THE EFFECTS OF USING A GRAPHIC CALCULATOR AS A COGNITIVE TOOL IN LEARNING GRADE 10 DATA HANDLING

By

RAMBAO MPHO

Submitted in accordance with the requirements for degree of

MASTERS OF EDUCATION IN MATHEMATICS EDUCATION

In the Subject

MATHEMATICS EDUCATION

At the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: Dr. Masilo MM

2022

DECLARATION

I hereby declare that: **THE EFFECTS OF USING A GRAPHIC CALCULATOR AS A COGNITIVE TOOL IN LEARNING GRADE 10 DATA HANDLING** is my original work, which I have never submitted for a degree at this or any other institution. All of the sources from which I have quoted or used have been indicated acknowledge with full citation.

________________ SEPTEMBER 2022

M Rambao

ACKNOWLEDGEMENTS

Firstly, I would like to give thanks to the Almighty Father for giving me strength throughout this journey, and His guidance during my studies.

I would like to express my sincere gratitude and appreciation to the following:

- My supervisor, Dr. MM Masilo, for her continuous support, encouragement and guidance through this project, her devotion, and all contribution to the success of this dissertation.
- The Limpopo Department of Education, Vhembe West and Vhembe East district, principals for allowing me to conduct the research at their schools.
- Teachers and learners for their commitment and participation in the study for the success of this research.
- My principal for understanding the value of education.
- Special thanks to my sister and my mother for their support and for believing in me.

ABSTRACT

The integration of technology in the mathematics classroom is believed to have an influence on how the learners learn and change their perception of mathematics.

Therefore, technology tools are developed to enhance the learners' cognition by helping them to improve their thinking skills in mathematics. The purpose of this study was to investigate the effects of using a graphic calculator as a cognitive tool for learning Grade 10 Data Handling. This study drew on Dubinsky's development of APOS theory, where the learners' thinking process is influenced by the integration of a technology tool in order to construct the mathematical concepts. In this study, a graphic calculator is a tool used to enable learning and assist learners to build appropriate mental structures. Furthermore, this study draws from a positivist stance with a focus on authenticating the scientific knowledge and understanding of human behaviour through scientific methods of experiments. Therefore, this is a quantitative study, based on a quasi-experimental research design, utilising pre-test – post-test non-equivalent group design. Participants were 136 learners from the Vhembe district who were conveniently sampled. They were classified into two groups, that is, 93 learners from Vhembe East were allocated the experimental group, while 43 learners from Vhembe West district were allocated the comparison group. For the purpose of this study, the experimental group was taught using a graphic calculator as a technology tool for learning, while the comparison group was taught using the usual conventional learning methods. A pre-test and a post-test were administered to both groups, and learners completed a closed-ended questionnaire to gather information on their perception of the use of graphic calculators in enhancing cognition in the learning of mathematics. Teachers (N= 6) also participated in the study by completing a closed-ended questionnaire on their perception of implementing the use of graphic calculator as a cognitive tool of learning into their teaching. A paired t-test was used to determine the statistically significant difference, and the results revealed that the learners who were exposed to the use of graphic calculator in learning Data Handling improved with a mean difference of (M= 7,385; SE= 4,968) as compared to their counterparts who were not exposed to the use of a graphic calculator, with a mean difference of ($M= 1,488$; $SE= 4,574$). The use of a graphic calculator had a significant impact on learners in the experimental group with $t= 14,179$ to be significant as $p=0,000$, $p<0,005$, and represented a large effect size of $d=0,958$; $d>0, 8$. This emphasises that the use of a graphic calculator in learning Data Handling has contributed significantly towards enhancing the learners' cognition. This study has shown that the formalist approach, that is, traditional learning, also referred to as conventional learning, influences learners to search for one answer to a mathematical problem and this does not promote a high level of thinking and understanding. Therefore, this study asserts that the use of a graphic calculator enhances the learners' cognition by promoting their conceptual understanding, visualisation, problem-solving skills, positive attitude towards the subject, and deepening their understanding of Data Handling.

Key terms:

Data Handling; technology tool; graphic calculator; cognitive technologies; cognitive tools; cognitive thinking; problem-solving; problem-solving skills

ACRONYMS

CAPS- Curriculum Assessment Policy Statement

GC-Graphic Calculator

DH-Data Handling

CAS- Computer Algebra System

FET- Further Education and Training

ICT- Integrated Computer Technology

IQ- Cognitive development

NCTM- National Council of Teachers of Mathematics

NIMB- Notion of learning, ICT in Education, Model for learning design, and Bloom's modified taxonomy framework

TPACK- Technology, Pedagogical, and Content Knowledge

UNESCO- United Nations Educational, Scientific and Cultural Organisation

H_0- Null Hypothesis

H_1- Directional Hypothesis

APOS- Action, Process, Object, and Schema

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

STUDY OVERVIEW

1.1 INTRODUCTION

Learners' cognitive development in mathematics is meant for reproduction in the examination, and retaining knowledge for long-term memory for future use is a challenge. In concurrence, Clark, Kraut, Mathews, and Wimbish (2007) emphasised that there is a gap between what learners are taught in the mathematics classroom and the knowledge they retain after having completed the examination. To enhance cognition in learning Data Handling and other mathematics content areas, teaching and learning aids play a key role. Teaching and learning aids include models, digital tools, or technology tools, and more. The current study uses the word digital tool or technology tool interchangeably, referring to a graphic calculator as a technology tool. In this study, technology tools, mostly graphic calculators, are highlighted as tools that can enhance cognition in learning Data Handling in Grade 10. In Grade 10 mathematics, Data Handling is defined as the means of gathering and recording data; organising and describing, and then representing it using graphs and charts in a way that will be meaningful to others (Shaughnessy, Garfield, Greer, 1996). In recent developments in technology, graphic calculators and statistics software packages have the potential to change how the Statistics or Data Handling content area is taught. In this study, statistics and Data Handling refer to one content area.

Technology tools are designed to help learners improve their thinking skills, in a way technology tools support cognition. Advanced technology has improved the use of portable, hand-held computing or electronic devices used in the mathematics classroom, such as four-function calculators, scientific calculators, graphing and symbolic calculators. This study engages learners in utilising the graphic calculator as a hand-held computing device that can assist them in doing multiple representations of Data during problem-solving, this is proven to enhance thinking skills and cognition. In emphasis, Eyyam and Yaratan (2014) stated that technology tools must be integrated into the classroom to prepare learners for the future and help them learn how to think, furthermore, for the purpose of helping the learners to learn how to think and gain a different perspective, technology has to be integrated into the classroom. Therefore, we cannot deny that the use of technology has a significant impact on our daily lives. Schools in South Africa are being challenged to use technology tools in the mathematics classroom during lessons to help learners change their perception about Data Handling that it is only meant for a certain group of learners, especially those who obtain good grades in mathematics (Khobo, 2015). In addition, Khobo (2015) highlights that the inclusion of technology tools in learning Data Handling should be a content area that may enhance learners' cognitive developments as statistical cognition applies in more other areas of everyday life. Learning mathematics should play an active role in learners' reasoning, discovery and how they apply what they have learnt, therefore, these technology tools or resources are there to build up and improve mathematical understanding.

The use of technology tools in the mathematics classroom needs much attention, from the use of computers, tablets for e-learning, scientific calculators, and graphic calculators. Amongst all the technology tools, this study focuses on the effect of using graphic calculators as a cognitive tool in learning Grade 10 Data Handling. Compared to the other technology tools, such as scientific calculators and computers, graphic calculators have different functions. Graphic calculators help perform different mathematical operations, such as, working on advanced mathematical functions such as Algebra, Geometry and Advanced Statistics; they also have the potential to sketch graphs and solve algebraic equations (Kor & Lim, 2004). Kissane, McConney and Hoo (2015) argue that the use of technology tools in schools can assist learners to learn mathematics in a way that will grant them an opportunity to take problems found in the real world and extend the length and scope of mathematical exploration and investigation.

This quantitative study draws from APOS theory that posits that an individual has necessary mental structures to make to comprehend given mathematical concept, and the appropriate learning activities should be developed to aid in the formation of those mental structures (Dubinsky & McDonald, 2001). Idris (2004) states that instructional technologies such as graphic calculators were developed as supporting tools of teaching and learning mathematics, therefore, a graphic calculator acts as an agent or means that helps learners to go beyond the mind limitations in thinking, learning, and problem-solving activities, and learners can construct new knowledge gained as a result of the understanding of mathematical concept developed through the use of these mental structures. With the use of technology tools, learners can analyse data numerically and graphically, by comparing the expected and the observed outcomes, and build up models to describe or define relationships. Burril (1996) highlights that technology tools allow learners to use real situations, and allow them to understand tabular, graphical, and symbolic representations of data.

1.2 BACKGROUND OF THE STUDY

According to Makina and Wessels (2009), Data handling (Statistics) at the secondary school level has been given less attention in terms of teaching and learning, and as a result, learners were not well prepared and lacked statistical knowledge when they moved to the tertiary level. In the South African curriculum, the scope of data handling is vast and essential for all grades, and plays a crucial role in our daily lives; the importance of its knowledge in many professions, and in developing critical thinking cannot be over emphasised (Frankling, Kader, Mewborn, Moreno, Peck, Perry, & Scheaffer, 2005; Makina & Wessels, 2009).

In the Further Education and Training (FET) phase, (that is Grades 10-12), Data handling is included as the fourth of four learning outcomes in mathematics, and learners in Grade 10 are expected to be able to collect, organise and interpret numerical data (both discrete and continuous) to determine the measures of central tendency of grouped and ungrouped data, for example, the average mean, median and modal value. Secondly are the measures of dispersion which include: percentiles, quartiles, range and inter-quartile range, they are also expected to be able to choose the appropriate graph representation of data such as, different types of bar graphs, frequency polygons, pie charts, line graph, box-and whisker-plot (Wessels, 2011; DBE, 2011). Furthermore, learners are presented with questions for investigation, and data is collected, summarised, and represented in order to interpret and predict situations. These learning outcomes allow a learner to relate with the real world of seeing the data themselves, reflect on it and be able to draw conclusion from it, and also develop critical reasoning (Makina & Wessels 2009).

The lack of understanding in data handling has led to learners' lack of interest in the content area, hence there should be a reconsideration of the way it is taught and there should be a need to have it taught to learners with understanding. Technology tool, such as a graphic calculator and statistics software packages are capable in changing the data handling content in the curriculum and how it should be taught. Burrill (2000) stated that teachers in the United States have accepted a graphic calculator as a critical tool for teaching and learning in the mathematics classroom. Graphic calculator makes statics and statistical reasoning accessible to all learners, they are able to analyse data numerically and graphically simultaneously, and as a result they are able to make sense of the results and describe the relationship.

There is a direct relationship between improving the quality of teaching and learning mathematics, the level of learning is influenced by the learners' learning experience in the mathematics classroom, meaning that what the learners learn and how they learn will be determined by how the lesson is conducted (Hiebert, Stigler & Manaster, 1999; Meletiou-Mavrotheris, Paparistodemou & Stlianou, 2009). Furthermore, Meletiou-Mavrotheris, Paparistodemou and Stlianou (2009) stated that to make statistical thinking accessible to all learners, there must be changes in the way learners are taught, curricula materials, tools, and cognitive technologies used in the classroom to teach statistics. Technology tools are designed to enable the visualisation of statistical concepts by allowing learners to make a connection between the physical experience and the formal representations.

Change in the mathematics curriculum has been recommended for several years, and this includes moving from the traditional way of learning mathematics to the use of technology tools. The phrases traditional learning/approach; conventional learning/approach and formalist approach will be used interchangeably in this study. According to the reports by the Mathematical Sciences Education Board (1990), a balance is required in terms of effecting changes in the utilisation of calculators in the teaching and learning of every topic in the school of mathematics (MSEB, 1990:2). The National Council of Teachers of Mathematics (NCTM) (2000) published Principles and Standards of Mathematics, a set of recommendation for mathematics curricula K-12, states, indicating that Technology is an important tool in the learning and teaching of mathematics. It influences what is taught and enhances learners' learning (NCTM, 2015). According to the Status of ICT in Education in South Africa, ICT should not reduce the value of the learning process but support it to have the intended effects (NECT, 2016).

According to Waits and Demana (2000), before the development of computers and calculators, learners had to spend a large amount of time trying to understand and become efficient in using paper-and-pencil techniques, whereas that time could be spent in building up their conceptual understanding, critical thinking and problem-solving skills.

Learners should not bother themselves with long, constant, and repeated calculations that will take away the joy of learning mathematics. However, integrating technology tools in the learning of mathematics, helps learners to focus on reasoning and problem solving (Idris, 2004). Furthermore, Idris (2004) stated that the various studies have revealed that the graphic calculator reduces the routine calculations which may hamper the learning process during lessons, and helps learners to perform certain computations quickly and precisely. The advancement of technology in developed countries, for example, Britain, Malaysia, Western Australia, Canada, and United States, had a positive impact on the use of technology as a learning tool in statistics classrooms.

In British schools, students at A-level were encouraged to have graphic calculators available at the beginning of their mathematics course, and there has been extensive research on the effectiveness of the use of graphic calculators and how they helped them to develop their understanding (Graham, Headlam, Honey, Sharp, & Smith, 2003). A-level in Britain refers to an advanced level that students undergo before going to the university and sitting for national examination to measure their academic potential to meet the university requirements. In Western Australia, it was found that graphic calculators have been used to replace the conventional approach to learning more than to enhance the learners' conceptual understanding; and since they are permitted to use them in mathematics examination but permitted to use scientific calculators only in other subjects (for example, Science), they are obliged to have expertise for both calculators (Kissane, McConney & Hoo, 2015). In Malaysia, integrating the use of graphic calculators in the learning of mathematics, has shown that when solving problems, the graphic calculator helps them improve their performance and the level of cognitive reasoning (Tarmizi & Konting, 2011).

Berger (1997) undertook a project, with the aim to understand and explain how graphic calculators mediate in first-year university mathematics students' understanding and application of mathematical concepts. He stated that the graphic calculator helps to change representations from one to another by providing easy-to-use graphing, numeric and less symbolic manipulation utilities. He further emphasised that graphic calculators are the appropriate technology tools for the South African environment because unlike the computers, they do not use electricity, they are portable, affordable, and easily accessible. With various studies revealing the benefits of the use of graphic calculators, Berger also pointed out that there are other studies which focused on problems aroused in the use of graphic calculators, and this has brought about a question in the study on whether the “graphic calculator is an appropriate and possible tool for learning mathematics at a tertiary level in South Africa?” (Berger, 1997:160). In addition, Berger’s study has shown that a graphic calculator may function as an amplifier of the Zone of Proximal Development, where a learner is able to carry out the mathematical computations with the help of a graphic calculator. Furthermore, he indicated that a graphic calculator was used as an ‘add-on-device’.

The major reason of integrating graphic calculator in teaching and learning mathematics its effects on cognitive processes and how it promotes mathematical thinking and understanding (Reznichenko, 2007). According to Ndlovu L and Ndlovu M (2020) graphic calculator is used as a visual tool that allows learners to master the properties of algebraic processes, furthermore, the consistent use of graphic calculator can encourage and enhance the learners’ application of graphical strategies. The use of graphic calculator in a mathematics classroom enhances the learners’ cognitive understanding and visualisation, as well as improving their performance.

