learners at four rural primary schools in the uMkhanyakude District. The sample size was small and might not have been large enough to be representative of the entire population of Grade 6 Natural Science in South Africa.
2. The PhET simulation was used as a demonstration by the teachers and the learners did not use the simulation interactively due to a lack of computer resources in public primary schools.
3. The interview sample size of 10 students drawn for this study might have been too small. A larger sample could have given a clearer picture of the conceptual understanding of the learners. Interviews were used for triangulation and shedding light on the identified challenges.
4. This study utilised a quasi-experimental design, nonrandomised pre-test-post-test-post, and delayed post-test design. To mitigate the lack of randomisation, the researcher tossed a coin to assign the groups to the experimental and control conditions.

5.8 RECOMMENDATIONS FOR FURTHER RESEARCH

The findings of this study have shown that the SOM PhET simulation helped encourage the retention and conceptual understanding of phase change of matter. Its use should therefore be encouraged for teaching in primary schools. The researcher recommends the following for further research:

- This study used the PhET simulation to promote conceptual understanding and retention. It would be interesting to investigate the effect of using simulation in promoting conceptual change. Furthermore, further research is needed to ascertain how different simulations affect the retention ability of phase change of matter concepts.
- Further research is needed to see how the results will change if the simulation is used interactively by the learners.

- A delayed post-test was administered after a month. It would be intriguing to find out if the results would be similar if the delayed post-test is administered after a year. Those results would give a clear indication of how the PhET simulation affects retention in long-term memory.
- Further research should be done to investigate how the PhET instructional approach affects primary school learners' cognitive structure.

5.8.1 Recommendations for Instruction

Based on the findings of this study, the following steps may be recommended in the teaching phase change of matter:

- Translating among three representations. Educators should design activities that allow students to translate among the three representations in an effort to link visual feature information to relevant quantitative information.
- Emphasis should be placed on energy changes when matter changes phases.
- Prospective teachers and in-service teachers must be mindful of the conceptual understanding challenges learners encounter when distinguishing between heat and temperature.
- During the teaching of phase change of matter instructors should focus on related prior knowledge and confront alternative conceptions.

REFERENCES

- Abou Faour, M., & Ayoubi, Z. (2017). The effect of using virtual laboratory on grade 10 students' conceptual understanding and their attitudes towards physics. *Journal of Education in Science Environment and Health*, 4(1), 54-68.
- Adadan, E., Irving, K. E., & Trundle, K. C. (2009). Impacts of multi-representational instruction on high school students' conceptual understandings of the particulate nature of matter. *International Journal of Science Education*, 31(13), 1743-1775.
- Ahmad, N. J., Ishak, N. A., & Bunyamin, M. A. H. (2019). Learning demand and classroom discourse design tools to improve students' conceptual understanding of the nature of electrolytes. *Asia Pacific Journal of Educators and Education*, 34, 187-218.
- Ajayi, V. O., & Angura, T. (2017). Improving Senior Secondary Students' Retention in Electrolysis Using Collaborative Concept Mapping Instructional Strategy (CCMIS). *Greener Journal of Educational Research*, 7(6), 87-92.
- Akhtar, D. M. I. (2016). Research design. *Research Design (February 1, 2016)*.
- Albus, P., Vogt, A., & Seufert, T. (2021). Signaling in virtual reality influences learning outcome and cognitive load. *Computers & education*, 166, 104154.
- Almasri, F. (2022). Simulations to teach Science subjects: Connections among students' engagement, self-confidence, satisfaction, and learning styles. *Education and Information Technologies*, 27(5), 7161-7181.
- Almasri, F., Hewapathirana, G. I., Ghaddar, F., Lee, N., & Ibrahim, B. (2021). Measuring attitudes towards biology major and non-major: Effect of students' gender, group composition, and learning environment. *PloS one*, 16(5), e0251453.
- Ayas, A., Özmen, H., & Çalik, M. (2010). STUDENTS' CONCEPTIONS OF THE PARTICULATE NATURE OF MATTER AT SECONDARY AND TERTIARY LEVEL. *International journal of Science and Mathematics education*, 8, 165-184.
- Aydeniz, M., Bilican, K., & Kirbulut, Z. D. (2017). Exploring pre-service elementary Science teachers' conceptual understanding of particulate nature of matter through three-tier diagnostic test. *International Journal of Education in Mathematics, Science and Technology*, 5(3), 221-234.
- Aydeniz, M., & Kotowski, E. L. (2012). What do middle and high school students know about the particulate nature of matter after instruction? Implications for practice. *School Science and Mathematics*, 112(2), 59-65.
- Ayre, C., & Scally, A. J. (2014). Critical values for Lawshe's content validity ratio: revisiting the original methods of calculation. *Measurement and evaluation in counseling and development*, 47(1), 79-86.
- BADRIAN, A., ABDINEJAD, T., & NASERIAZAR, A. (2011). A cross-age study of Iranian students' various conceptions about the particulate nature of matter. *Journal of Turkish Science Education*, 8(2), 49-63.
- Bain, K., & Towns, M. H. (2016). A review of research on the teaching and learning of chemical kinetics. *Chemistry Education Research and Practice*, 17(2), 246-262.
- Baldwin, N., & Orgill, M. (2019). Relationship between teaching assistants' perceptions of student learning challenges and their use of external representations when teaching acid-base