According to the curriculum statement of the FET (Grades 10-12), the aim of mathematics is fluent computational skills without relying on the use of a calculator, however, the use of calculator in learning mathematics helps learners to perform these computations. The Curriculum Assessment Policy Statement (CAPS) in South Africa, only encourages learners to use the non-programmable calculator, and prohibits the use of programmable calculators which run on CAS (Computer Algebra System) (DBE, 2011). The programmable calculator which runs on CAS is a calculator that allows algebraic expressions to be manipulated and simplified by the user, and has a huge memory to store saved data (Grzadzielewski, 2005).The Department of Basic Education in South Africa only permits the use of scientific calculators during exams and not the graphic calculator, this could be reason why the department is hesitating to incorporate the use of graphic calculators during data handling lessons in mathematics classroom. With various studies that have revealed the benefits of using graphic calculators in the mathematics classroom in different countries, like Australia and Britain; Krishnan and Idris (2013) stated that graphic calculators in the mathematics and statistics classroom have been well received and successful in Malaysia

According to Krishnan and Idris (2013), there is a scarcity of studies involving secondary school learners or university students on the use of graphic calculators or in other technology tools, and the reason could be that any technology tool for learning other than scientific calculator, is controlled by the requirements of the course that the students undertake. In this view, this study hopes to investigate the difference between the understanding of statistical concepts with or without the aid of a graphic calculator.

1.3 RATIONALE OF THE STUDY

Graphic calculators were introduced in education in the mainstream, which led to different studies conducted on the use of hand-held technology as a tool for learning mathematics, and most of these studies were focused on the effectiveness of these mobile devices and how they help learners to improve their understanding and performance (Graham et al., 2003). There are many studies that have been conducted on the effects of using graphic calculators in learning statistics at the secondary level. Most of these studies were conducted in countries outside Africa, countries such as Malaysia, Western Australia, Canada and other developed countries, but there were few studies which were conducted in Africa, especially in Southern Africa, hence this study has considered a research gap on the effects of using graphic calculators in learning statistics in Grade 10.

The argument for the hand-held technology, specifically graphic calculators in learning mathematics at schools, has focused on its capability to help learners learn mathematics by engaging with each other (cooperative learning). This gives them an opportunity to use real-world problem situations and allows them to explore the scope of mathematics (Kissane, McConney, & Hoo, 2015). The study seeks to investigate the effects of using graphic calculators in learning Data Handling at Grade 10. The findings provide information on how learners can use graphic calculator as a tool for learning to support their thinking skills and their mathematical understanding in statistical concepts.

1.4 PROBLEM STATEMENT

Mathematics is seen as a difficult subject, and learners believe that it is only meant for a few gifted individuals (Mutodi & Ngirande, 2014). The myths and negative perceptions of mathematics are common among learners, particularly in developed countries (Gadanidis, 2012). Sam (2002) claims that most learners are intimidated and fearful in the presence of mathematics ideas or mathematics as a subject and in all that, many people still believe that mathematics is only meant for learners who are smarter than others and those are the ones who have inherited mathematics ability (Mutodi & Ngirande, 2014). According to Chen and Lai (2015); Waits and Demana (2000), in the past, learners usually used only paper and pencil in mathematics classrooms, but today, it is evident that most people agree that technology can engage the learners' interest in the process of learning data handling. Learners lack thinking and problem-solving skills because they spend unnecessary time in long and repetitive calculations, hence they are not developing new thinking skills or mathematical understanding of data handling (Idris, 2004).

Data handling is a branch in mathematics that deals with the collection, organising, representation and interpretation of mathematical data to solve real-life situation, as a result, the main purpose of learning data handling is to enable learners to make sense of situations and make predictions about the future (Makina & Wessels, 2009; Mkhabela & Naidoo, 2017). In the South African mathematics curriculum, data handling is not taught as a separate subject, but rather as an essential component of the mathematics curriculum (Makwakwa, 2012). Wessels (2011) observed that data handling in South Africa is still at the early stages, and there is a need to broaden the statistical curriculum at schools so that they have enough statistical content knowledge when they leave for tertiary level. The base knowledge on data handling that the teacher has, influences how the learners learn and their perception of the content area; learners lack statistical knowledge because of the way they are taught, using the traditional approach, which prepares them to look for a single correct solution to a problem, such as calculating mean, median, or range (Meletiou-Mavrotheris, et al., 2009).

In the traditional approach, chalk-and-board are used where each problem on the board is erased after the other, and learners can only use pen-and-paper to save their own work, which is time consuming. Therefore, there should be various tools such as technology tools used in learning statistics that will help them to improve their critical thinking. Learners tend to focus more on procedural aspects of data handling rather than conceptual understanding (Meletiou-Mavrotheris, et al., 2009). Furthermore, the importance of fundamental changes in the instructional practices, curricular materials, tools, and cognitive technologies used to teach and learn data handling was emphasised.

The purpose of graphical calculators is not to give learners answers to a mathematical problem, but to enhance their visual statistical concepts and support their thinking and problem-solving skills. Burril (2000) argues that technology allows learners to use data which involves real-life situations. In addition, the use of hand-held technology, specifically graphic calculators, may contribute to changing learners' perception of statistical concepts (Burril, 2000). Furthermore, learners often do long routine calculations without them understanding the concept. However, dealing with real-data or real-life situations will result in developing a positive attitude towards the topic. Learners benefit from cognitive tools, such as graphic calculator as they progressed from procedural knowledge to computational understanding. In addition, graphic calculator enables learners to easily access computational and graphical results. This study focused on evaluating the effects of using graphic calculators in learning statistics in Grade 10. Therefore, this quantitative study bears the hypothesis that there is no difference between learning supported by the graphic calculator technology and conventional learning. In support of the hypothesis, the following primary research question is asked: does the use of graphic calculator influence learning Grade 10 Data Handling? Supporting questions asked are as follows:

- How can graphic calculators be applied in learning grade 10 Data Handling?

- What are the effects of using graphic calculator as a cognitive tool in learning Data Handling?

1.5 HYPOTHESIS

Learners spend much time mastering long and repetitive calculations from textbooks without having a conceptual understanding of the content and without displaying problem solving skills (Waits & Demana, 2000). The use of handheld technology tools is needed to enhance learners' visualisation, their critical thinking, and understanding of connections of statistics. Learners form a better understanding of mathematics and are encouraged to challenge themselves by working on more complex problems (Idris, 2004).

Therefore, this study bears the following null hypothesis (H_0): there is no difference between learning supported by graphic calculator technology and conventional learning.

$$H_0: \mu graphic\ calculator\ technology\ learning \neq \mu conventional\ learning\ approach$$

In support of the null hypothesis, the directional hypothesis also known as alternative hypothesis (H_1) states that learning that is aided by graphic technology enhances understanding of data handling.

$$H_1: \mu graphic\ calculator\ technology\ learning = Meaningful\ learning$$

1.6 AIMS AND OBJECTIVES

This study is aimed at investigating the effects of using a graphic calculator as a cognitive tool in learning Grade 10 Data Handling.

The objectives of the study are to:

- Evaluate the effects of intervention through usage of graphic calculator in learning Data Handling in Grade 10.

- Determine how graphic calculators support the learning of Data handling in Grade 10.
- Determine the effects of using graphic calculators in learning data handling Grade 10.

1.7 DEFINITION OF TERMS

A brief definition of terms is given as the terms are used in the context of this study.

- **Data handling** is part of what traditionally used to be called descriptive statistics, which puts a strong emphasis on organising, describing, representing, and analysing of data, and is visually displayed using diagrams, graphs, charts, and plots (Shaughnessy, Garfield & Greer B, 1996). It is defined as an approach and an environment in which one deals with data.
- **Data** refers to collection of information, in a form of numbers, words, measurement, observation or description of things (Shaughnessy, Garfield, & Greer, 1996).
- **Handheld technology tools** are flexible, accessible, and portable technologies that help learners to build knowledge through their daily activities. They have the ability to incorporate computer technology into their everyday lives (Inkpen, 1999). These technology tools include the following: four-function calculator, scientific calculator, graphing and symbolic calculator, which are used most in mathematics and science classrooms.
- **Graphic calculators** are advanced calculators that run with computer algebra system (CAS) with the dynamics of graphs and geometry. The combination of the software and the calculator allows a learner or user an opportunity to choose any representation to use, from numerical, symbolic, graphical, and geometric representations (Person, 2011).
- **Cognitive technologies** are viewed as means for empowering the learners' cognitive capacities that aids in transcending mental limitations in thinking,

learning, and problem-solving activities, for example, computer technology, that is graphic calculators, smartboards, computer software, and they are used for learning and help learners to think mathematically (Inzunsa & Quintero, 2007). Furthermore, Dror and Harnad (2008) urge that cognitive technology extends the scope and power of cognition.

- **Cognitive tools** are tools that have the capability of assimilation to the established modes of thinking, and they are capable of promoting cognitive development of a learner (Groves & Obregon, 2009) They are also viewed as tools that have the capability to bring about structural changes in the system of a learner's cognitive through a reorganisation and transformation of the activities they perform. Furthermore, cognitive tools are both mental and computational devices that aid, guide, extend the user's thinking process (Inzunsa & Quintero, 2007)
- **Cognitive thinking**- is described as how individuals thinking processes are related to learners' cultural context and social interactions of learners that provide guidance, support, directions, challenges, and impetus for development (Rogoff, 1990). When learners are exposed to the use of new technology tools in a new environment, it changes the process of thinking.
- **Problem-solving** is a process where previously known data is used in a new unknown situation. This is a process where learners must deal with a mathematical problem and need to have only one insight to find a solution (Pehkonen, 2007)
- **Problem-solving skills** are considered as an important component of understanding and learning mathematics (Parrot & Leong, 2018). In this study, they refer to the ability to integrate the use of a graphic calculator in the learning of Data Handling, by allowing a learner to use the numerical and graphical representation of Data Handling simultaneously, which enhances the learner's visualisation.
- **Traditional teaching and learning approach** refer to the conventional and formalist approach.

1.8 THE RESEARCH METHODS USED IN THIS STUDY

This quantitative study focused on evaluating the effects of using a graphic calculator as a cognitive tool in learning grade 10 data handling. Hypothesis testing was completed through a quasi-experimental design, the pre-test-post-test non-equivalent group design and a questionnaire was used for triangulation purpose in clarifying the research questions. Pre-post-test design applied in the quasi-experimental design, intervention before the post-test was conducted in the experimental group while teaching in the comparison group progresses as usual. The intervention involved the usage of a graphic calculator in data handling problem solving facilitated by the researcher, while the usual method of teaching encompassed the conventional learning methods facilitated by subject teachers. After all groups were taught, the post-test was conducted by the researcher to both the experimental and the control group. A questionnaire was administered to learners to evaluate attitude and experience of utilising a graphic calculator in Data handling problem-solving in the experimental group. The questionnaire in the comparison group was aimed at evaluating the students' views about the probability of including a graphic calculator in data handling problem-solving.

To ensure research ethics, an ethical clearance was obtained from the University of South Africa (UNISA) College of Education, Department of Mathematics Education, and Ethics Committee. In addition, permission was sought from Limpopo Department of Basic Education to collect data from the sampled schools in Vhembe West and Vhembe East. Prior to the research, principals of the sampled schools were contacted in writing, requesting that the research be conducted in their schools, and stating the aims and scope of research study. The participants in the study were informed that they had a right to refuse to take part or withdraw once the research has begun.

This study follows a positivist paradigm, as it focuses in investigating the effect of using GC as a cognitive tool in learning data handling. Ndlovu (2021) states that scientific method of investigation or experiment evidence, is the only justifiable way to genuine scientific knowledge and understanding of human behaviour. Inferential statistical analysis applied through a paired T-test method comparing the test results (pre-test and post-test) for both the comparison and the experimental group. The T-test is used to compare the mean scores of the pre-test and the post-test for both groups to determine whether there are statistically significant different. Data that was collected through questionnaires was analysed through the descriptive statistical analysis method. The triangulated results reveal that usage of a graphic calculator as a cognitive tool supports learning and enhances different stages of the mental structures through the APOS levels of logical mathematical thinking.

1.9 SCOPE AND ASSUMPTION

1.9.1 SCOPE

The scope of the study includes secondary schools in two districts, that is, Vhembe East and West in the Limpopo province in South Africa. The population comprised Grade 10 mathematics learners and three schools in each district, with a total of 136 learners. Convenience sampling was used in this study because the schools sampled were within a close radius, and for reasons of availability of the researcher. Learners in Vhembe East were allocated to the experimental group whereas learners in Vhembe West were allocated to the comparison group; and both groups participated in the pre-and post-test. The researcher conducted the data handling lessons at the three schools allocated to the experimental group and carried out the intervention where learners used graphic calculators when learning data handling, and in the comparison group the researcher observed and made sure that data handling was taught to the learners using the traditional instruction or approach.

1.9.2 ASSUMPTION

The assumptions made in this study are that all learners who participated in this study are Grade 10 mathematics learners, and have studied mathematics from the lower grades (Grades 1-9), and only scientific calculators are used at schools not graphic calculators, since CAPS encourages the use of non-programmable calculators. In this study, it is assumed that there is still a need to improve the quality of Data handling content area in the South African school curriculum by providing tools that can help learners improve their content knowledge.

1.10 OUTLINE OF CHAPTERS

Chapter 1: The study overview provides a background and outlines the rationale, problem statement, hypothesis, the definition of terms including the aim and the objectives of the study.

Chapter 2: Literature review and theoretical framework, where literature is reviewed on the studies that have been conducted on the same field of study. The study draws on Dubinsky's APOS theory, which is in line with constructivist theories, which propose that for an individual to make sense of any given mathematical concept, they must have relevant mental structures. Action conceptions are transformed into processes, where objects and organised schemas are utilised.

Chapter 3: Research design- this section discusses the methodology and methods, the positivist paradigm that is used, population and sample, data collecting tools and process, data analysis, validity and reliability, and ethics issues.

Chapter 4: Presentation of study findings.

Chapter 5: Interpretation of data, discussion conclusion and recommendations.

1.11 CHAPTER SUMMARY

This chapter has provided the study's introduction and background which outlines the necessity of graphic calculator technology in supporting the learning of Data handling in Grade 10. The rationale, problem statement, objectives, hypothesis, and research questions of the study were set out. This quantitative study involved 136 learners that were conveniently sampled for reasons of availability of the researcher. This study avers that a graphic calculator supports the learning of Data handling. The support involves assisting students to avoid utilising more time in doing long repetitive calculations instead of using time to hone their conceptual understanding, thinking and problem-solving skills. The next chapter identifies the existing literature on this study, which is the literature review and the theoretical framework.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 INTRODUCTION

Statistics play an important role in our daily lives and the mathematical curriculum, and every citizen must have the ability to analyse, interpret and communicate information from data; however, people continue to have poor statistical reasoning and little understanding of data, even if they have studied it beyond the secondary level (Meletiou-Marvrotheris, Paparistodemou, & Stylianou, 2009). In the past, there was a strong emphasis on developing arithmetic, algebra and geometry in mathematics, and for that reason, data handling has been neglected in both South African primary and secondary school, and with the introduction of RNCS (Grades R-9) and NCS (Grades 10-12), the scope of Data Handling has been broadened and statistical reasoning also now being encouraged (Makina & Wessels, 2009). However, learning data handling is highly influenced by the formalist mathematical tradition (Meletiou-Marvrotheris, Paparistodemou, & Stylianou, 2009), and data handling (statistics) has become a focus of the call for change in mathematics education (NCTM, 2000). Technology is an efficient cognitive tool in learning, and the use of cognitive tools helps learners to learn how to broaden their knowledge and connect with outside world (Eyyam & Yaratan, 2014). Hence, the use of a graphic calculator reduces the sequence of calculations which may hinder the learning process, and enhances learners' achievement in data handling (Idris, 2004).

The National Council of Teachers of Mathematics (2000) has indicated that there are several research studies that claim that the use of graphic calculators in learning mathematics has a great potential for enhancing learning in mathematics, and their claims are based on the findings such as an increase in test scores of conceptual understanding, improvement of learners problem-solving, and learners developing a positive attitude towards the subject (Grzadzielewski, 2005). Berry, Graham and Smith (2005) stated that both teachers and learners must have a positive attitude towards the use of technology tools.

They referred to many scholars (Dunham & Dick, 1994; Penglase & Arnold, 1996; Hennessy, 1999; Burril et al., 2002) who have researched on the impact of the use of graphic calculators in learning mathematics whose studies have shown a great positive outcome. In contrast, Berry, Graham and Smith (2005) argue that it is difficult to process the thinking process of learners when using graphic calculators to solve mathematical problems because the only outcome that we usually see is the written solution of a mathematical problem.