- titrations in introductory chemistry laboratory courses. *Chemistry Education Research and Practice*, 20(4), 821-836.
- Bantwini, B. (2017). Analysis of teaching and learning of Natural Sciences and Technology in selected Eastern Cape province primary schools, South Africa. *Journal of Education*(67), 39-64.
- Berg, S., & Nyachwaya, J. (2019). General Chemistry Students' Perceptions of the Particulate Nature of Matter in Different Physical States. *Gas*, 10(10), 0.
- Blown, E. J., & Bryce, T. G. (2017). Switching between everyday and scientific language. *Research in Science Education*, 47(3), 621-653.
- Bond, M. (2020). Facilitating student engagement through the flipped learning approach in K-12: A systematic review. *Computers & education*, 151, 103819.
- Bruce, M., Coffey, P. K., Rees, S., & Robson, J. M. (2016). Write on the edge: using a chemistry corpus to develop academic writing skills resources for undergraduate chemists. *Chemistry Education Research and Practice*, 17(3), 580-589.
- Bussey, T. J., & Orgill, M. (2019). Biochemistry instructors' use of intentions for student learning to evaluate and select external representations of protein translation. *Chemistry Education Research and Practice*, 20(4), 787-803.
- Cakmakci, G., Leach, J., & Donnelly, J. (2006). Students' ideas about reaction rate and its relationship with concentration or pressure. *International Journal of Science Education*, 28(15), 1795-1815.
- Calik, M., & Ayas, A. (2005). A comparison of level of understanding of eighth-grade students and Science student teachers related to selected chemistry concepts. *Journal of research in Science teaching*, 42(6), 638-667.
- Campbell, D. T., & Stanley, J. C. (2015). *Experimental and quasi-experimental designs for research*. Ravenio books.
- Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and instruction*, 8(4), 293-332.
- Chilisa, B., & Kawulich, B. (2012). Selecting a research approach: Paradigm, methodology and methods. *Doing social research: A global context*, 5(1), 51-61.
- Clewett, D., DuBrow, S., & Davachi, L. (2019). Transcending time in the brain: How event memories are constructed from experience. *Hippocampus*, 29(3), 162-183.
- Cohen, L., Manion, L., & Morrison, K. (2017). *Research Methods in Education*. Routledge.
- Cohen, L., Manion, L., & Morrison, K. (2018). Research methods in education (Eighth Edi). In: London: Routledge.
- Cook, M. P. (2006). Visual representations in Science education: The influence of prior knowledge and cognitive load theory on instructional design principles. *Science education*, 90(6), 1073-1091.
- Correia, A.-P., Koehler, N., Thompson, A., & Phye, G. (2019). The application of PhET simulation to teach gas behavior on the submicroscopic level: secondary school students' perceptions. *Research in Science & Technological Education*, 37(2), 193-217.
- Council, N. R. (2012). *A framework for K-12 Science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.
- Creswell, J. W. (2014). *A concise introduction to mixed methods research*. SAGE publications.
- Creswell, J. W. (2015). Revisiting mixed methods and advancing scientific practices. *The Oxford handbook of multimethod and mixed methods research inquiry*.

- Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Crossgrove, K., & Curran, K. L. (2008). Using clickers in nonmajors-and majors-level biology courses: student opinion, learning, and long-term retention of course material. *CBE—Life Sciences Education*, 7(1), 146-154.
- D’Ottone, L., & Ochonogor, E. C. (2017). Educational explorations of chemical kinetics in a Problem Based Learning context. *Orbital: The Electronic Journal of Chemistry*, 299-307.
- Dawson, C. (2019). *Introduction to Research Methods 5th Edition: A Practical Guide for Anyone Undertaking a Research Project*. Robinson.
- Didiş, N. (2015). The analysis of analogy use in the teaching of introductory quantum theory. *Chemistry Education Research and Practice*, 16(2), 355-376.
- Durmuş, J., & Bayraktar, Ş. (2010). Effects of conceptual change texts and laboratory experiments on fourth grade students’ understanding of matter and change concepts. *Journal of Science Education and Technology*, 19, 498-504.
- Ekenobi, T., Mumuni, A., & Nwanekezi, A. (2016). Enhancing chemistry students’ retention of redox reaction concept through intervention with advance organizers. *British Journal of Psychology Research*, 4(4), 34-46.
- Engelbrecht, J., Harding, A., & Du Preez, J. (2007). Long-term retention of basic mathematical knowledge and skills with engineering students. *European Journal of Engineering Education*, 32(6), 735-744.
- Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, 5(1), 1-4.
- Fairbanks, R. (2021). Masterpiece or Mess: The Mosaic Theory of the Fourth Amendment Post-Carpenter. *Berkeley J. Crim. L.*, 26, 71.
- Falloon, G. (2019). Using simulations to teach young students Science concepts: An Experiential Learning theoretical analysis. *Computers & education*, 135, 138-159.
- Farrell, O., & Brunton, J. (2020). A balancing act: a window into online student engagement experiences. *International Journal of Educational Technology in Higher Education*, 17(1), 1-19.
- Fitzgerald, A., & Smith, K. (2016). Science that matters: Exploring Science learning and teaching in primary schools. *Australian Journal of Teacher Education*, 41(4), 4.
- George, D., & Mallery, P. (2010). SPSS for Windows step by step. A simple study guide and reference (10. Baskı). *GEN, Boston, MA: Pearson Education, Inc*, 10, 152-165.
- Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK. I: A. Berry, P. Friedrichsen & J. Loughran (red.). *Re-examining pedagogical content knowledge in Science education*, 28-42.
- Gibbons, R. E., Villafañe, S. M., Stains, M., Murphy, K. L., & Raker, J. R. (2018). Beliefs about learning and enacted instructional practices: An investigation in postsecondary chemistry education. *Journal of research in Science teaching*, 55(8), 1111-1133.
- Gilbert, J. K., & Treagust, D. F. (2009). *Multiple representations in chemical education* (Vol. 4). Springer.

- Gkitzia, V., Salta, K., & Tzougraki, C. (2020). Students' competence in translating between different types of chemical representations. *Chemistry Education Research and Practice*, 21(1), 307-330.
- Halverson, K. (2007). Why teach Science in early childhood. *Retrieved from*.
- Hayley, K., Schumacher, J., MacMillan, G., & Boutin, L. (2014). Highly parameterized model calibration with cloud computing: an example of regional flow model calibration in northeast Alberta, Canada. *Hydrogeology Journal*, 22(3), 729.
- Hejnová, E., & Králík, J. (2019). Images of atoms in physics textbooks for lower secondary schools vs. misconceptions of pupils about atoms. AIP Conference Proceedings,
- Huang, F., Hoi, C. K. W., & Teo, T. (2018). The influence of learning style on English learning achievement among undergraduates in Mainland China. *Journal of Psycholinguistic Research*, 47, 1069-1084.
- Hughes, P. (2020). Paradigms, methods and knowledge. In *Doing early childhood research* (pp. 35-61). Routledge.
- Inayah, N., & Masrurroh, M. (2021). PhET simulation effectiveness as laboratory practices learning media to improve students' concept understanding. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, 9(2), 152-162.
- Irby, S. M., Phu, A. L., Borda, E. J., Haskell, T. R., Steed, N., & Meyer, Z. (2016). Use of a card sort task to assess students' ability to coordinate three levels of representation in chemistry. *Chemistry Education Research and Practice*, 17(2), 337-352.
- Jawad, L. F., Raheem, M. K., & Majeed, B. H. (2021). The Effectiveness of Educational Pillars Based on Vygotsky's Theory in Achievement and Information Processing Among First Intermediate Class Students. *International Journal of Emerging Technologies in Learning (IJET)*, 16(12), 246-262.
- Johnson, P. (1998). Children's understanding of changes of state involving the gas state, Part 2: Evaporation and condensation below boiling point. *International Journal of Science Education*, 20(6), 695-709.
- Johnstone, A. H. (2010). You can't get there from here. *Journal of Chemical Education*, 87(1), 22-29.
- Jukić Matić, L., & Dahl, B. (2014). Retention of differential and integral calculus: a case study of a university student in physical chemistry. *International Journal of Mathematical Education in Science and Technology*, 45(8), 1167-1187.
- Kala, N., Yaman, F., & Ayas, A. (2013). THE EFFECTIVENESS OF PREDICT–OBSERVE–EXPLAIN TECHNIQUE IN PROBING STUDENTS' UNDERSTANDING ABOUT ACID–BASE CHEMISTRY: A CASE FOR THE CONCEPTS OF pH, pOH, AND STRENGTH. *International journal of Science and mathematics education*, 11, 555-574.
- Kapıcı, H., & Akçay, H. (2016). Particulate nature of matter misconceptions held by middle and high school students in Turkey. *European Journal of Education Studies*, 2(8).
- Kara, I. (2008). The effect on retention of computer assisted instruction in Science education. *Journal of instructional Psychology*, 35(4), 357-365.
- Kelly, M. (2014). Applying the tiers of assessment: A holistic and systematic approach to assessing library collections. *The journal of academic librarianship*, 40(6), 585-591.
- Kelly, R. M., & Hansen, S. J. (2017). Exploring the design and use of molecular animations that conflict for understanding chemical reactions. *Química Nova*, 40, 476-481.
- Ketokivi, M. (2019). Avoiding bias and fallacy in survey research: A behavioral multilevel approach. *Journal of Operations Management*, 65(4), 380-402.

- Khishfe, R. (2015). A look into students' retention of acquired nature of Science understandings. *International Journal of Science Education*, 37(10), 1639-1667.
- Khlaif, Z. N., Salha, S., & Kouraichi, B. (2021). Emergency remote learning during COVID-19 crisis: Students' engagement. *Education and Information Technologies*, 26(6), 7033-7055.
- Khumalo, N. P., & Maphalala, M. C. (2018). Students' perspectives on the role played by academic literacy in the higher education curriculum of South Africa. *Journal of Gender, Information and Development in Africa (JGIDA)*, 7(1), 155-173.
- Klahr, D., & Wallace, J. G. (2022). *Cognitive development: An information-processing view*. Routledge.
- Konicek-Moran, R., & Keeley, P. (2015). *Teaching for conceptual understanding in Science*. NSTA Press, National Science Teachers Association Arlington.
- Kotoka, J., & Kriek, J. (2014). The impact of computer simulations as interactive demonstration tools on the performance of grade 11 learners in electromagnetism. *African Journal of Research in Mathematics, Science and Technology Education*, 18(1), 100-110.
- Küçüközer, H. (2004). The influence of teaching method which was designed according to constructivist learning theory for the first year high school students' on simple electric circuit. *Unpublished Ph. D. Thesis, Balikesir University, Balikesir, Turkey*.
- Kumar, R. (2018). *Research methodology: A step-by-step guide for beginners*. Sage.
- Kunnath, B., & Kriek, J. (2018). Exploring effective pedagogies using computer simulations to improve Grade 12 learners' understanding of the photoelectric effect. *African Journal of Research in Mathematics, Science and Technology Education*, 22(3), 329-339.
- Kurt, S., & Ayas, A. (2012). Improving students' understanding and explaining real life problems on concepts of reaction rate by using a four step constructivist approach. *Energy Education Science and Technology Part B: Social and Educational Studies*, 4(2), 979-992.
- Langer, N., Ho, E. J., Alexander, L. M., Xu, H. Y., Jozanovic, R. K., Henin, S., Petroni, A., Cohen, S., Marcelle, E. T., & Parra, L. C. (2017). A resource for assessing information processing in the developing brain using EEG and eye tracking. *Scientific data*, 4(1), 1-20.
- Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel psychology*, 28(4), 563-575.
- Lee, W. C., Neo, W. L., Chen, D.-T., & Lin, T.-B. (2021). Fostering changes in teacher attitudes toward the use of computer simulations: Flexibility, pedagogy, usability and needs. *Education and Information Technologies*, 26(4), 4905-4923.
- Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. *Journal of educational psychology*, 97(2), 184.
- Lindgren, R., Tscholl, M., Wang, S., & Johnson, E. (2016). Enhancing learning and engagement through embodied interaction within a mixed reality simulation. *Computers & education*, 95, 174-187.
- Lyon, A. R., Connors, E., Jensen-Doss, A., Landes, S. J., Lewis, C. C., McLeod, B. D., Rutt, C., Stanick, C., & Weiner, B. J. (2017). Intentional research design in implementation Science: implications for the use of nomothetic and idiographic assessment. *Translational behavioral medicine*, 7(3), 567-580.
- Lysne, S. J., & Miller, B. G. (2017). A comparison of long-term knowledge retention between two teaching approaches. *Journal of College Science Teaching*, 46(6), 100.