In support of Pea, Dror and Harnad (2008), Pea (1987) describes a graphic calculator as a ‘cognitive technology’, that is capable of changing how we think, learn, and communicate. Therefore, a graphic calculator is a tool that helps learners not to be limited by their mind thinking. Thus, this study is drawn from Dubinsky’s development of the Action-Process-Object-Schema theory (APOS) which is influenced by Piaget’s proposal of the process of reflective abstraction as the key to the construction of logical mathematical concepts (Meel, 2003). The literature is reviewed on the graphic calculator as a cognitive tool; secondly on how learners learn data handling using conventional/ traditional approach and the use of a graphic calculator. The literature is reviewed not only to compare the effects of traditional and technology-enhanced instructional approaches, but also to support the alternative hypothesis that learning of data handling can be enhanced with the aid of graphic calculators.

In support of Pea (1987) distinction, a graphic calculator is a cognitive tool that can be used to restructure functional systems for thinking, and to support and promote thinking mathematically. A graphic calculator has the potential to assist learners in their learning and understanding of mathematical ideas (Groves & Obregon 2009). Furthermore, a graphic calculator is used as a visualisation, conceptual, investigative and focusing tool for learners; it helps learners to be critical thinkers and has the potential to create an environment that encourages mathematical thinking.

2.2 Learner Cognition in Data Handling

Learning is based on the learner's mathematical knowledge, where a learner tends to respond and solve a given mathematical problem and seek the solution for a given problem, and also form the mental structures of a given problem. Therefore, learning can occur only if the learner's mind forms mental structures that correspond to given mathematical concept, and if the expected mental structures are not formed, learning about the concept will fail (Syamsuri & Santosa, 2021). This means that the appropriate learning tools should be incorporated into learning Data Handling and other mathematical topics to help learners to form the expected mental structures to build an understanding of a given mathematical concept.

About 14%-18% of the South African mathematics curriculum from grades 10-12 constitutes Data Handling (Makina & Wessels, 2009; Bansilal, 2014). In addition, Makina and Wessels (2009) argue that the reason that leads to limited teaching and learning in data handling is that teachers have limited knowledge in the content area. Therefore, learners must learn Data Handling with understanding, and the appropriate mental structures should be formed for learning to take place. Mathews and Clark (2003) underwent a study to determine the possible conception of mean, standard deviation, and the Central Limit Theorem held by college students after completing the elementary statistics course. The study describes how college students form mental constructs when learning Statistics (Data Handling) in mean, standard deviation, and Central Limit Theorem. These constructs were through a theoretical perspective to provide an extreme model of cognitive development of the college students' understanding of these concepts. The study involved freshmen, upper-class, and graduates who took Statistics as a course from four different campuses, but only restricted to the students who received 'A' in their statistics course. The students were interviewed and given enough time to elaborate or write something down to give a meaningful response.

Out of the seventeen students from four different campuses who were interviewed, none of them were limited to the action conception of 'mean'. The action conception was interiorised into the process, and there was consistence among all students. However, there were some challenges beyond the process of conception. Some students had developed a weak object conception, while others had developed a strong object conception that is compatible with the understanding of statistics. Only two students showed consistency in the development of a strong object conception. The researchers, therefore, suggested that there should be new pedagogical treatments other than traditional approaches, for example, technology tools, that would enable students to encapsulate the process conception into object conceptions. With regards to the standard deviation, the results revealed that more than a third of the students had not progressed beyond the action conception, other students had an instrumental understanding of this process because there was no cognitive link to the concept of distance when determining the standard deviation. On the other hand, only two students out of the entire group developed a relational understanding of the concept when computing a standard deviation, hence the process has been encapsulated into object conception. Although not only limited to the action conception in the computation of mean and standard deviation, and some were able to develop process and object conception, only one student demonstrated a reasonable understanding of the 'Central Limit Theorem' and the others did not develop the other mental constructs of this concept. The researchers claim that the traditional approach creates pedagogical barriers for the learners, hence they suggest that there is a need for a new pedagogical approach that will promote object conception of the concepts. Furthermore, they urge that it is crucial for learners to be actively engaged in doing and reflecting on mental constructs.

Bansilal (2014) has noted that most teachers, especially from the rural areas were disadvantaged due to the old education system and were considered underqualified, hence they had little knowledge of statistics. A program was designed for these teachers based in the Kwa-Zulu Natal province, South Africa, to help them gain more knowledge and learn about the approaches to teaching statistics. The researcher conducted a study that consisted of 290 participants, and it aimed at unpacking the teachers' understanding of the concept (Normal distribution) that is required in developing the mental constructs.

The study's findings reveal that, despite incorrect application of formula in standardisation, there was evidence of some engagement, hence there was evidence of action conception. However, there was no interiorisation into process conception in some learners. A small percentage (27%) in this program had shown the object conception. This indicates that they had great difficulty in standardisation and reasoning about probability. The researcher therefore suggests that for these learners to engage with the concepts at different levels, there should be different tools or treatments used in order to help them develop the necessary mental constructs. In respect to the second question of normal distribution, the responses show that the learners in the program had very little knowledge of what they were being asked, and their responses suggest that they were only limited to the action conception and their responses have not been interiorised into process conception, meaning that they did not have the opportunity to internalise the concept and needed further engagement.

In conclusion, when the traditional approach is used in learning the mathematical concepts, Data Handling to be specific, and when teachers have limited statistical knowledge, the learners will learn formalism without any understanding of the concept, hence learners should be exposed to activities that will allow them to engage in those activities, as well as the interventions or treatments that will enable the learners to develop the mental construct and not be limited to one level. The accessibility to technology tools will allow the learners to focus more on the understanding of the mathematical concept. In support of this, it has been noted that the use of technology tools such as graphic calculators, allows learners an opportunity to work with diagrams and encourage them to visualise them as they create their own mental images (Chagwiza, 2019; Mukavhi, Brijlall & Abraham, 2021)

2.3 The graphic Calculator as a cognitive technology tool

2.3.1 Features of a Graphic Calculator

Before graphic calculators were introduced, the first four-function calculators which performed basic calculations such as addition, subtraction, multiplication and division were introduced between the late 1960s and early 1970s, then followed by the scientific calculators in the early 1980s which had features such as algorithm and trigonometry (Grzadzielewski, 2005). The first graphic calculator was introduced in 1985, and it was later developed, which provided access to mathematical problem solving (Waits & Demana, 1998). Graphic calculators are hand-held technologies that can plot graphs, solve equations numerically, perform statistical calculations, operate matrices, and perform more mathematical functions such as algebra, geometry, and advance statistics (Kor & Lim, 2004). A graphic calculator is a unique calculator that it is equipped with programs that can be shared between calculators using a cable or through an internet connection (Grzadzielewski, 2005).

A graphic calculator is a technology tool that was developed to enhance the learning of mathematics. It is a connection between a scientific calculator and a computer, and can perform different computations (Idris, 2004). The recent models of graphic calculators have display and visualisation capabilities, and they include three linked mathematical constructs, which are: graphical, numerical and symbolic views; they do not only perform numeric and symbolic calculation, but are also equipped in such a way that they can display geometric figures as well as integrative diagrams (Roschelle & Singleton, 2008). Furthermore, the researchers indicated that graphic calculators are connected via a wireless network, and they allow learners to interact with their teacher and get instant feedback on their work (formative assessment: homework, classwork, quiz, etc.) This feature enables learners to have active classroom participation, and their work can be displayed on a projected view in front of the classroom for everyone to see and engage in classroom discussion. According to Mittag and Taylor (1996), graphic calculators are not designed to replace computer software, but to enhance it. Furthermore, every learner may have access to a graphic calculator and may be available at any time, at any place, either at home or in the classroom. According to Burrill (1996), using graphic calculators is a way of creating innovations in the classroom at a lower cost than a computer. According to Demana and Waits (1992), graphic calculators are portable and affordable unlike the computers located in the laboratories; they enable learners to move from the use of traditional learning as they are equipped with educational software for better illustration.

2.3.2 The impact of a graphic a calculator as a 'cognitive tool' for Mathematics learning

A graphic calculator is a powerful tool of cognitive technology for learning to think mathematically, as it does not only operate with numbers, but also with graphs and numeric views (Pea, 1987; Groves & Obregon, 2009). A graphic calculator has a great ability to help learners to develop mastery of mathematics concepts because it provides specific functionalities that are important in mathematics learning, and many factors contribute to the learners' cognitive thinking (Roschelle & Singleton, 2008). Furthermore, the researchers outline three important cognitive factors that contribute to learners' learning. A graphic calculator as a cognitive technology enables learners to take the traditional tasks to a whole new level by avoiding long, tedious and repetitive calculations that will take more time which can be used to develop the learners' understanding and the ability to assess the quality of proposed solutions. Learners can carry out calculations on different concepts and data sets that may be too complex or difficult to work with. Secondly, is the combination of symbolic, tabular, and graphical representations, which enables learners to make conceptual understanding, for example, how a given data set can be organised and represented numerically and graphically. The combination of these representations can be connected to other visual aids, encouraging further conceptual understanding. The third cognitive factor is that graphic calculators help learners to engage in higher order mathematical reasoning. They enable learners to explore multiple solutions at the same time, and can solve algebraic problems more than learners who do not have access to graphic calculators.

Technology tools are certainly amplifiers for human mental powers (Pea & Kurland, 1984 as cited in Pea, 1987). Vygotsky's orientation provides a frame structure for the roles of technology tools in mathematical thinking and learning, and the mental process always involves signs. Furthermore, technology tools such as graphic calculators are forms of mediating tools that support learners in their learning process (Berger, 1997). As described by Vygotsky, a graphic calculator acts as both a mediating physical tool and a psychological sign by enhancing the learners' mental processes (Gage, 2005). Berger (1996) studied how a graphic calculator mediates the learning and use of mathematical concepts, and the main objective of the study was to describe ways in which a graphic calculator acts as a mediating sign in the zone of proximal development of first-year learners in a mathematics course, at the University of Witwatersrand South Africa. Students were lent graphic calculators at the beginning of the academic year and were required to use them during tutorials and lectures. According to the study's findings, students were able to perform numeric and graphical representations with ease, hence the graphic calculator was used to support the learning of those students who had access to graphic calculators during lectures and tutorials, since it was not allowed to be used during exams, therefore, the researcher suggests that a graphic calculator can be used as an 'add-on' device that supports learning and mathematical thinking.

2.4 The influence of Learning Approaches on cognition of Data Handling

2.4.1 Conventional/Traditional Learning Approach

According to Makina and Wessels (2009), instruction in data handling is highly influenced by the formalist tradition, where learners are given out rules and tasks that are from the textbooks, and their understanding is based on the marks obtained from re-repeating the tasks from the textbooks. In the traditional learning approach of statistics, learners are trained to search for one correct answer to the problem, for example, finding the mean and the median (Meletiou-Marvrotheris, Paparistodemou, & Stylianou, 2009). Learners learn data handling and other mathematical concepts by rote learning, which does not lead to a deep understanding of mathematical concepts and learners can easily forget because they do not attach meaning to those concepts (UNISA, 2012), for example, the basic statistic measures such as mean, median, mode, range, variance and standard deviation are formula based, and as a result learners lack basic statistical knowledge (Wessels, 2011). Furthermore, learners learn through teacher-talk, demonstration and worked examples and master through repetitive practice and they are only judged by reproducing the knowledge imparted to them by the teacher.

In the traditional learning approach, mathematical concepts are learned by remembering the formula, substitution of equations, and repetitive long and tedious calculations, and many learners find it tiring and boring because it is complicated and teachers do not use a lot of real-life situations, so the learners will not be able to relate to any experience outside the classroom. In this learning approach, learners fail to relate through their personal experiences and real-life situation because teachers do not use real-life situation examples (Ye, 2011). Meletiou-Marvrotheris et al. (2009) have indicated that the formalist tradition focuses on procedural aspects of probability and statistics rather than conceptual understanding, and in light of this view, this study asserts that conventional learning focuses on rote learning and does not give the learners the opportunity to diverse learning through self-learning, cooperation and exploration. Studies have proven that the incorporation of the new technology tool facilitates the visualisation of statistical concepts and other mathematical concepts and allows the learners the opportunity to connect the physical experience with its formal representation.

2.4.2 Meaningful learning with the use of Graphic Calculators

The new curriculum in South Africa includes a significant amount of data handling at all grades, and it offers data handling to improve the quality of statistical knowledge to all citizens (Makina & Wessels 2009), hence the mission statement of the Department of Education is to stress the importance of preparing learners to meet the social and economic needs of the 21st century (DBE, 2008). According to Burrill (1996), the development of technology tools, such as graphic calculators, is capable of changing how data handling is taught and learnt, and allows easy access to statistical reasoning to all learners. The use of a graphic calculator as a technology tool allows learners to move from learning data handling using a formula-based approach and repeating tasks from the textbook to using real data in a real situation where they can understand the representation of data from tabulating, graphically, and symbolic representation. Burrill (1996) used an example of a classroom experiment during a lesson where learners were asked how much pocket money they carried with them to school, with that data being entered into a spreadsheet in a graphic calculator, learners were able to produce a histogram of the data and they could estimate the numerical summaries, hence learners were able to investigate the relationship between the graphical representation and the numerical summaries. Furthermore, technology tools such as graphic calculators allow learners to develop statistical reasoning. Mittag and Taylor (1996) stated that the curriculum should eliminate the use of “artificial” data and use real data sets, because it is authentic and relevant to the content area, and also learners find it interesting as it relates to the world outside of the classroom.

According to Kee and Sam (2004), it is evident that the appropriate use of graphic calculators enhances learners’ conceptual understanding, problem-solving skills and attitude towards statistics and other mathematical concepts. Graphic calculators are designed to minimise the time spent doing calculations and drawing graphs using paper-and-pencil, it helps them to draw graphs and give numerical summaries simultaneously, which is faster, more accurate, and less tedious; in this way, learners will have more time to understand and have the ability to apply statistical concepts and the learning process. Furthermore, a mathematical problem done using a paper-and-pencil method should be judged as to whether the method contributes to the conceptual understanding of mathematics, and if not, there must be a tool that can be used to enhance the learners’ understanding (Waits & Demana, 1998).

Changes in instructional practices of learning data handling, such as curricular materials, tools, and cognitive technologies are essential. They enable statistical thinking to learners, and these tools are designed to facilitate the visualisation of statistical concepts, and also allow the learners to make a connection between the physical world (outside the classroom) and the formal representations (Meltiou-Marvrotheris, Paparistodemou & Stylinou, 2009). Tools such as graphic calculators enhance learners’ understanding of mathematical concepts, visualisation, and achievement in data handling and other mathematical concepts (Ye, 2011). This study asserts that learning using a cognitive technology such as a graphic calculator enables learners’ visualisation and understanding, and also improves their achievement in data handling as learners are able to make a connection between the numerical and graphical representation of data, thereby understanding the concept more than focusing on getting the right answer. Furthermore, learners can relate what they learn in class with the physical world and understand the importance of statistical knowledge outside the classroom. Research has proven that a graphic calculator promotes changes from the passive and formalist learning approach to diverse learning including the learner-centred approach, cooperative learning, and learning through discovery (Ye, 2011).

2.5 The influence of a graphic calculator on conceptual understanding

Graphic calculators have gained great significance in mathematics education in secondary schools across the world; they allow learners who find it difficult to work with calculations to gain more understanding and the ability to apply mathematical concepts and process (Abu-Naja, 2008). Abu-Naja (2008) studied the influence of the use of graphic calculators on mathematical thinking and understanding of positivity and negativity of functions for Grade 9 secondary school learners in Negev Arabi. The findings showed a great significance in learners' better understanding of concepts of positivity and negativity of functions. Furthermore, Abu-Naja (2008) argues that learners are attached to the traditional way of learning, and this way of thinking is not a lack of understanding or mathematical skills but rather a lack of motivation, hence graphic calculators should be used as a form of motivation to increase concentration. Kor and Lim (2004) focused on the use of graphic calculators and the impact they have on the learners' understanding of statistics. Their findings showed that learners have improved their conceptual understanding of statistics and a possible reason for this is that the graphic calculators enabled learners to visualise and explore different values in learning statistics. Furthermore, they claim that learning statistics with the use of graphic calculators does not only help learners to understand the concepts but also gain confidence and find the lessons very exciting, hence the negative perception about the subject changes altogether.

According to Chen and Lai (2015), the use of technology tools can help learners gain more interest in learning, and the use of the graphic calculator allows leaners to have more time to develop mathematical understanding, reasoning and other high levels of application. Kee and Sam (2004) studied learners' daily experiences with the use of graphic calculators in learning statistics. The results show that a great number of learners pointed out that the use of a graphic calculator works to their advantage as it helped them to enhance their understanding of statistical concepts, and assisted them to draw graphs more accurately. Furthermore, the results showed that learners were able to compare graphs, and this motivated the learners who were more passive to develop more interest in learning statistics. Ye (2011) studied the effects of graphic calculators in teaching and learning mathematics in secondary school in Zhejiang China, and the results show that the use of graphic calculators in teaching and learning does not affect learning, but it helps learners to understand mathematics concepts, visualise, and enhance learning through active learning, cooperation, and exploration.

It is evident that technology tools such as graphic calculators are designed to change the old formalist learning approach, which only focuses on rote learning and providing one solution for a given problem. Technology gives the learners an opportunity for exploration, and self-learning to enhance their understanding of the mathematical concept and leads to the development of mental constructs. Research has revealed that a graphic calculator has the potential to assist in learners' learning, understanding of mathematical concepts and achieve higher mathematics goals and it has multiple representations that allow learners to focus on the concepts (Groves & Obregon, 2009). This study asserts that when learners move from the old passive learning approach and incorporate the graphic calculator, their cognitive understanding is enhanced and the graphic calculator promotes mathematical thinking.

2.6 The effect of a graphic calculator on learner achievement in Data handling

According to Penglase and Arnold (1996), a graphic calculator is a technology tool that has great potential and capabilities to transform the mathematics content and curricula. Many studies conducted have shown great positive results on the effectiveness of a graphic calculator as a tool for instruction and learning mathematics. Jones (2005) as cited in Abu-Naja (2008) states that the use of a graphic calculator in learning mathematics can improve learners' achievement through learner and teacher involvement, frequent use of this tool and availability. Idris (2004) investigated the use of a graphic calculator (TI-83) as a tool for enhancing learners' achievement and developing self-confidence. Both qualitative and quantitative research designs were used to collect data from Form 4 (Grade 11) in Malaysian secondary schools, where both quasi-experimental and interviews were employed. Learners in the experimental group were found to have improved on their achievement than the learners who were not exposed to the use of graphic calculators (comparison group), and a higher percentage in the experimental group shows a positive reaction towards the use of graphic calculators. Learners seemed to have enjoyed the lesson more and agreed that learning mathematics was easier than before while using the traditional instruction of learning.

2.7 The support of a graphic calculator towards learners' problem-solving strategies

Graphic calculators have the ability to enhance learners' conceptual understanding, reasoning, problem-solving and transforming their attitude towards the new instructional tool (Sam & Kor, 2004). In addition, graphic calculators help teachers to encourage problem-solving and assist learners to think mathematically (Roschelle & Singleton, 2008). In support of this, Beckers and Niekerk (2021) stated that in their findings most teachers agree with the Dutch mathematics examination policy regarding the inclusion of graphic calculators in a mathematics classroom, that the use of graphic calculator provides a positive into the learners' learning as it allows them to engage with questions that are interesting and more meaningful. Roschelle and Singleton (2008) further outline how a graphic calculator enhances learners' problem-solving and reasoning; this includes the following: reducing the burden of difficult computations, by helping learners to be more attentive and sharpening their conceptual understanding; exposing learners to multiple representations, interactive exploration, and using real-life data that is meaningful and authentic; learners' are responsible for their own learning, they are able to check their work and justify their solutions; creating supportive environment for productive mathematical thinking. People face challenges in their everyday life that require them to make decisions, solve problems to deal with unexpected events; in order for learners to live in that world there are skills required to be problem solvers, reason and think mathematically (Leong & Parrot, 2018). Furthermore, the researchers have indicated that learners in Malaysia find mathematics very challenging because they lack problem-solving skills and the ability to visualise mathematical problems and concepts.

Leong and Parrot (2018) investigated the impact of a graphic calculator on learners' success in solving problems in linear equations and their attitude towards problem-solving in mathematics. A quasi-experimental design was employed in Leong Parrot's study where the focus was on Form 4 (Grade 11) learners in one of the public secondary schools in Malaysia. A test was used to compare two groups, the experimental and comparison group in pre-test and post-test, and a questionnaire was used to assess the learners' attitude towards the use of graphic calculators. The learners in the experimental group scored more than the learners in the comparison group and developed a positive attitude towards the new instructional tool. Learners in the experimental group were exposed to a new method of learning and the graphic calculator enhanced learners' problem-solving abilities.

Many research studies have shown that using of graphic calculator in mathematics contributes greatly in the learners' achievement in solving algebraic application, interpretation and mathematical understanding (Chen & Lai, 2015). In addition, learners who use graphic calculators are more likely to be consistent, innovative, and mostly likely to be accurate when solving mathematical problems, and more likely to demonstrate more reasoning and visualisation in their algebraic and graphical representation of a mathematical problem (Ndlovu & Ndlovu, 2020). Ndlovu and Ndlovu (2020) investigated the effects of using graphic calculator on grade 11 learners' achievement and problem-solving strategies in quadratic inequalities. A pre-test -- post-test control group design was employed in this study, where the experimental group was engaged in using the graphic calculator during data handling problem-solving, while the control group were taught using the traditional method. The use of graphic calculator helped leaners in the experimental group to show great skills in the properties of algebraic process, and provide them an opportunity to explore quadratic inequalities problems by making a connection between the verbal, symbolic, and graphical representations. Learners were also able to use more than one problem-solving strategy, and were able to switch between representations and realise how they are connected to each other.

2.8 Challenges associated with Graphic Calculators

Berry and Graham (2005) state that both learners and teachers need to have a positive attitude towards the use of graphic calculators and other technology tools of learning, in order for these tools to be used effectively. Many studies on the use of graphic calculators in learning have shown a great positive impact and its effectiveness, however, some researchers have indicated that graphic calculators may not be able to help in learning other mathematics concepts, such as Pre-Calculus topics (Penglase & Arnold, 1996).

Grzadzielewski (2005) investigated the validity of the learners' perception regarding the use of graphic calculators and their effectiveness. The researcher designed mathematical problems such as linear functions, quadratic functions, exponential functions, and system of equations; as part of their assessment, which were included in their homework, quiz, and exams. They were observed and interviewed; during the interviewed, learners were required to solve and discuss the given mathematical problems in order to assess the effectiveness of the graphic calculator. The learners claimed that the use of a graphic calculator helped them in some topics in Pre-Calculus. However, the evidence from the study shows that learners had a poor understanding of Pre-Calculus because they made many errors when working with the problems during interview sessions, and had a poor understanding of the concepts yet they believed that a graphic calculator is essential as a tool of learning.

Graham et al. (2003) investigated how second-year A-level learners use graphic calculators under examination conditions. This group of students had access to the use of graphic calculators for 18 months and had used graphic calculators during lessons throughout the academic year. The learners wrote a mock examination which was designed in such a way that it would allow learners to use a graphic calculator and the researcher would record the learners' keystrokes. The study indicated that many students were not aware of the benefits of graphic calculators and were not able to use some of the features in a graphic calculator. As a result, students were not motivated to use graphic calculators because they were not familiar with them since they were not used from the lower grades, and they were not allowed in the examination. Mitchelmore and Cavanagh (2012) investigated learners' difficulties in using graphic calculators which were caused by a lack of understanding of technology tools and those caused by mathematical misconceptions. Learners were interviewed, and the study found that most learners were unable to make proper numerical estimate values, even the high achieving learners had difficulties in using graphic calculators due to a lack of understanding of some fundamental mathematical concepts such as scale, accuracy, and approximation.

There is still a need to incorporate and increase the use of graphic calculators and the mathematics curriculum, to encourage active learning and help learners to be innovative. Learners should be exposed to the use of graphic calculators from the lower grade and the textbooks should be designed in such a way that they will allow learners to use graphic calculators. Graphic calculators are not allowed during the examination, and as a result learners are not motivated to move away from the traditional learning approach to the use of technology tools, such as graphic calculators.

2.9 Development of mental structures in Data Handling integrating APOS theory

According to Pea (1987) and Groves and Obregon (2009), a graphic calculator is seen as a cognitive technology tool that helps mathematical thinking to be purposeful and help learners to become mathematical thinkers and participate in their own learning. Furthermore, the purpose of cognitive technology tools should be for enhancing the learners' perception of taking ownership of their own learning of mathematics. Mathematical thinking is an essential cognitive in the process of learning of mathematics and learners are expected to develop mathematical reasoning (Syamsuri & Santosa; 2021; Mukavhi, Brijil & Abrahams, 2021), furthermore, with the inclusion of technology tool such as graphic calculator, the APOS theory was able to effectively explain the mathematical thinking process involved in the development of mathematics concept.

Thus, this study drew on Dubinsky's development of Action-Process-Object-Schema theory (APOS) which is influenced by Piaget's proposal of the process of reflective abstraction as the key to the construction of logical mathematical thinking (Dubinsky & McDonald, 2001). Studies have shown that the APOS theory has managed to elucidate the success of the mathematical thinking process in learners involved in the construction of a mathematical concept based on the integration of technology tools into mathematical learning (Mukavhi, Brijil & Abrahams, 2021). According to the APOS theory focuses on how a mathematical concept is learned and it aims at assisting learners to build understanding of various mathematical concept (Chagwiza, 2019; Kamid, Huda, Rohati, Sufri, Iriani & Anwar, 2021). Furthermore, the APOS theory describes ways that learners go through to develop a mathematical concept and directs how to start and apply mathematics learning without any difficulty (Syamsuri & Santosa, 2021). Hence this study has incorporated the use of technology tools, graphic calculators in learning Data Handling suitable for the learning activities administered to help the learners to develop the proposed mental structures.

According to the APOS theory, consists of action, process, object, and schema; and the main mental mechanism in developing these mental structures are interiorisation and encapsulation (Asiala, Brown, De Vries, Dubinsky, Mathews & Thomas, 1997; Dubinsky & McDonald, 2001; Clark, Kraut, Michigan & Wimbish, 2007; Maharaj, 2013; Oktac, Trigueros & Romo, 2019; Syamsuri & Santosa, 2021) and learning only occurs when a learner constructs mental structures through the mental mechanism. In this framework, before being acted upon by other actions or processes, actions and processes perform operations on previously established objects, and a schema is a coherent collection of structures that are linked to one another (Bansilal, 2014; Oktac, Trigueros & Romo, 2019). This means that learners do not learn the mathematical concepts directly, but apply the constructed mental structures to make sense of the mathematical concept by using a certain mental mechanism to build these constructs (Maharaj, 2013; Bansilal, 2014; Oktac, Trigueros & Romo, 2019; Syamsuri & Santosa, 2021), therefore, it is necessary to study the mental structures that occur in the learners' minds when learning a mathematical concept, data handling in this instance. To enable learning, learners must be assisted to develop appropriate mental structures and be guided to use these mental structures in order to construct their own understanding of mathematical concepts, and it is the teacher's responsibility to identify the mental structures that are needed in learning a given mathematical concept, use the appropriate tool and activities that will help learners develop the proposed mental constructs (Oktac, Trigueros, & Romo, 2019).

According to studies based on this theory, appropriate mental structures for a given concept must be detected, and then an appropriate learning activity should be designed to support the construction of these mental structures. (Maharaj, 2013; Meel, 2003; Mukavhi, Brijlall, & Abraham, 2021). The APOS theory suggests that a mathematical concept evolves as learners try to change the existing mental objects (Maharaja, 2013).

In the APOS theory, five different types of Piaget's constructs are important to describe how new objects, processes, and schemes can be built in order and develop an abstract mathematical concept, namely: generalisation, interiorisation, encapsulation, coordination, and reversal (Dubinksy, 2002) as demonstrated on Figure 2.8.1 below.

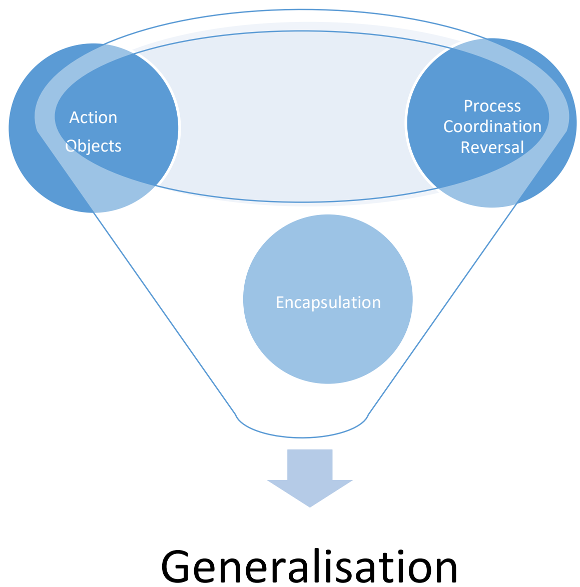


Figure 2.8.1: The APOS Theory

A theoretical framework for APOS based on curriculum development was proposed by Asiala, et al., (1997), which consisted of the following components: Theoretical Analysis, Instructional Treatment, Observation and assessment of the learners' learning.

The APOS Research framework is demonstrated in Figure 2.8.2 below.

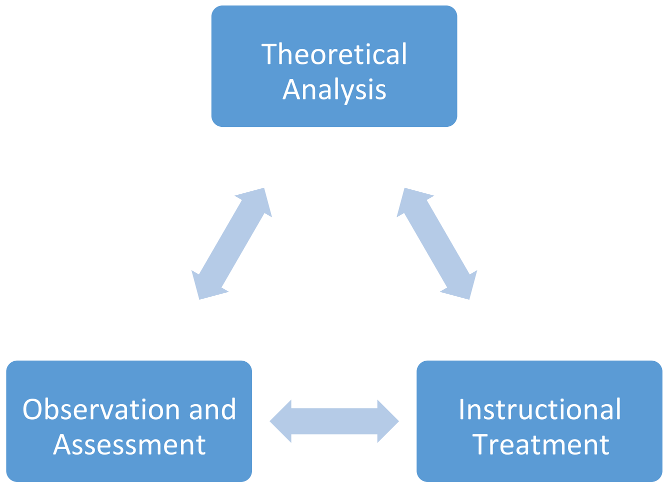


Figure 2.8.2: APOS Research Framework

The theoretical analysis allows learners to envisage the mental structures that are required to learn the mathematical concepts, and it also informs the design and implementation of instruction in the given mathematical concepts (Maharaj, 2013; Oktac, Trigueros, & Romo, 2019). According to this framework, beginning with theoretical analysis is essential for developing a conceptual understanding of a given mathematical concept. Furthermore, the designed activities and the tool incorporated during learning allow the learners to construct the proposed mental structures, and learners are observed and assessed to check if they have developed those mental structures. The APOS theory and its application are based on an assumption of mathematical knowledge, that: an individual's mathematical knowledge is their tendency to respond to perceived mathematical problems by reflecting on them and their solutions in a social context, and by reconstructing and constructing these mental structures.

This framework involves the combination of the following; learners are being observed during the learning process to determine the development of the mental structures; analyses of data to generate a genetic decomposition indicating one of the possible ways in which a learner might construct these concepts; instructional activities are designed to assist learners from these constructions and make reflective abstractions indicated by the genetic decomposition; the process is repeated after reflecting on genetic decomposition and instructional treatment (Dubinsky & McDonald, 2001; Oktac, Trigueros & Romo, 2019; Syamsuri & Santosa, 2021).