- Mayer, R. E. (2002). Cognitive theory and the design of multimedia instruction: an example of the two-way street between cognition and instruction. *New directions for teaching and learning*, 2002(89), 55-71.
- Mayer, R. E. (2011). Multimedia learning and games.
- Mayer, R. E. (2012). Information processing.
- Mayer, R. E. (2014). Incorporating motivation into multimedia learning. *Learning and instruction*, 29, 171-173.
- Mayer, R. E. (2019). How multimedia can improve learning and instruction.
- Mayer, R. E., & Clark, R. (2003). The promise of educational psychology (vol II): Teaching for meaningful learning. In: Wiley Online Library.
- McMillan, J. H., & Schumacher, S. (2010). Research in Education: Evidence-Based Inquiry, MyEducationLab Series. *Pearson*.
- Mills, G. E., & Gay, L. R. (2019). *Educational research: Competencies for analysis and applications*. ERIC.
- Mohafa, L. G., Qhobela, M., & George, M. J. (2022). Evaluating the influence of interactive simulations on learners' academic performance in stoichiometry. *South African Journal of Chemistry*, 76, 1-8.
- Molina-Azorin, J. F., & Fetters, M. D. (2016). Mixed methods research prevalence studies: Field-specific studies on the state of the art of mixed methods research. *Journal of mixed methods research*, 10(2), 123-128.
- Moodley, G. (2013). *Implementation of the curriculum and assessment policy statements: Challenges and implications for teaching and learning* University of South Africa Pretoria, South Africa].
- Morse, J. M., & Maddox, L. J. (2014). Analytic integration in qualitatively driven (QUAL) mixed and multiple methods designs. *The SAGE handbook of qualitative data analysis*, 524-539.
- Nakhleh, M. B., Samarapungavan, A., & Saglam, Y. (2005). Middle school students' beliefs about matter. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 42(5), 581-612.
- Ndihokubwayo, K., Uwamahoro, J., & Ndayambaje, I. (2020). Effectiveness of PhET simulations and YouTube videos to improve the learning of optics in Rwandan secondary schools. *African Journal of Research in Mathematics, Science and Technology Education*, 24(2), 253-265.
- Nieswandt, M. (2007). Student affect and conceptual understanding in learning chemistry. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 44(7), 908-937.
- Norris, D. (2017). Short-term memory and long-term memory are still different. *Psychological bulletin*, 143(9), 992.
- Nyachwaya, J. M., & Gillaspie, M. (2016). Features of representations in general chemistry textbooks: a peek through the lens of the cognitive load theory. *Chemistry Education Research and Practice*, 17(1), 58-71.
- Othman, J., Treagust, D. F., & Chandrasegaran, A. (2008). An investigation into the relationship between students' conceptions of the particulate nature of matter and their understanding of chemical bonding. *International Journal of Science Education*, 30(11), 1531-1550.
- Owobi, E. (2018). A Survey of Hand Washing Behavior and Awareness among Health Care Workers in Health Care Facilities in Kubwa District of Bwari Area Council, FCT Abuja, Nigeria. *Annals of Ecology and Environmental Science*, 2(2), 1-18.

- Ozmen, H. (2011). Turkish Primary Students' Conceptions about the Particulate Nature of Matter. *International Journal of Environmental and Science Education*, 6(1), 99-121.
- Özmen, H. (2011). Effect of animation enhanced conceptual change texts on 6th grade students' understanding of the particulate nature of matter and transformation during phase changes. *Computers & education*, 57(1), 1114-1126.
- Özmen, H. (2013a). A cross-national review of the studies on the particulate nature of matter and related concepts. *International Journal of Physics & Chemistry Education*, 5(2), 81-110.
- Özmen, H. (2013b). A cross-national review of the studies on the particulate nature of matter and related concepts. *International Journal of physics and chemistry Education*, 5(2), 81-110.
- Paas, F., & Ayres, P. (2014). Cognitive load theory: A broader view on the role of memory in learning and education. *Educational Psychology Review*, 26, 191-195.
- Parker, W. S. (2013). Computer simulation. In *The Routledge companion to philosophy of Science* (pp. 167-177). Routledge.
- Petillion, R. J., & McNeil, W. S. (2020). Johnstone's triangle as a pedagogical framework for flipped-class instructional videos in introductory chemistry. *Journal of Chemical Education*, 97(6), 1536-1542.
- Popova, M., & Bretz, S. L. (2018). "It's Only the Major Product That We Care About in Organic Chemistry": An Analysis of Students' Annotations of Reaction Coordinate Diagrams. *Journal of Chemical Education*, 95(7), 1086-1093.
- Popova, M., & Jones, T. (2021). Chemistry instructors' intentions toward developing, teaching, and assessing student representational competence skills. *Chemistry Education Research and Practice*, 22(3), 733-748.
- Popova, S., Petrisheva, L., Popova, E., & Ushakova, O. (2020). Modern educational formats: Technology of flipped chemistry teaching. *Journal of Physics: Conference Series*,
- Pratiwi, E., Nusantara, T., Susiswo, S., Muksar, M., & Subanji, S. (2019). Characteristics of students' cognitive conflict in solving a problem based on information processing theory. *International Journal of Learning, Teaching and Educational Research*, 18(2), 76-88.
- Quellmalz, E. S., Timms, M. J., Silberglitt, M. D., & Buckley, B. C. (2012). Science assessments for all: Integrating Science simulations into balanced state Science assessment systems. *Journal of research in Science teaching*, 49(3), 363-393.
- Ramma, Y., Bholoa, A., Watts, M., & Nadal, P. S. (2018). Teaching and learning physics using Technology: Making a case for the affective domain. *Education Inquiry*, 9(2), 210-236.
- Robertson, B., Schumacher, L., Gosman, G., Kanfer, R., Kelley, M., & DeVita, M. (2009). Simulation-based crisis team training for multidisciplinary obstetric providers. *Simulation in Healthcare*, 4(2), 77-83.
- Rooney, M. K., Zhu, F., Gillespie, E. F., Gunther, J. R., McKillip, R. P., Lineberry, M., Tekian, A., & Golden, D. W. (2018). Simulation as more than a treatment-planning tool: A systematic review of the literature on radiation oncology simulation-based medical education. *International Journal of Radiation Oncology* Biology* Physics*, 102(2), 257-283.
- Rutten, N., Van Joolingen, W. R., & Van Der Veen, J. T. (2012). The learning effects of computer simulations in Science education. *Computers & education*, 58(1), 136-153.
- Sanina, A., Kutergina, E., & Balashov, A. (2020). The Co-Creative approach to digital simulation games in social Science education. *Computers & education*, 149, 103813.