The theoretical analysis indicated the mental structures relevant to this study, and they are explained below.

2.9.1 Action stage in constructing mental structures

The essential building block of understanding the mathematical concepts is action, in which the transformation of objects to obtain other objects, which an individual leaner becomes aware of as being driven by external influences, requires step-by-step instruction on how to perform the operation (Dubinsky & McDonald, 2001; Meel, 2003). An action is a concept that exist outside the mind, each step of transformation must be done explicitly or from memory and in accordance with external guidance, furthermore, a learner's response may be a single-step response or following a step-by-step procedure for performing an operation, by recalling facts from their memory (Dubinsky & McDonald, 2001; Chagwiza, 2019). For example, a learner develops an appropriate action conception of the arithmetic mean of a set, but would be unable to do so in the absence of a formula. This is called the action stage where learner can only perceive a mathematical concept in the form of what is learnt.

Understanding of mathematical concepts comes by manipulating the previously constructed mental objects to form actions, and an action is the same as the repeated mental object/operation that transforms either a physical or mental object in some manner (Asiala et al., 1997; Meel, 2003). A learner who acts at an action conception mean computation can complete a step-by-step instruction, and the procedure can be applied through algebraic representation. For example, a learner of a procedure of calculating mean of a given data set; A = { 45, 39, 53, 53,45,43,48,50,40,40,45}, they will use a formula $\bar{x} = x_{1,}\ x_{2,}\ x_{3,}\ldots\ldots\ldots\ldots\ldots x_{n/10}$, an individual learner would be restricted to work with the given data set using the formula.

2.9.2 Process stage of mental structure construction

When an action is repeated and reflected on, it may be interiorised into a mental process, in which the action is no longer driven by external influences, which an individual learner can think of performing the same type of action but without the need of the external stimuli (Dubinsky & McDonald, 2001). A Process performs the same operation as the Action, but entirely in the individual's mind, allowing them to imagine performing the corresponding operation without any difficulty having to explicitly carry out each step (Dubinsky & McDonald, 2001; Chagwiza, 2019). A learner can now acquire new processes either through coordination or reversal by using this process, and this is necessary when a learner comes across new elements of a topic and recognises underlying structures that allow the application of several processes developed in a different context. For example, a learner is able to observe the difference of mean computation of grouped data set and ungrouped data set. When a process is internalised, it allows learners to think about it in the opposite form by constructing a new process using the reverse process, and this ability of thinking is called reversal. At this stage, a learner is now able to apply what they have learnt during the process of problem-solving.

A learner has control over the transformation of an object at the process level. A Process enable a learner to think of computations for several values, and think about these computations at once (Chagwiza, 2019). Furthermore, an individual learner is able to describe or reflect upon all of the steps in a transformation without actually executing them. When working with mean computation of mean of grouped data, a learner can now imagine the midpoint of each interval. Encapsulation requires a radical shift in a learner's conceptualisation because it denotes the ability to consider a concept as a mathematical entity to which new higher-level transformations can be applied. As many mathematical situations, the mental process that leads to mental objects via encapsulation may remain available, and such situations may require an individual learner to de-encapsulate an Object back the Process that led to it, hence it is important for an individual learner to be able to move back and forth between Process and Object (Chagwiza, 2019).

2.9.3 Objects conception in formulating the mental structures

When an individual becomes aware of a process as a whole and transforms it by some action and can construct such transformation in an individual's mind, then the process is said to have been encapsulated and turned into an object, and the object exists in an individual's mind once the process has been encapsulated (Dubinsky & McDonald, 2001). Consequently, a learner is able to name the object and connect it with the process which the object is constructed from. For example, an individual learner understands the mean computation as an object when they can think of using different types of data, thus, grouped or ungrouped data. If a learner can think of all these processes as a whole in any representational context and work flexibly in different representational context, it is considered that a learner has encapsulated the Process of applying a transformation any statistical computation into Object. Learners are said to have an Object conception of transformation if they are able to apply Actions on transformed statistical measures.

According to Chagwiza (2019) mathematical topics frequently involve many Actions, Process, and Objects that must be considered to be organised into a coherent framework that allows the learners to decide which set of mental processes to use when dealing with mathematical situation; this framework is called a Schema. Schema is used to see the relationship between the statistical measures and their relevance to a real world.

2.9.4 Schema development in constructing mental structures

An individual's collection of actions, processes, and objects is organised and linked together by some general principles to form a mental framework that can be applied to a problem situation involving mathematical concept known as schema. The learners use this collection to organise, understand, and make sense of the observed mathematical concepts (Dubinsky & McDonald, 2001). Schemas are organising structures that include actions, processes, objects, and other schemas that a learner uses when working with a new mathematical concept. Schema can be used to find solution of a problem situation involving a mathematical field (Chigwiza, 2019), in this study, Schema is used to make sense of statistical measures in a real-life situation. The schema is generalised when a learner learns to apply the existing schema and other structures on a wider set of phenomena. For example, in data handling, if a learner can create their own understanding of concepts rather than relying solely on external stimuli, they are able to solve higher order questions.

Evoking Scheme brings into play the previously constructed structures and the relationship between them that the learners would build up to that point. It is clear that when learners are given the same task, they can use different structures and methods, the establishment of new relationships between existing one's structures created by various learners allows us to determine each learner's level of development (Chigwiza, 2019). A mathematical topic involves many Actions, Processes and Objects that need to be organised into a coherent framework that enables a learner to decide which mental construction to use in dealing with a mathematical situation.

The APOS theory suggests that an individual needs to have the appropriate mental structures (actions, processes, objects, and schemas) to make sense of any given mathematical concept, and a learning activity should be designed in such a way that it will be able to support these mental structures. In this theory, the construction of understanding moves through several stages driven by external influences which then become internalised, reflected upon and organised in the end (Dubinsky & McDonald, 2001). In order for an individual to be able to learn or understand mathematical concepts, the appropriate mental structures should be applied to make sense of a mathematical concept (Maharaj, 2013; Syamsuri & Santosa, 2019). When an individual learner is develops their understanding of a mathematical concept, the construction of mental structures does not occur in a linear manner. However, an individual learner will begin by being restricted to specific kinds of formulas, reflect on calculations and start thinking about the process, return to an action interpretation, perhaps with more sophisticated formulas, further develop a process conception and so on. To put it simply, the construction of different structures of a particular mathematical concept is more dialectic than a linear sequence (Dubinsky & McDonald, 2001). This study focuses on the effects of using a graphic calculator as a cognitive tool in learning Grade 10 Data Handling. Drawing from the APOS theory, it is believed that technology tools (graphic calculators) can help learners construct action conception which can be transformed into processes, objects, and schemas, thereby constructing their understanding of mathematical concepts. Table 2.1 outlines how the APOS stages can be integrated with the usage of the cognitive tools to create mental structures essential for problem-solving in Data Handling.

2.1 Incorporating the cognitive tool in the Action-Process-Object-Schema framework in Data handling

APOS stages of mental structures construction	Mental structures constructed	The effect of cognitive technology
1. ACTION level engagement	• Perceiving a mathematical concept in the form of what is learnt. • Specific instructions are required to perform each step of transformation explicitly. • Actions are needed to determine the median and the range, at this stage a learner is only learning the use of a procedure, that is, following the formula to median and range. • At this stage, learners understand the mathematical language, as they view median and range as tendencies of data.	• Recognition of mathematical concepts that are usually presented abstractly. • Transformation of linking real-life situations with the numerical and graphical representation of data.

2. PROCESS level of engagement	• Reflection upon the incorporated procedures. • Actions are interiorised into a process without a learner having to work out each step separately but this can be done in the mind of a learner.	Interpretation of verbal, mathematical language and routine manipulations for processing visual and graphical representations using the affordance of a technology tool.
	• A process understanding will enable a learner to identify the quartiles (in the mind) without actually working them out and use that to calculate the IQR and represent them graphically in a box-and-whisker plot.	
3. OBJECT level of engagement	• Being aware of the process as a whole and realising that the transformation can act in totality and construct such transformation. Object conception enables a learner to understand the computation of the mean for grouped and ungrouped data.	• A learner's successful connection of object conception can have mental capture that comes from the use of technology tools.
4. SCHEMA level of engagement	• A coherent collection of mental structures connected to each other. A learner is able to make sense of the perceived problem situation.	• A logical schema of Data Handling is formed from the cognition enhanced by technology tool manipulation.

Ultimately, incorporating a graphic calculator as a cognitive tool allows the learning processes to be effective and the opportunity to develop the appropriate mental structures. When learners are given a mathematical problem, these actions and processes are interiorised. Furthermore, the integration of a technology tool into the computation of a mathematical problem where the mental constructions (action, process, and objects) are connected to each other enables the development of the schema constructs.

2.11 Chapter Summary

Different studies have been reviewed in this study and have shown evidence of how graphic calculators can help learners develop mathematical conceptual understanding, visualisation, and problem-solving. However, other studies have indicated challenges associated with the use of graphic calculators and recommended how the mathematics curricula should be changed to incorporate the use of the new technology tools so that learners can work with real-life problems. The research study is based on the APOS theory which states that in order to make sense of mathematical concepts an individual must have appropriate mental structures.

CHAPTER 3

RESEARCH DESIGN

3.1 INTRODUCTION

Many researchers see or define themselves as either qualitative or quantitative researchers. Quantitative research involves explaining the nature of an event by collecting numerical data that are analysed statistically, while on the other hand, qualitative research includes an extensive method, such as phenomenology, ethnographic research, and many more. Quantitative and qualitative research are seen as two different philosophical assumptions that researchers bring to the study. The quantitative researcher is viewed as a 'realist' or a 'positivist' while a qualitative researcher is regarded as a 'subjectivist' (Muijs, 2004). In addition, Muijs (2004) further outlined how 'realists' view the world. Realists are of the view that one needs to use objective research methods to reveal or confirm the reality or the truth that already exists, and to achieve that, the researcher needs to detach themselves from the research. According to positivists, the world operates on sets of laws that are tested through scientific thinking, and they are either rejected or provisionally accepted, and the realists believe that through using objective measurement the truth is out there to be found through research (Cohen, Manion & Morrison, 2018; Ndlovu, 2021).

In the nineteenth century, August Comte's metaphysics and his assertion that only scientific knowledge can reveal the truth about reality was rejected, and positivism became known as a philosophical paradigm. The positivist paradigm recommends that real-life experiences can be observed through an experiment and explained with logical analysis. According to Comte and his philosophy, the foundation of true philosophy and the character which he defines *positivist philosophy* is that we do not have knowledge of anything but of experience and we relate to things through our own experiences. Positivists further claim that science gives us with a possible ideal or knowledge that is clear and this can be obtained through scientific methods of investigation or experiment and this is the only way to authenticate the scientific knowledge and understanding of human behaviour (Ndlovu, 2021). Moreover, the positivist philosophers believe that in order for researchers to be able to report accurately about reality, they need to understand it and not be biased but objective.

Researchers try to understand their surroundings using three types of reasoning, thus: deductive, inductive, and abductive (combined inductive and deductive) reasoning. Aristotle had a great contribution to the development of formal logic for gaining knowledge. He introduced the use of deductive reasoning, which is described through a sequence of formal logic (a step-by-step logic) in which one moves from general to specific knowledge, and a valid premise can lead to a logical conclusion (Cohen, Manion, & Morrison, 2007). To have a logical conclusion, one must start with the true premise, the conclusion of a syllogism cannot be greater than the content of the premise, because the deductive conclusion is enhanced on the knowledge that exists already. Deductive reasoning can coordinate existing knowledge and point out new relationships as you move from general to specific knowledge, and its importance in research is that it gives a connection between a theory and observations (Ary et al., 2010).

According to Ndlovu (2021), the positivist paradigm is best for exploring *cause-effect* relationships between variables, and it is aimed at bringing a positive outcome. This study followed the positivist paradigm as it investigated the effects of a graphic calculator as a cognitive tool in learning Data handling; and the experimental evidence, that is the significance difference ($p<0,005$), is used to authenticate the *cause-effect* of the new technology tool introduced in learning Data Handling.

3.2 Research methods and methodology

Methods are tools and procedures used to collect data in educational research, and methodology is used to describe and analyse these methods (Kaplan, 1973). Research methodology is a plan used to solve a research problem; it explains why a particular tool or procedure is used (Kothari, 2004). This study is quantitative. It employs the use of an experimental research design and closed-ended questionnaire to obtain data. The experimental research design involves the manipulation of one variable(s) on another variable in a controlled environment to avoid extraneous variables or influences; and the manipulated variable is called the independent variable or treatment, and the dependent variable is the observed and measured variable (Ary et al. 2010). The researcher controls and manipulates the conditions intentionally to have the desired outcome, and the researcher will introduce the treatment and measure the difference that it brings to the subjects (Cohen, Manion, & Morrison, 2007). There is a difference between traditional experiments (true experiments) and quasi-experimental research designs. In a true experimental research design, the participants or subjects are allocated to groups through randomisation to minimise biasness, meaning that each participant has an equal chance of being assigned to any of the groups. In a quasi-experimental research design, there is no random allocation of participants, there is a control group (comparison group in this study) and the experimental group (for example, schools, classrooms, etc.) depending on the setting that the researcher decides to use.

In a case where it is not possible for the participants to be randomly allocated to treatment groups because a researcher cannot interfere with the programmes of a school or reorganise the classes that have already been assembled, but uses the classes that have already been assembled, the researcher has to use quasi-experimental research design as it allows him/her to get to a logical conclusion (Ary et al., 2010). This study has adopted the use of quasi-experimental design: the pre-test, post-test non-equivalent group design based on the fact that random assignment of classroom or schools does not apply, and the comparison and the experimental group have not been randomly assigned.

Parrot and Leong (2018) investigated the impact of using graphic calculators in problem-solving, a quasi-experimental non-equivalent control was and the study consisted of (n=60) Form 4 learners who took mathematics as their primary subject, as it was not feasible to conduct a true experiment when assessing the learners' proficiency in problem-solving. Both the experimental and the comparison groups completed a pre-test and a post-test. Similarly, Idris (2004) employed a quasi-experimental non-equivalent control pre-test and post-test design, and teachers were trained to teach the experimental group for five weeks using the graphic calculator, whilst the comparison group was taught using the conventional method.

Table 3.1: Pre-test--Post-test Non-equivalent research design			
Group	Pre-test	Independent Variable	Post-test
E	Y_1	X	Y_2
C	Y_1	-	Y_2

Table 3.1 demonstrates that there is no random assignment of experimental and comparison groups (Ary et al., 2010). Three schools from one district are assigned as an experimental group and the other three schools from the other district are assigned as a comparison group. Both groups, experimental and comparison groups are given a pre-test before the treatment is carried out. The comparison group is taught data handling through the traditional method as normal, while the experimental group receives the treatment, learning data handling with the use of a graphic calculator. After the intervention, the post-test is administered to both groups. The results of the post-test for both groups are compared with those of the pre-test to test the null hypothesis that there is no difference between learning data handling enhanced by a graphic calculator and conventional learning, with the statistical difference the researcher could make a reasonable conclusion.

3.3 MEASUREMENTS

Measurement is the process of allocating numbers to objects or observation, a matching process of transforming properties of an object of some sets into some other sets (Kothari, 2004). One must select or develop an appropriate measuring instrument that can be used to measure complex constructs such as attitude, achievement, intelligence, interests, and self-concept that are being studied (Ary et al., 2010). In measurement, one needs to differentiate the numbers they are dealing with in the study. The differentiation can be classified into four levels of data known as measurement scales.

Table 3.2: The measurement scales

Nominal scale: a system of allocating numbers to categories, using classification but no numerical order. This includes, sex (female= 1; male=2), age group, subject taught at school, type of school, and socio-economic status. A nominal scale indicates discrete data, for example, a soccer player wearing jersey number 6 is not twice as anything as a player wearing jersey number 3, the jersey number simply identifies the category.
Ordinal scale: a system of placing events in order. It classifies and rank-orders data, such as weakest to strongest, smallest to biggest, lowest to highest, least to most.
Interval scale: this includes the concept of equality of interval, which is an equal interval between numbers, for example, the distance between 11℃ and 12℃, and the distance between 32℃ and 33℃ are equal. Units are equal but there is no proportion.
Ratio scale: it encloses classification, order, equal interval, and has a true zero of measurement, there is proportion. This includes the measures of money, distance, population, time, years, temperature, and marks on a test.

Source: Cohen, Manion and Morrison (2007)

In this study learning is the dependent variable and the treatment which is measured through the pre-test and the post-test is the independent variable, and the numbers are used to differentiate the achievements of learners, and the measuring instrument used to measure what they have learnt is a test. The level of measurement used in this study is an interval and ratio scale. Learners are ranked in order based on their pre-test and post-test scores to determine their level of content knowledge and understanding in data handling. In addition, the interval and ratio scale measure the difference in the achievement of the pre-test and the post-test before and after the intervention for both groups. Furthermore, an ordinal scale is used to determine the learners' attitude or opinion in the closed-ended questionnaire after the intervention or the treatment using the rating scale.

3.4 POPULATION AND SAMPLE

3.4.1 Population

All elements in any field of study form a population, and the selected elements in this field of study represent what we call a sample (Kothari, 2004). According to Ary et al. (2010), population is a larger group (for example, an individual of a certain class, organisation, social activities, objects, etc.) and a sample is the portion of a population which is the small group that is observed. The population to be studied may be too big and as a result, it may take years and many resources, hence the researcher has to select a small group from a larger group; the process of selecting the small group from a larger group is called a sampling technique (Kothari, 2004). In the current study, the population comprised approximately 7500 learners and 250 teachers from 282 schools around the Vhembe district in the Limpopo province. Participants in the Vhembe district were selected from the two divisions of the district which are Vhembe East and West.

3.4.2 Sample

As outlined by Cohen, Manion, and Morrison (2007), there are two types of sample design, that is, probability sampling and non-probability sampling. The non-probability sampling technique was used in this study as it does not seek to generalise the wider population, and the target is a particular group. Non-probability sampling is less complicated and less expensive as it allows the researcher not to generalise the findings (Cohen, Manion & Morrison, 2018). Furthermore, Cohen, Manion and Morrison (2018) outline that the types of non-probability samples are: convenience sampling, quota sampling, dimensional sampling, purposive sampling, and snowball sampling. In nonprobability sampling, every member (subject) cannot be included in the study because the population is finite; and for this reason, this study used convenience sampling as it allowed the researcher easy accessibility to participants and the research site. The in this study comprised three schools from each district and they were allocated into two groups, the experimental and the comparison groups. The sampled schools are easily accessible and in close proximity in each district, hence it was not difficult for the researcher to move from one school to another within their respective groups. Of the two divisions of Vhembe district, Vhembe West was classified as the comparison with 48 Grade 10 learners and Vhembe East as the experimental group with 94 learners; all learners studying mathematics as their core subject. Participants who completed the research cycle in the comparison group were 43 (n=43) Grade 10 learners while only 93 (n=93) learners in the experimental group completed the research cycle, that is, they wrote the pre-test, attended classes for Data handling and wrote the post-test, completed a questionnaire and their teachers (n=6) also completed a questionnaire. Absenteeism is the main attrition factor that contributed to the non-participation of 5 learners in the experimental group and 1 learner in the comparison group.

3.5 DATA COLLECTION PROCESS

In experimental research, data is collected first-hand using different measuring instruments. There are different methods of collecting data in qualitative research or quantitative research. In quantitative research, the methods of collecting data are: experiments, questionnaires, surveys, polls, longitudinal studies, and many more. Methods used to collect data in qualitative research are: depth interviews, case studies, content analysis, warranty cards, and more (Kothari, 2004). According to Muijs (2004), the measurement instrument must measure all that the researcher intends to, so as to ensure validity and reliability of the measuring instruments or tools.

3.5.1 Pre-Test and Post-Test

The measuring tools used for this research is an achievement test, which is used to measure what the participants (learners) have learnt and measures mastery and proficiency of content knowledge (Ary et al., 2010). Before the intervention, a pre-test was administered to both the control and the experimental group to determine the participants' level of knowledge and understanding of Data Handling. The post-test was only administered after the treatment to examine the effect of the use of a graphic calculator in learning data handling. Both the comparison and the experimental group were given the same pre-test and post-test, the questions that were address in the pre-test were the same as those in the post-test, the reason for this was to identify and compare the mental structures before and after the intervention. The objectives of the test in this study were to assess the learners' ability to acquire new thinking skills, reasoning, and mathematical understanding of Data Handling. The test asked 10 questions which were addressing 4 mental structures according to the APOS theory (cf. Appendix B). Table 3.3 shows the classification of questions according to mental structures.

Table 3.3: The classification of questions according to mental structures

Question number	Mental structure	Definition
1.1 1.2 and 1.3	Action mental structure	The question evaluates the learners' ability to apply procedures, for example, using a formula to determine the median and the range.
1.4 and 1.5	Process mental structure	The question assesses the learners' ability to use the measures of dispersion and represent them graphically.
2.1 to 2.3 and 2.5	Object	The learners' ability to use computations of mean for group and ungrouped data was evaluated.
2.4	Schema mental structure	To assess learners' ability to make sense of the measures and represent them graphically and interpret.

3.5.1.1 Experimental group

Three schools from one district serve as an experimental group (E1, E2, and E3). The data collection process was carried out during school hours, during mathematics periods, and for this reason, it was not to disturb the programmes of the school, and this was carried out for two weeks (10 days). Due to Covid-19, learners attended school on a rotational basis, hence they were asked to attend school on the days which were not allocated for their class for the progress of the research study. The pre-test was administered and invigilated by the researcher at the three schools allocated as the experimental group. The total number of learners who wrote the pre-test is 93, and the number of learners in each school was distributed as follows: E1=26; E2=28; E3=39. The area content covered in the pre-test is Data Handling in mathematics, Grade 10 (South African Curriculum-CAPS).

After the pre-test, the treatment (intervention) was administered to all the learners from three schools allocated as the experimental group. Learners learned Data Handling (Central measures of the tendency of grouped and ungrouped data; measures of dispersion, percentiles, and quartiles; five-number summary in the form of a box-and-whisker-diagram; and analysing data on the graphs). The researcher taught the experimental group using a graphic calculator during the mathematics period, graphic calculators were provided by the researcher and learners were asked to use them in groups as there were not enough for each and every learner. There was consistency in teaching learners from all the three schools sampled as the experimental group, using the graphic calculator. There were three lessons conducted for each class in these schools, and each lesson was conducted on the same day but separately in all the three schools to ensure that no class was left behind. The duration of each lesson was 1 hour. A lesson plan was followed when the learners in the experimental group were taught, from lesson 1 to 3 as it appears on the lesson plan. The researcher was able to move from one school to the other as the three schools in the experimental group were in close proximity.

The post-test was carried out on a different day. After all the groups had received the treatment and all lessons had been covered, the post-test was administered and invigilated by the researcher. The content of the post-test was the same as that of the pre-test. However, the number of learners who wrote the post-test was less than the number of learners who wrote the pre-test. There was a reduction of 1 learner who did not participate in the post-test, thus only 93 learners wrote the post-test. There was a 1, 08% attrition rate in the experimental group. A closed-ended questionnaire was carried out after the post-test, to allow the participants to choose from the scales strongly agree, agree, strongly disagree, and disagree. The responses allowed the researcher to make a comparison in both teachers' and learners' perceptions across the groups in the sample, that is, perceptions of the experimental group against those of the comparison group. The teachers in the experimental group were given a questionnaire as they observed the lesson, while those in the comparison group were given questionnaires to give their perspectives of utilising a GC contrary to what they practice in the classroom.

The researcher carried out the pre-and-post-test, as well as the intervention, following the process outlined in table 3.4.

Table 3.4: The research process (Experimental group)

DAY	ACTIVITIES
1	• Seek approval to conduct the research study was requested from the principal of each school. • Request teacher's consent from the teachers involved. • Planning: firstly, check the days in which the Grade 10 learners will be at school since they were attending on a rotational basis due to Covid-19. Check the time-table for mathematics periods, and arrange with other teachers where necessary
2	• The teacher involved has allowed the researcher the opportunity to do a class visit, introduce myself to the learners, and outline the purpose of my visit and their involvement in the research study. • Learners were given consent forms for their parents to sign.
3	• Consent forms were collected, and learners were requested to sign the assent forms. • A pre-test was administered to the learners.
4	Lesson 1 • Learners were asked to identify the measures of central tendency to analyse data, that is: mean; median, and the mode which they have learnt in the senior phase. • Learners were asked to group the given data in ascending order using stem-and-leaf for both grouped and ungrouped data. • Learners were allowed to identify them with a given set of data using both grouped and ungrouped data. • Learners were allowed an opportunity to calculate the measures of central tendency using the formula. • The role of a researcher was to guide the learners on how to use the Graphic calculator (Fx-9750GII) to calculate the measures of central tendency.

5	Lesson 2 • The facilitation role of the researcher was to guide learners on how the graphic calculator is used, and learners were to determine the measures of dispersion: range; percentiles; quartiles; interquartile and semi-inter-quartile range.
	• Learners were allowed to interact with each other and with the teacher to analyse the level of their knowledge and understanding.
6	Lesson 3 • In this lesson, learners were allowed an opportunity to make a connection between measures of central tendency and measures of dispersion, and how those measures can be used to analyse data. • Learners were asked to refer to their books and use the given data from the previous lesson to represent the data on the graphs and plots and make an interpretation. • Learners were given an opportunity to present the plots and graphs they had used to represent the data given. • Since the Graphic calculator is able to represent multiple representation, learners used the data and saved data on the GC to view different plots and graphs that can be used to represent the data. • Learners were guided on how to interpret each plot and graph: box-and-whisker; scatter plot, histogram for grouped data, bar and pie charts as appearing on the graphic calculator.
7	Post-test • A post-test was administered to all three classes in the experimental group.
8	Questionnaire • Learners were given a closed-ended questionnaire. • Teachers in the experimental group observed the lesson and were also given questionnaires to complete.

3.5.1.2 Comparison group

Three schools from the other district (District 2) served as the comparison group (C1, C2, and C3). A pre-test was administered to these schools allocated to the comparison group, and this was done during school hours. The pre-test was written during the mathematics period because the researcher did not want to disturb the programmes of the schools. Interaction with the comparison group took two weeks (ten days), and a total number of 48 learners wrote the pre-test (same as the experimental groups). The pre-test was administered and invigilated by the researcher, the number of participants in each class was: C1=08; C2=14; C3=26; the content area covered in this pre-test is Data Handling in mathematics Grade 10.

The participants in the comparison did not receive the treatment, it was only administered to the experimental group to make the comparison of both groups in the sample. The participants in the comparison group continued to learn Data Handling using the traditional method of learning as usual by their teachers. No usage of a graphic calculator or any digital learning tool was evident. After the lesson, the participants wrote a post-test administered by the researcher, which was administered on a different day and all these groups wrote the post-test on the same day since the three schools are within the same radius. However, the number of learners who wrote the post-test decreased from 48 to 43, which is an attrition value of 11, 63%. Learners and teachers in the comparison group were given a closed-ended questionnaire. The process as reflected in Table 3.5 was followed when the researcher conducted the lesson.

The schools in the comparison group are approximately 15 km from the experimental group. Each lesson in the comparison group was observed on the same day in all three schools as they are within close proximity, therefore the researcher was able to move from one school to the other. The table 3.5 outlines the activities observed in the comparison group.

Table 3.5: The research process (comparison group)

DAY	ACTIVITIES
1	• Seek approval to conduct the research study was requested from the principal of each school. • Request teacher's consent from the teachers involved. • Planning: firstly, check the days in which the Grade 10 learners will be at school since they were attending on a rotational basis due to Covid-19. Check the time-table for mathematics periods, and arrange with other teachers where necessary.
2	• The teacher involved has allowed the researcher the opportunity to do a class visit, do an introduction to the learners, and outline the purpose of the visit and their involvement in the research study. • Learners were given consent forms for their parents to sign.
3	• Consent forms were collected, and learners were requested to sign the assent forms. • A pre-test was administered to the learners.
4	Lesson 1 • Arrange grouped and ungrouped data in ascending order using stem-and-leaf. • Central measures of tendency: estimate the mean; the median, and the modal score of grouped and ungrouped data. • Organise grouped data using a frequency table.
5	Lesson 2 • Measures of dispersion: range; percentile; quartiles; interquartile and semi-interquartile range.
6	Lesson 3 • Five-number summary using a box-and-whisker plot. • Represent and analyse data using graphs: histogram; pie and bar charts.

7	Post-test • A post-test was administered to all three classes in the comparison group.
8	Questionnaire • Learners were given a closed-ended questionnaire. • Teachers in the comparison group were also given the questionnaires to complete.

3.5.2 Questionnaire

A questionnaire is made up of questions (open-ended or closed-ended) questions in a definite order (Kothari, 2004). Open-ended questions allow the respondents to come up with their own responses, and closed-ended questions only allow the respondents to choose between answers provided by the researcher (Muijs, 2004). Closed-ended questions require a respondent to choose from a wide range of responses, and they are more focused than open-ended questions (Cohen, Manion, & Morrison, 2018). The questionnaire administered for this study consists of closed-ended and structured questions, and it enabled the researcher to observe the patterns and make comparison across groups. The researcher applied a paper-pencil-questionnaire, both learners and teachers from each group were allowed to complete a closed-ended questionnaire. A total number of 93 learners and 3 teachers were able to complete the questionnaire in the experimental group, and in the comparison group, 43 learners and 3 teachers completed the closed-ended questionnaire. The learner participants in the experimental group completed the questionnaire based on their experience and attitude towards the use of a graphic calculator. Learner participants in the comparison group completed a questionnaire based on their views of the inclusion of a GC in learning data handling and their attitudes. The teacher participants in both groups completed questionnaires to give their views about the inclusion of the GC in learning Data handling.

3.6 DATA ANALYSIS

A test is a measuring instrument that is designed and presented to individuals to obtain responses to a set of questions, and a numerical score can be allocated, based on the responses obtained, the score is a measure of how much the subject possesses the characteristics being measured (Ary et al., 2010). In numerical data analysis, there is parametric data and non-parametric data. Parametric data makes an assumption or inferences about the larger population, and the level of measurement includes interval and ratio scale; non-parametric data does not make an assumption about the wider population because their characteristics are unknown and the level of measurement includes nominal and ordinal scale (Cohen, Manion, & Morrison, 2018). The level of measurement in this study is interval and ratio scale or data, therefore this is parametric data that is derived from experiments and tests, for example, scores obtained from the test (numerical scores). These tests can be either norm-referenced or criterion-referenced tests. Norm-referenced tests compare the performance of the learners to the performance of other learners, it gives the researcher information about how learners have achieved in comparison with the others. Furthermore, the group achievement of learners in the comparison group was compared to that of learners in the experimental group. On the other hand, a criterion-referenced test requires a learner to achieve a given set of tests; it gives the researcher information on what the learner has learned and the results are expressed as a percentage of correctly answered items.

In this study, a pre-test and post-test were administered to both the comparison groups and the experimental groups to measure their level of understanding of the content area and determine whether they have developed the mental structures, and keep track of the learners' performance by comparing their scores before and after the treatment. This study employs criterion-referencing because the learners' performance shows what the learners have learned by comparing their level of understanding in data handling (measures of central tendency, dispersion, five number summary, using graphs to analyse data and make a meaningful interpretation) and their score compared to the following skills: statistical understanding and visualisation. The instrument was created in accordance with the APOS theory in order to allow the learners an opportunity to develop their mental structures. Validity and reliability were tested through feedback from experts in mathematics education.