- Saunders, M. (2015). The (re) emergence of mixed methods research: to combine or not combine. Keynote address ECRM conference, Malta, June,
- Savasci-Acikalin, F. (2019). How Middle School Students Represent Phase Change and Interpret Textbook Representations: a Comparison of Student and Textbook Representations. *Research in Science Education*, 50.
- Savasci-Acikalin, F. (2021). How Middle School Students Represent Phase Change and Interpret Textbook Representations: A Comparison of Student and Textbook Representations. *Research in Science Education*, 51, 1651-1685.
- Schrader, C., & Bastiaens, T. (2012). Learning in educational computer games for novices: the impact of support provision types on virtual presence, cognitive load, and learning outcomes. *International Review of Research in Open and Distributed Learning*, 13(3), 206-227.
- Schwedler, S., & Kaldewey, M. (2020). Linking the submicroscopic and symbolic level in physical chemistry: how voluntary simulation-based learning activities foster first-year university students' conceptual understanding. *Chemistry Education Research and Practice*, 21(4), 1132-1147.
- Sendur, G., Polat, M., & Kazancı, C. (2017). Does a course on the history and philosophy of chemistry have any effect on prospective chemistry teachers' perceptions? The case of chemistry and the chemist. *Chemistry Education Research and Practice*, 18(4), 601-629.
- Serevina, V., & Raida, R. (2021). Improving the quality of education in the COVID-19 era through the implementation of online learning resources with poe2we model on parabolic motion. *International Journal of Educational Management and Innovation*, 2(1), 13-28.
- Set, B., Hadman, J., & Ashipala, D. O. (2017). An Investigation into How Grade 5 Teachers Teach Natural Science Concepts in Three Western Cape Primary Schools. *World Journal of Education*, 7(1), 33-43.
- Singer, J. E., Tal, R., & Wu, H. K. (2003). Students' understanding of the particulate nature of matter. *School Science and Mathematics*, 103(1), 28-44.
- Smith, Z. B. (2016). *Evaluation of glaciothermal engines for the generation of polar renewable energy* [University of Tasmania].
- Sorden, S. D. (2012). The cognitive theory of multimedia learning. *Handbook of educational theories*, 1(2012), 1-22.
- Sousa, D. A. (2016). *How the brain learns*. Corwin Press.
- Souza, A. S., & Oberauer, K. (2017). Time to process information in working memory improves episodic memory. *Journal of Memory and Language*, 96, 155-167.
- Stieff, M., & Wilensky, U. (2003). Connected chemistry—incorporating interactive simulations into the chemistry classroom. *Journal of Science Education and Technology*, 12(3), 285-302.
- Stojanovska, M. I., Soptrajanov, B. T., & Petrusevski, V. M. (2012). Addressing misconceptions about the particulate nature of matter among Secondary-School and High-School students in the Republic of Macedonia. *Creative Education*, 3(05), 619.
- Stott, A., & Case, J. M. (2014). Electronic tutoring as a tool for promoting conceptual change: A case study of in-service Science teacher workshops. *African Journal of Research in Mathematics, Science and Technology Education*, 18(2), 139-150.
- Sujak, K. B., & Daniel, E. G. S. (2018). Understanding of macroscopic, microscopic and symbolic representations among form four students in solving stoichiometric problems. *MOJES: Malaysian Online Journal of Educational Sciences*, 5(3), 83-96.

- Supasorn, S., & Promarak, V. (2015). Implementation of 5E inquiry incorporated with analogy learning approach to enhance conceptual understanding of chemical reaction rate for grade 11 students. *Chemistry Education Research and Practice*, 16(1), 121-132.
- Sweller, J. (2003). Evolution of human cognitive architecture. *Psychology of learning and motivation*, 43, 216-266.
- Taber, K. S. (2013). Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemistry Education Research and Practice*, 14(2), 156-168.
- Taber, K. S., & García-Franco, A. (2010). Learning processes in chemistry: Drawing upon cognitive resources to learn about the particulate structure of matter. *The Journal of the Learning Sciences*, 19(1), 99-142.
- Taibu, R., Mataka, L., & Shekoyan, V. (2021). Using PhET Simulations to Improve Scientific Skills and Attitudes of Community College Students. *International Journal of Education in Mathematics, Science and Technology*, 9(3), 353-370.
- Talanquer, V. (2007). Explanations and teleology in chemistry education. *International Journal of Science Education*, 29(7), 853-870.
- Talanquer, V. (2018). Exploring mechanistic reasoning in chemistry. *Science education research and practice in Asia-Pacific and beyond*, 39-52.
- Tang, H., & Abraham, M. R. (2016). Effect of computer simulations at the particulate and macroscopic levels on students' understanding of the particulate nature of matter. *Journal of Chemical Education*, 93(1), 31-38.
- Taylor, A. T., Olofson, E. L., & Novak, W. R. (2017). Enhancing student retention of prerequisite knowledge through pre-class activities and in-class reinforcement. *Biochemistry and Molecular Biology Education*, 45(2), 97-104.
- Tho, S. W., & Yeung, Y. Y. (2016). Technology-enhanced Science learning through remote laboratory: System design and pilot implementation in tertiary education. *Australasian Journal of Educational Technology*, 32(3).
- Tsui, C. Y., & Treagust, D. (2010). Evaluating secondary students' scientific reasoning in genetics using a two-tier diagnostic instrument. *International Journal of Science Education*, 32(8), 1073-1098.
- Türkoguz, S. (2020). Investigation of Three-Tier Diagnostic and Multiple Choice Tests on Chemistry Concepts with Response Change Behaviour. *International Education Studies*, 13(9), 10-22.
- Türkoguz, S., & Ercan, I. (2022). Effect of visual anthropomorphic stories on students' understanding of the particulate nature of matter and anthropomorphic discourse. *Chemistry Education Research and Practice*, 23(1), 206-225.
- Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: a systematic literature review. *International Journal of Educational Technology in Higher Education*, 14(1), 1-33.
- Wilcox, B. R., & Lewandowski, H. J. (2017). Developing skills versus reinforcing concepts in physics labs: Insight from a survey of students' beliefs about experimental physics. *Physical Review Physics Education Research*, 13(1), 010108.
- Winsberg, E. (2013). Computer simulations in Science.
- Wright, L. K., Fisk, J. N., & Newman, D. L. (2014). DNA→ RNA: What do students think the arrow means? *CBE—Life Sciences Education*, 13(2), 338-348.