Numerical data can be reported using a wide range of statistics to analyse data, descriptive statistics make no predictions, it describes and presents data by reporting what has been found in a variety of ways, this includes: mean; mode; median; maximum and minimum; variance; standard deviations. In contrast, inferential statistics make predictions about the population based on sample data, such as: Hypothesis testing; Regression; Multiple Regression; T-test; Analysis of Variance; Factor Analysis; and Structural Equation Modelling.

The results of the comparison group and the experimental group were compared using the paired T-test, a paired T-test is a method used to determine whether there is statistical difference between two groups, that is the experimental group and the comparison group after the treatment. It is also used to compare the differences between two related variables which are the pre-test and the post-test in the experimental and comparison groups.

The questionnaire asks respondents (learners) to rate how much they agree or disagree with the following statement using a four-point Likert scale: Strongly Agree, Agree, Disagree, and Strongly Disagree. The questionnaire is used to assess the learners' perception of the use of graphic calculators in learning data handling. Learners' responses were coded and analysed through descriptive analysis and presented using graphs and charts. In contrast, the questionnaire administered to the comparison group was used to assess learners' perception of the conventional way of learning and their view on whether the introduction of a technology tool could help close the gap of the challenges they have.

3.7 Fidelity of the Intervention

The delivery of an intervention as planned is referred to as intervention; it is critical for determining why the intervention succeeded or failed (Swanson, Wanzek, Haring, Ciullo & McCulley, 2011; Nelson, Cordray, Hulleman, Darrow & Sommer, 2012), it is, critical to assess the fidelity and incorporate the analysis of the outcomes. Swanson et al. (2011) state that the Institute of Education Sciences encourages the researchers not to only focus on the outcomes of the intervention, but also gather enough evidence that will explain the level of fidelity implementation that will assist the researchers to identify the conditions, tools, and procedures required to support the implementation of the intervention. When the intervention produces a positive outcome that indicates that the fidelity is high. For this study, the intervention was only implemented in the experimental group, and they were given a direct step-by-step on the features of the graphic calculator and how it operates by the facilitator, and they were given time to learn how to operate it, whilst on the other hand, the comparison group continued using the formalist approach of learning the same content, using the same workbook, and were assessed using the same achievement test. Their performance was compared and the study yielded a positive outcome which supports the alternative hypothesis.

3.8 RELIABILITY AND VALIDITY

The level to which an instrument measures what it is intended to is defined as its validity, whereas the level of consistency with which it measures what it is intended to, is defined as its reliability (Ary et al., 2010). Furthermore, the degree to which the test scores enable the researcher to make a meaningful and relevant judgment is referred to as validity, and reliability shows how a test can measure whatever it does frequently, with a similar outcome. Validity has three categories used to provide the validity of the score-base, which are, content, criterion, and construct validity. Muijs (2004) refers to content validity as to whether or not the content of the variable (questions on the test) is evident enough to measure what it is intended to measure; the level of questions on the test should be representative of the content. Ary et al. (2010) state that the researcher must ensure that the test used represents all relevant knowledge and skills making up the content. Criterion validity refers to the level to which scores are connected to one or more outcome criteria, there are two types of criterion validity, predictive validity referred to as the relationship between scores, and whether or not the measuring instrument can predict the expected outcome. The second type of criterion validity is concurrent validity, which refers to whether or not results of the measuring instrument match the results of other factors to which they are expected to be related. Construct validity relates to the internal structure of the measuring instrument and the measured concept.

This study is attached to content validity, and to ensure validity the content in the test is in line with Curriculum Assessment Policy Statement (CAPS) document for mathematics Grade 10. An expert (a mathematics education lecturer at the university) made a judgment on the content validity of the test as well as the subject advisor at a district level to ensure that the questions asked in the test are in line with the CAPS document. Validity refers to inferences, and is not a property of experimental design. Internal validity refers to the inferences about whether differences made on the dependent variables are brought by the independent variables in a study (Ary et al., 2010). External validity is the level to which the findings can be generalised to a wider population (Cohen, Manion, & Morrison, 2007). Internal and external validity were used to ensure validity in this study. Internal validity was ensured by observing changes in the dependent variable caused by experimental treatment, ensuring that the collected data is related to the research problem. External validity was ensured, and samples not studied were represented by the data collected which is broad and applicable beyond the context of the study.

Ary et al. (2010) stated that a test is reliable when learners' scores remain the same in a repeated measurement. Consistency of the test is indicated by the extent to which an individual will score almost the same score on repeated occasions, this means that if learners were to be given the same measuring instrument repeatedly on different occasions, they will have the same or nearly the same ranking. Furthermore, it was indicated that to estimate the reliability of the test, it has to be carried out on the same group of learners on two occasions, that is the pre-test and post-test, and there must be a mutual connection between the two sets of scores and this is called test-retest reliability coefficient. This study adhered to test-retest reliability by using the same measuring instrument with the same set of questions administered within the same group of learners on two distinct occasions, and scores are measures to ensure consistency.

The validity of a questionnaire is viewed as to whether the respondents who have completed the questionnaire are honest, or if the questionnaires are correctly done and accurate. Secondly, it refers to whether those who did not return their questionnaires gave the same responses as the respondents who managed to return their questionnaires

(Cohen, Manion, & Morrison, 2007). All respondents managed to complete the questionnaire given to them and the responses were compared.

3.9 ETHICAL ISSUES

According to Cohen, Manion, and Morrison (2007), the initial stage of the research study is to gain access to the institution or an organisation where the research will be carried out and also be granted permission before conducting the study. Furthermore, the researchers need to prove their worth of being granted permission to conduct their research study in that institution. According to the Standards of the American Educational Research Association (1992), researchers should sustain the integrity of their study, and of all those with whom they have professional relations, they also need to remain competent as well as the people who are directly involved in the study and it can be achieved by continuously evaluating the researcher’s honesty and conducting internal and external relations to the highest ethical standards. Researchers need to respect the participants’ rights, dignity, privacy, and sensitivity (Ary et al., 2010).

To adhere to research ethics, an ethical clearance was requested from the College of Education, Department of Mathematics Education, Ethics Committee of the University of South Africa (UNISA). Furthermore, permission was requested from the Limpopo Department of Basic Education to collect data from the sampled schools in Vhembe West and Vhembe East districts. The principals of the sampled schools were contacted in writing requesting to conduct the research study in their schools prior to the research, and stated the aims and the scope of the research study.

According to Cohen, Manion, and Morrison (2007), the right to freedom and self-determination of participant is the source of informed consent. The consent respects and protects the right of self-determination while also putting some of the blame on the participants if anything goes wrong during the study. Parents of the learners who participated in the study, in the sampled schools received consent forms and assent forms for the learners. Each participant signed a consent form and assent form for learners. Participants were given a chance to participate voluntarily in the study or to withdrawing or refusing to participate if they so desired. The research findings or recommendations should be published in a manner that will be clear and relevant to the research population, and anonymity and confidentiality were considered in this study.

3.10 CHAPTER SUMMARY

This study follows the positivists' paradigm which has a strong emphasis on sets of laws that are tested through scientific thinking and are either rejected or accepted Positivism recommends that real-life experiences can be observed through an experiment and be explained with logical analysis. This paradigm was adopted by observing the effect that a graphic calculator (treatment) has on the learning of Data Handling in Mathematics Grade 10, by supporting learners to acquire the necessary level of knowledge and understanding to improve their thinking ability.

This is a quantitative study, quasi-experimental non-equivalent design, and a pre-test and post-test were used as measuring instruments when collecting data and the dependent and independent variables were well described. Non-random sampling was followed, and an achievement test was used to measure what the learners have learned after the treatment. Reliability and validity were ensured when collecting and analysing data.

CHAPTER 4

PRESENTATION OF RESULTS

4.1 INTRODUCTION

Data results are presented in this chapter to compare the test results of both the experimental group and the comparison group before and after the intervention. The data were collected from 136 learners from the six sampled schools. To begin with, the presentation of the results starts with how a GC supports learning Grade 10 Data handling, and to determine the influence of a GC on learners' learning, to analyse the results of the pre-test and the post-test to track the improvement of the experimental group in comparison with the contrast group, descriptive statistics are used. Averages are essential in comparing the degree of the improvement of both groups. Tables and charts are used to compare the development pattern of both the experimental and comparison groups.

In addition, the results presented show the effects of using a GC in learning Data Handling, how it enhances learners' statistical knowledge and understanding, problem-solving, and critical thinking. Inferential statistics are employed in data analysis, and a paired T-test statistical analysis is used to determine the statistical difference between the experimental and the comparison groups. The variances and the mean scores of both groups are also compared. To obtain the results presented in the study, the following primary research question was posed: Does the use of a graphic calculator (GC) have an effect on learning Grade 10 Data Handling? And to enable the researcher to make a provisional statement about the relations between the variables that are being studied, a hypothesis was formulated as follows:

Null Hypothesis (H_0): There is no difference between learning supported by graphic calculator technology and conventional learning.

Alternate Hypothesis (H_1): Learning that is aided by graphic technology enhances understanding of data handling.

Furthermore, the cognitive development of learners supported and not supported through the use of a GC is compared. A closed-ended questionnaire was administered and the findings were analysed using descriptive statistics. In conclusion, means and variance were used to establish the analysis of the pre-test and post-test, tables and charts (bar and line) were used in descriptive statistics analysis.

4.2 THE ANALYSIS OF DATA AND RESULTS: LEARNER PERFORMANCE

4.2.1 INFERENTIAL STATISTICAL ANALYSIS

4.2.1.1 Paired T-test

The paired T-test is helpful for scrutinising the difference between two groups' responses, and in the study, the pre-test results of the experimental and the comparison group are compared, furthermore, the T-test is used to determine whether there is a statistical significant difference between the means of the experimental and the comparison group. The effects of using a graphic calculator in learning Data Handling Grade 10 was tested using the paired t-test, and it was carried out on pre- and post-test results of and the results of 94 learners of the experimental group and 48 comparison group. However, due to missing values, the number of respondents recorded in SPSS generated table seems to be 93 learners in the experimental group and 43 learners in the comparison group. The missing values are 1 case in the experimental group and 5 cases in the comparison group. The number of missing cases is small that it cannot lead to the misinterpretation of the overall findings of the study. According to Cohen, Manion, and Morrison (2018), if the number of missing cases is low it will not distort the findings, hence the researcher may adopt a deletion method for missing data, exclude cases whose data are incomplete, and use cases whose data is complete. Therefore, the results that will be accounted for are those of the learners who wrote both the pre-test and the post-test in the experimental and comparison groups.

To determine whether there is a significant difference in the achievement scores of learners in the comparison group, that is, learners who were not exposed to the use of graphic calculator in learning Data Handling: the comparison group's pre- and post-test scores are presented in Table 4.1. (H_{01}): There is no significant difference in the academic achievement for pre- and post-test scores of learners in the comparison group.

Table 4.1 (a): Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Test	7.05	43	4.830	.737
	Post-Test	8.53	43	5.865	.894

Table 4.1 above revealed that the learners who had not been exposed to the use of a GC in Data handling had the mean score of 7, 05 and 8, 53 in the pre-test and post- test, respectively, with a standard deviation of 4,830 and 5,865. Although there is a mean difference in mean score between the pre-test and the post-test we set the level of significance to use for supporting or rejecting the null hypotheses. Table 4.2 (a) and 4.2 (b) show the level of significant difference.

Table 4.2 (a) : Paired Samples Test[a]

	Paired Differences			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference

					Lower
Pair 1	Pre-Test - Post-Test	-1.488	4.574	.698	-2.896

4.2 (b): Paired Samples Test[a]

		Paired Differences			
		95% Confidence Interval of the Difference			
		Upper	t	Df	Sig. (2-tailed)
Pair 1	Pre-Test - Post-Test	-.081	-2.134	42	.039

Tables 4.2. (a) and (b) depict that the difference is not significant with t= -2,134 at a 5% level of significance which makes p=0,039 not significant since p>0,005. Although there is no significant difference between the pre-test and the post-test, an increase in the mean, standard error mean, and standard deviation in the post-test indicates that the learners' achievement has improved slightly.

To analyse the pre-test and the post-test of the learners' achievement scores in the experimental group, the null hypotheses states that, (H_{02}): There is no significant difference in the academic achievement for pre- and post-test scores of learners in the experimental group. For the pre- and post-test scores of the experimental group, learners who were exposed to the use of the GC were analysed using a paired sampled t-test and the results are presented in Table 4.3.

Table 4.3 (a): Paired Samples Statistics[a]

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Test	5.76	91	4.372	.458
	Post-Test	13.14	91	4.649	.487

Table 4.3 (a) has revealed that learners who were exposed to the use of graphic calculators, that is, the experimental group had a mean score of 5, 76 and 13, 14 in the pre- and post-test, with a standard deviation of 4,372 and 4,649, respectively. The means scores differ between the pre-test and post-test. Despite the fact that there a mean difference, we set the level of significance for supporting or rejecting the null hypotheses. Tables 4.3 (a) and 4.3 (b), show the level of significant difference.

Table 4.3 (b): Paired Samples Statistics[a]

		Paired Differences			
					95% Confidence Interval of the Difference
		Mean	Std. Deviation	Std. Error Mean	Lower
Pair 1	Pre-Test - Post-Test	-7.385	4.968	.521	-8.419

Table 4.3 (c): Paired Samples Statistics[a]

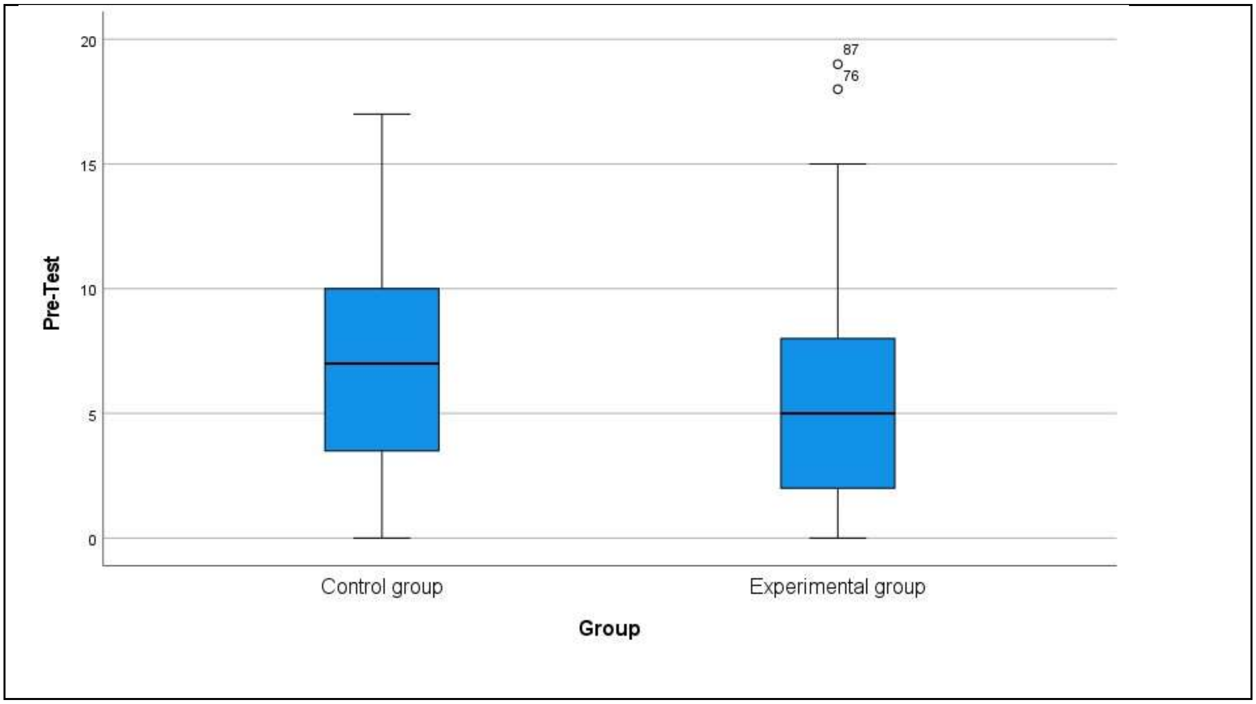
		Paired Differences	t	Df	Sig. (2-tailed)
		95% Confidence Interval of the Difference			
		Upper			
Pair 1	Pre-Test - Post-Test	-6.350	-14.179	90	.000

Tables 4.3 (a), (b) and (c) above show that the use of a graphic calculator has a significant impact on the learners with t= - 14,179 to be significant as p=0,000, that is p<0,005.