- Yan, Y. K., & Subramaniam, R. (2018). Using a multi-tier diagnostic test to explore the nature of students' alternative conceptions on reaction kinetics. *Chemistry Education Research and Practice*, 19(1), 213-226.
- Yaseen, Z., & Akaygun, S. (2016). Comparison of the high school students' mental models of atom with the illustrations in their textbooks. *Mehmet Akif Ersoy University Education Faculty Journal*, 1(40), 469-490.
- Yin, X., Wang, X., Yu, J., Zhang, M., Fua, P., & Tao, D. (2018). Fisheyerecnet: A multi-context collaborative deep network for fisheye image rectification. Proceedings of the European conference on computer vision (ECCV),
- Yu, S., Zhang, Y., Zheng, Y., Yuan, K., & Zhang, L. (2019). Understanding student engagement with peer feedback on master's theses: A Macau study. *Assessment & Evaluation in Higher Education*, 44(1), 50-65.
- Zajkov, O., Gegovska-Zajkova, S., & Mitrevski, B. (2017). Textbook-caused misconceptions, inconsistencies, and experimental safety risks of a grade 8 physics textbook. *International journal of Science and mathematics education*, 15, 837-852.
- Zhao, J., & Gallant, D. J. (2012). Student evaluation of instruction in higher education: Exploring issues of validity and reliability. *Assessment & Evaluation in Higher Education*, 37(2), 227-235.

ANNEXURES

ANNEXURE A: UNIVERSITY ETHICAL CLEARANCE

**UNIVERSITY OF ZULULAND
RESEARCH ETHICS COMMITTEE**
(Reg No: UZREC 171110-030)



RESEARCH & INNOVATION

Website: <http://www.unizulu.ac.za>
Private Bag X1001
KwaDlangezwa 3886
Tel: 035 902 6374/6374
Email: MbonaM@unizulu.ac.za/
MangoleS@unizulu.ac.za

PROVISIONAL APPROVAL - ETHICAL CLEARANCE CERTIFICATE

Certificate Number	UZREC 171110-030 PGM 2021/250		
Project Title	Exploring the use of simulations on Grade 6 learners' conceptual understanding of phase changes of matter: A case study of selected schools in Umkhanyakude district		
Principal Researcher/ Investigator	L.B Nkosi		
Supervisor and Co-supervisor	Dr T.W Chinaka	Mr A Sindi	
Department	Mathematics, Science and Technology Education		
Faculty	Education		
Type of Risk	Medium Risk- Data collection from people		
Nature of Project	Honours/4 th Year	Master's	Doctoral
	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
			Departmental
			<input type="checkbox"/>

The University of Zululand's Research Ethics Committee (UZREC) hereby grants provisional approval pending gatekeeper/permission letter from the following institution(s):

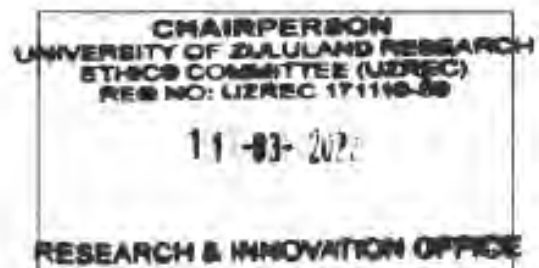
- a) umkhanyakude District

The Researcher may therefore NOT commence with data collection until gatekeeper/permission letter is obtained. The letter can be sent to MbonaM@unizulu.ac.za or MangoleS@unizulu.ac.za so that final approval letter will be issued for data collection to commence

SPECIAL CONDITIONS: [1] Principal researcher must provide gatekeeper/permission letter of where the research will be conducted and submit to UZREC to acquire full approval certificate of 1- year.

The UZREC wishes the researcher well in conducting research.


Prof. Nokuthula Kunene
Chairperson: University Research Ethics Committee
Deputy Vice-Chancellor: Research & Innovation
11 March 2022



ANNEXURE B: DBE PERMISSION FOR RESEARCH



KWAZULU-NATAL PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

Private Bag X9137, PIETERMARITZBURG, 3200
Anton Lembede Building, 247 Burger Street, Pietermaritzburg, 3201
Tel: 033 392 1051

Email: buyi.ntuli@kzndoe.gov.za

Enquiries: Buyi Ntuli

Ref.:2/4/8/7140

Miss Landiwe Beauty Nkosi
P.O. Box 71
HLUHLUWE
3960

Dear Miss Nkosi

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: "EXPLORING THE USE OF SIMULATIONS ON LEARNER'S CONCEPTUAL UNDERSTANDING OF PHASE CHANGES OF MATTER: CASE STUDY OF UMKHANYAKUDE DISTRICT KZN:", in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 02 August 2021 to 31 August 2023.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

Dr. EV Nzama
Head of Department: Education
Date: 02 August 2021

GROWING KWAZULU-NATAL TOGETHER

ANNEXURE C: PARTICIPANT INFORMED CONSENT DECLARATION

Informed Consent Declaration

(Participant)

Project Title: Exploring the use of simulations on Grade 6 learners' conceptual understanding of phase changes of matter: A case study of selected schools in uMkhanyakude District.

Landiwe Nkosi (Ms) from the Department of Mathematics, Science and Technology Education (MSTE) University of Zululand has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project, and of this informed consent declaration have been explained to me in a language that I understand.

I am aware that:

1. The purpose of the research project is to explore the use of simulations on Grade 6 learners' conceptual understanding of phase changes of matter: a case study of selected schools in uMkhanyakude District.
2. The University of Zululand has given ethical clearance to this research project and I have seen/ may request to see the clearance certificate.
3. By participating in this research project I will be contributing towards improving conceptual understanding of phase changes of matter.
4. I will participate in the project by completing the research questionnaire
5. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.
6. I will not be compensated for participating in the research, but my out-of-pocket expenses will be reimbursed.
7. There may be risks associated with my participation in the project. I am aware that:
 - a. the following risks are associated with my participation: there are no known risks at the moment.
 - b. the following steps have been taken to prevent the risks: N/A.
 - c. there is a 0 % chance of the risk materialising: N/A.
8. The researcher intends publishing the research results in the form of an article. However, confidentiality and anonymity of records will be maintained and that my name and identity will not be revealed to anyone who has not been involved in the conduct of the research.

9. I will not receive feedback/will receive feedback in the form of statistics regarding the results obtained during the study.
10. Any further questions that I might have concerning the research or my participation will be answered.
11. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies.
12. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I,, have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research.

I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

Name: _____

Participant's signature: _____

Date: _____

ANNEXURE D: PARENT AND GUARDIAN'S INFORMED CONSENT DECLARATION

(Parent or Guardian)

Project Title: **Exploring the use of simulations on learners' conceptual understanding of phase changes of matter: A case study of selected schools in uMkhanyakude District**

Miss Landiwe Nkosi from the Department of Mathematics, Science and Technology Education (MSTE) University of Zululand has requested my permission to participate in the above-mentioned research project.

The nature and the purpose of the research project, and of this informed consent declaration have been explained to me in a language that I understand.

I am aware that:

1. The purpose of the research project is to explore the use of simulations on learner's conceptual understanding of phase changes of matter.
2. The University of Zululand has given ethical clearance to this research project and I have seen/ may request to see the clearance certificate.
3. By participating in this research project my child/ward will be contributing towards improving 'Assessment for Learning' which necessitates that learners are given opportunities to reflect and to be informed about their learning, while the teachers persistently assess learners' task and adjust instruction to meet their needs.
4. My child/ward will participate in the project by interview, test and questionnaire administration
5. My child's/ward's participation is entirely voluntary and if my child/ward is older than seven (7) years, s/he must also agree to participate.
6. Should I or my child/ward at any stage wish to withdraw my child/ward from participating further, we may do so without any negative consequences.
7. My child/ward may be asked to withdraw from the research before it has finished if the researcher or any other appropriate person feels it is in my child's/ward's best interests, or if my child/ward does not follow instructions.
8. Neither my child/ward nor I will be compensated for participating in the research.
9. There may be risks associated with my child's/ward's participation in the project. I am aware that:
 - a) the following risks are associated with my participation: there are no known risks at the moment.
 - b) the following steps have been taken to prevent the risks: N/A.
 - c) there is a small chance of the risk materialising: N/A.

10. The researcher intends publishing the research results in the form of an article. However, confidentiality and anonymity of records will be maintained and that my or my child's/ward's name and identity will not be revealed to anyone who has not been involved in the conduct of the research.
11. I will not receive feedback/will receive feedback in the form of statistics regarding the results obtained during the study.
12. Any further questions that I might have concerning the research or my participation will be answered by Landiwe Nkosi (Ms)
13. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies that I or my child/ward may have.
14. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I,, have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of my child/ward during the research.

I have not been pressurised in any way to let my child/ward take part. By signing below, I voluntarily agree that my child/ward....., who is years old, may participate in the above-mentioned research project.

Name: _____

Parent/Guardian's signature: _____

Date: _____

ANNEXURE E: CHILD PARTICIPANT'S CONSENT FORM

INFORMED CONSENT DECLARATION (Child participant)



Exploring the use of simulations on learners conceptual understanding of phase changes of matter. A case study of grade 6 in UMkhanyakude district, KZN.

Project Title: (Simplify it if necessary)

Researcher's name: LANDIWE NKOSI

Name of participant:

1. Has the researcher explained what s/he will be doing and wants you to do?

YES NO

2. Has the researcher explained why s/he wants you to take part?

YES NO

3. Do you understand what the research wants to do

YES NO

4. Do you know if anything good or bad can happen to you during the research?

ANNEXURE F: TRANSLATED PARENT /GUARDIAN'S INFORMED CONSENT

INCWADI EVEZA IGUNYA LOMZALI UKUTHI UMNTWANA ABAMBE IQHAZA (Umzali noma onegunya lokunakekela umntwana)

Isihloko: Ukuhlola kokusetshenziswa kwama khompyutha simulations kubafundi bebanga lesithupha ekuqondeni isayensi.Ucwaningo luzokwenziwa kwinxenye yezikole esufundeni uMkhanyakude.

Miss Landiwe Nkosi osophikweni lweMathematics, Science and Technology Education (MSTE) enyuvesi yakwaZulu (Ongoye) ucela imvume yami ukuhlanganyela ocwaningweni lwakhe olukusihloko esingenhla. Inqubo nomgomo walolu cwaningo, nalesi sivumelwano luchazwe ngolimi engilwaziyo.

Ngiyaqonda ukuthi:

1. Inhloso yalolucwaningo: Ukuthola ulwazi ngokusetshenziswa kwama khompyutha simulations kubafundi bebanga lesithupha ekuqondeni isayensi. Ucwaningo luzokwenziwa kwinxenye yezikole esufundeni uMkhanyakude.
2. I University of Zululand iluvumele lolucwaningo.
3. Ngokuzimbandakanya nalo lucwaningo umntwana wami angasiza ekwenzeni ngcono le ndlela yokufundisa ngoku 'hlolelwa kokufunda' lapho kunesidingo sokuba umfundi anikezwe ithuba lokuveza, aziswe ngokufunda kwakhe, kwenye ingxenye uthisha aqhubeke abahlole imisebenzi yabafundi anyakazise nezindlela zokwenza ukuze ahlangebazine nezidingo zabo.
4. Umntwana wami uzozimbandakanya kulolu ucwaningo ngokuphendula imibuzo bebhekene, imibuzo esephepheni nalo kuhlwa okungatheni.
5. Umntwana wami uzivumele yena ukuba ingxenye yalolu cwaningo futhi uneminyaka engaphezu kweyisikhombisa.
6. Uma mina noma umntwana wami engasathandi ukuba ingxenye yalo, uyohoxa engalindelwa zinkinga ngokuhoxa kwakhe.
7. Umntwana wami angacelwa ukuthi ahoxe ngaphambi kokuphela kocwaningo uma umcwaningi noma ubani omunye ophathelene nalo ebona kufanele noma engalandeli imigomo yalo.

8. Mina nomntwana wami asilindele muholo/mhlomulo ngokuba yingxenye yalolu cwaningo.

9. Angilindele bungozi obungahambisana nalolu cwaningo, akesibheke ukuthi kokulandelayo kungenzeka yini:

a) ingozi ehlobene nokuhlanganyela kwakhe? –Ayikho ingozi eyaziwayo engenzeka ngalesi sikhathi.

b) izinyathelo ezothathwa uma kungenzeka ukube nobungozi - Azikho (ngoba imibuzo yodwa).

c) kukhona ingozi engu 0% engenzeka ngalesi sikhathi - Ayikho 10. Umcwaningi ufisa ukulushicilela lolu cwaningo lube umqingo wencwadi eqikelela ukuthi igama lomntwana wami, nemi niningwane yakhe kuyohlala kuyimfihlo.

11. Ngingathanda/ngingethande ukuzwa ngemiphumela yocwaningo ngokufunda lowo mqingo ozoyoshicilelwa

12. Imibuzo engingaba nayo mayelana nalolu cwaningo iyophendulwa umcwaningi uqobo ogama lakhe ngu Landiwe Nkosi ku 079 0886 096.

13. Ngokuzinikela kwami ekusayineni leli fomu angizibophezeli ekutheni ngingethathe izinyathelo okungaba ezomthetho noma ukunxeshezela komntwana wami.

14. Ngizogcina ikhophi yaleli fomu lokuzibophezela bese lona ligcinwe nguye umcwaningi. Mina..... Ngiyifundile yonke imininingwane ekuleli fomu futhi ngichazelwe yona ngolimi engilulwaziyo. Ngiyakwazi okubhalwe kuleli fomu. Ngibuze yonke imibuzo ebengingaba nayo ngaphenduleka ngendlela engenelisayo. Ngiyazi konke okulindeleke kumntwana wami ngesikhathi salolu mcwaningo. Angifakwanga ingcindezi, ngizingenele mina ngokuthanda kulolu cwaningo. Ngokusayina ngiyazivumela mina ukuthi umntwana wami u oneminyaka engu.....angazibandakanya nalolucwaningo.

Isiginesha..... Usuku.....

ANNEXURE G: LETTER TO SCHOOL PRINCIPALS

University of Zululand
Faculty of Education
Private Bag x 1001
KwaDlangezwa
Empangeni
3886

The Principal
Dear Sir/ Madam

REF: REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN SCHOOLS

I am employed by the department of education and I am currently teaching at Primary school in uMkhanyakude District. I am a registered student at University of Zululand doing Master of Education in the department Maths, Science and Technology Education (MSTE). The topic of my research is **Exploring the use of simulations on Grade 6 learners' conceptual understanding of phase changes of matter. A case study of selected schools in uMkhanyakude District.** I cordially request for permission to conduct research in your school. The Grade 6 learners will be used as participants to gather data for this study. The researcher will use pre-test, post-test and interviews as a data collection method.

I hope the findings of this study will benefit and assist the Department of Basic Education and educators teaching in primary schools.

Yours faithfully

Miss Landiwe Nkosi

Contact number :079 0886096 and Email :landiwelb@gmail.com

Dr T.WChinaka (Supervisor) and Mr A Sondlo (Co- Supervisor)

ANNEXURE H: PRE-TEST AND POST TEST

University of Zululand Faculty of Education
Department of Mathematics and Science Education
Researcher: Nkosi, L.B. Phase change of matter

TOTAL: 10 Marks

Biographical information:

1. Student assigned: No: _____
2. Gender: Male Female
3. Age _____

INSTRUCTIONS AND INFORMATION

1. This question paper consists of 10 multiple choice questions. Answer **ALL** the questions.
2. Answer all questions in the space provided.

Questions:

1. During evaporation phase:



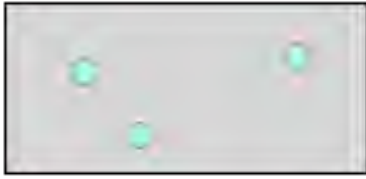
- a) Solid changes into gas.
- b) Liquid changes into a gas.
- c) Gas changes into a liquid.
- d) Solid changes into a liquid.

Answer _____

2. When you heat a sample of a gas, what happens to the particles that make up the gas?
 - a) The particles move faster.
 - b) The particles break apart.
 - c) The particles get smaller.
 - d) The particles become denser.

Answer _____

3. Particles in a _____ move quickly in all directions.



- a) Solid
- b) Liquid
- c) Gas
- d) None of the above

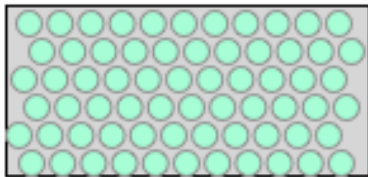
Answer _____

4. Which of the following process will make water molecules larger?

- a) Freezing
- b) Melting
- c) Evaporation
- d) Condensation

Answer _____

5. Particles in a _____ are tightly packed, usually in a regular patten.



- a) Gas
- b) Liquid
- c) Solid
- d) None of the above

Answer _____

6. A process by which solids turns into liquids



- a) Freezing
- b) Melting
- c) Evaporation
- d) Condensation

Answer _____

7. Which of the changes involve release of energy?

- a) Evaporation and melting.
- b) Evaporation and condensation.
- c) Condensation and freezing.
- d) Condensation and melting.

Answer _____

8. You find the inside of the car window getting foggy in winters. This is because of:



- a) Condensation
- b) Freezing
- c) Melting
- d) Evaporation

Answer _____

9. Which of the following is an incorrect statement?

- a) Evaporation takes place at all temperatures
- b) Evaporation causes a change in state
- c) Evaporation take place at a fixed temperature
- d) Evaporation takes is a slow process

Answer _____

10. When you heat a simple solid, the particles that make up the solid:

- a) Get bigger
- b) Loose mass
- c) Move faster
- d) Slow down

Answer _____

ANNEXURE I: INTERVIEW SCHEDULE

The interview protocol

Biographical information:

1. Student assigned

No: _____

2. Gender: Male Female

3. Age _____

Questions



1. What are changes of states?
2. Why do phase changes occur?
3. How would you describe freezing?
4. How would you describe condensation?