Learners who had access to the use of a graphic calculator in learning Data Handling significantly scored higher compared to their counterparts who did not have access to the use of a graphic calculator as a learning tool. With a mean difference and a significant difference between the pre-test and the post-test, it has led to the rejection of the null hypothesis that stated that there is no significant difference in the academic achievement of pre-test and the post-test scores of learners in the experimental group. Therefore, this will lead to the supporting of the alternate hypothesis, which states that: learning that is aided by a graphic calculator (technology tool) enhances understanding of Data Handling. To support the findings made from inferential statistical analysis, descriptive analysis was used.

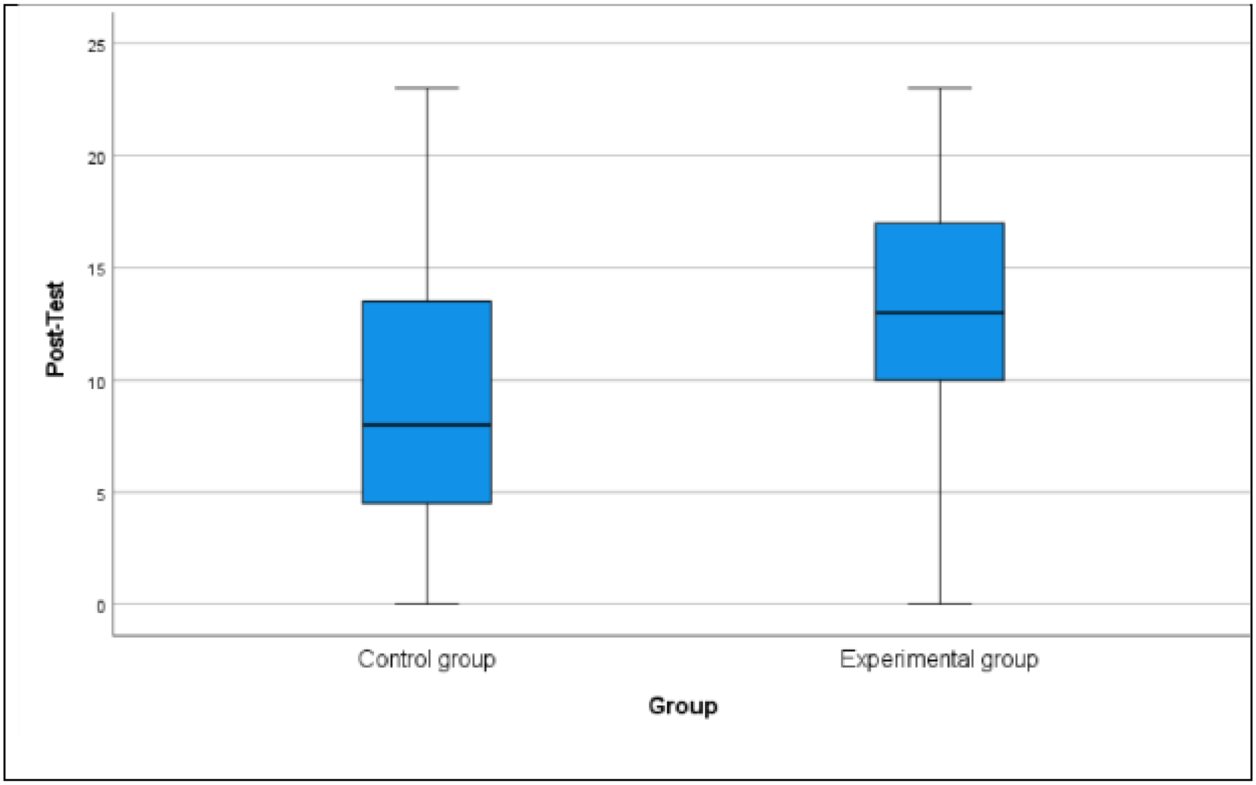
Figures 4.1 and 4.2 show the results of the pre-test and the post-test for both the comparison and experimental groups.

Figure 4.1.1: Pre-Test



The box-and-whisker plots for both comparison and experimental groups indicate a wider range of marks. The median of the experimental group is generally lower than the median of the comparison group, and the small circle indicates the outliers, that is, the learners whose scores are more than the interquartile range. In addition, the box-and-whisker plots indicate that there was no great difference in the results of the pre-test and the post-test for both the experimental and the comparison group, the plots representing the results are negatively skewed, therefore both groups performed at the same level in the pre-test.

Figure 4.1.2: Post-Test



The box-and-whisker plots for both comparison and experimental groups indicate a wider range of marks. The median of the experimental group is generally above the median of the comparison group. The chart indicates that there is a great difference in the results of the post-test of the comparison and the experimental groups.

4.2.1.2 Effect Size

Most researchers report the statistical probability in research studies, and the statistical significance only claims to tell the researcher the difference between two groups. The p value has an effect on the amount of confidence that we can place in the findings, however, it does not provide the magnitude of the treatment effect and it is not adequate when reported alone (Cohen, Manion, & Morrison, 2018; Rhea, 2004; Sullivan & Feinn, 2012). Therefore, the effect size is a way of measuring the difference (how big) between two or more groups, of which the statistical significance does not tell, because the statistical significance is dependent on the sample size and effect size, whereas on the other hand, the effect size is independent of the sample size.

According to Glass (1981), Cohen (1988), and Cumming (2012) using the Cohen d, the effect size is calculated as follows:

$$Effect\ Size = \frac{Mean_{Experimental\ group} - Mean_{Conrol\ Group}}{Standard\ Deviation_{\ Conrol\ Group}}$$

Cohen d effect size is classified as follows: weak (d: 0-0, 2); modest/ satisfactory (d: 0, 210, 50); moderate/average (d: 0, 51-1, 00); and strong effect (d>1). The effect size is illustrated in the table below:

Table 4.4: Independent Samples Effect Sizes

		Standardiser[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Pre-Test	Cohen's d	4.546	.268	-.092	.628
	Hedges' correction	4.572	.267	-.092	.624
	Glass's delta	4.431	.275	-.086	.635
Post-Test	Cohen's d	5.055	-.958	-1.327	-.587
	Hedges' correction	5.083	-.953	-1.320	-.584
	Glass's delta	4.649	-1.042	-1.423	-.656

For this research study, the effect size was calculated according to Cohen. In the pre-test, the effect size is reported to be d= 0,268, that is d>0, 2 it is not trivial but satisfactory, it is noticeably smaller than the medium relative effect size. The effect size of the post-test was reported to be d=0,958, that is d>0, 8; it is a moderate or average effect, in the case of this study it is a large effect. This asserts that there is a great mean difference in scores between the comparison group and the experimental group in the post-test.

In conclusion, the mean score for the comparison group was higher than the mean score of the experimental group in the pre-test, with a small effect size and a $p>0,005$; while on the other hand, the mean score of the comparison group was lower than the mean score of the experimental group in the post-test with a large effect size, and a $p<0,005$, with a large effect size, implies that the strength of the treatment did not occur by chance and that the sample size was adequate to yield to a large effect size of the intervention.

4.2.2 Descriptive statistical Analysis

Descriptive statistical analysis involves visual techniques of data presentation such as: frequency and percentage tables; bar charts for discrete data; histogram for continuous data; line graph which shows the trends of two or more variables; pie charts for showing proportions; and scatter plots to show the relationship between two variables, for example, pre-and-post-test and box-and-whisker plots show the distribution of values for several variables (Cohen, Manion, & Morrison, 2018). The learners' raw marks for both pre-test and post-test are compared to the experimental and comparison group using a frequency table.

Table 4.5: Raw marks obtained by the learners

		Frequency(f) Experimental Group		Frequency(f) Comparison Group	
Marks Interval	Midpoint	Pre-Test	Post-Test	Pre-Test	Post-Test
0-10	5.5	25	3	13	10
10-20	15.5	16	0	4	3
20-30	20.5	25	15	10	10
30-40	30.5	12	6	9	5
40-50	40.5	7	16	6	7
50-60	50.5	4	10	3	5
60-70	60.5	3	31	3	0
70-80	70.5	2	6	0	1
80-90	80.5	0	4	0	1
90-100	90.5	0	2	0	1

The frequency table or frequency distribution is a systematic way of arranging and organising the learners' scores for both pre-test and the post-test. The learners' scores for both experimental and comparison groups are compared using the achievement levels. The scores are classified as:

- 0-39 Low Achievement
- 40-59 Medium/ Moderate Achievement
- 60-100 High/Outstanding Achievement

Tables 4.6 and 4.7 show the frequency and percentages of the learners' scores for both pre-test and post-test, to demonstrate the level of achievement of the comparison and experimental group.

Table 4.6: Experimental group (N=93)

Level of Achievement	**Pre-Test**		**Post-Test**	
Low Achievement	78	82,98%	24	25,81%
Medium/Moderate Achievement	11	11,70%	26	27,96%
High/Outstanding Achievement	5	5,32%	43	46,24%
TOTAL	**93**		**93**	

Table 4.7: Comparison group (N=43)

Level of Achievement	**Pre-Test**		**Post-Test**	
Low Achievement	36	75%	28	65%
Medium/Moderate Achievement	9	18,75%	12	25%
High/Outstanding Achievement	3	6,25%	3	6,98%
TOTAL	**48**		**43**	

The experimental group had 94 learners who wrote the pre-test, however, only 93 learners wrote the post-test, and the comparison group had 48 learners who wrote the pre-test but only 43 wrote the post-test. The attrition value is 1 in the experimental group and 5 in the comparison group. This was due to some learners wrote the pre-test but were absent on the day that other learners wrote the post-test, therefore, Tables 4.6 and 4.7 report on the performance of learners who wrote both the pre-test and the post-test.

Tables 4.6 and 4.7 show how the learners improved their scores in the post-test. In the experimental group, 78(82,98%) learners performed in low achievement in the pre-test, and on the post-test the number of learners who performed in low achievement decreased significantly to 24(25,81%) learners, that is a decrease rate of -57,17%. In the comparison group, 31 (72, 09%) learners performed with low achievement in the pre-test and decreased to 28(65%) learners performing with low achievement. Learners in the experimental group who performed in the medium/moderate achievement increased from 10(10, 75%) learners to 26(27, 96%) learners. In the comparison group, 9(18,75%) learners performed in medium/moderate achievement in the pre-test, and 12 (25%) in the post-test, which is at the rate of 6,25% which is very low as compared to the 16,26% increase rate of learners in medium achievement in the experimental group. The number of learners who performed in high achievement in the pre-test is 5(5, 32%) learners in the experimental group and it increased to 43(46, 24%) learners in the post-test. In contrast, in the comparison group, the number of learners who performed with the high achievement is 3(6, 25%) in the pre-test and 3(6, 98%) where there was no increase nor a decrease. This analysis has shown that the experimental group has a great increase in the number of learners who performed in both the medium and high achievement. Descriptive analysis requires visual techniques of data presentation in a form of graphical presentation, and for this reason, graphs are more accessible and comprehensible than tables of figures. A graphical representation of the differentiation for the pre-test and the post-test are shown in figures 4.2.1 and 4.2.2.

Figure 4.2.1: Differentiation for the pre-test and the post-test (Experimental group)

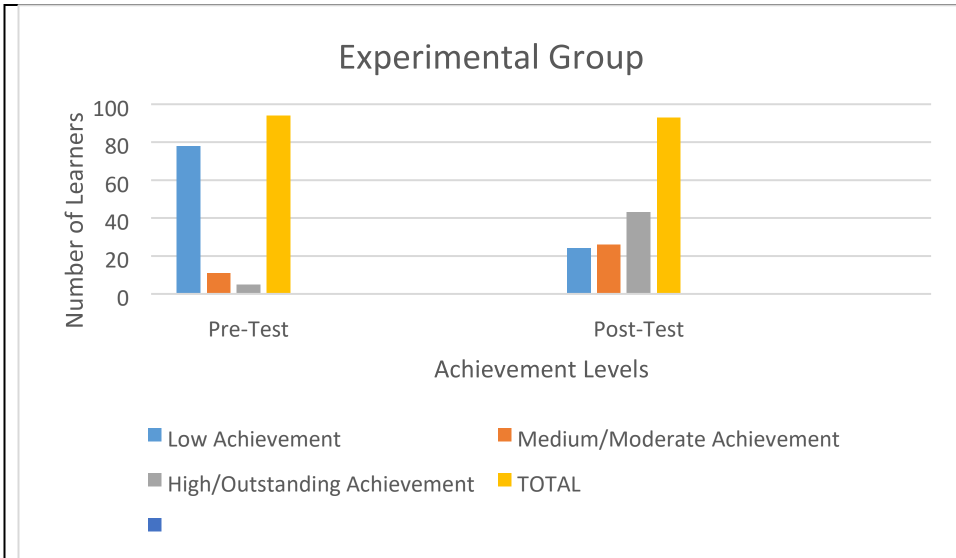
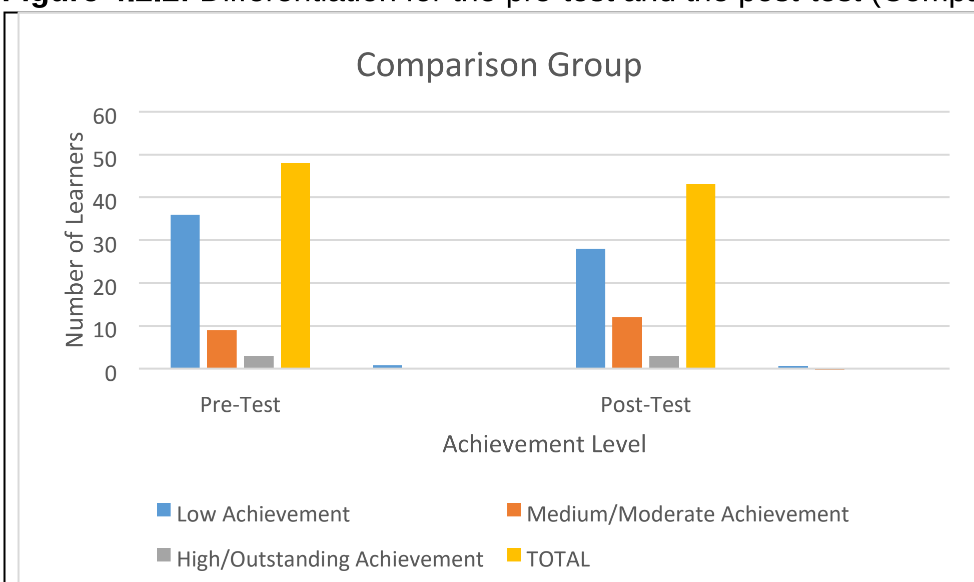


Figure 4.2.2: Differentiation for the pre-test and the post-test (Comparison group)



Inferential statistical analysis has been used to determine the significant difference between learners who were exposed to the use of graphic calculators and those who were not exposed to the use of a graphic calculator, which showed that there is a significant difference of p=0,039 and p=0,00 respectively between the comparison and the experimental group. The comparison group revealed that a mean difference between the pre-test and the post-test 1,48; while the experimental group showed a mean difference of 7,38 This shows that the graphic calculator has contributed greatly to the learning of Data Handling for learners who were exposed to the use of graphic calculators. This finding is supported by the descriptive statistical analysis as it demonstrates that the achievement of learners in the experimental group has shown a great increase between the pre-test and the post-test compared to the learners in the comparison group. The test scores in the comparison have shown a decline of 10% in the low achievement level and an increase of 0, 73% in the high achievement level, while the sores of the pre-test compared to the post-test of the of learners in the experimental group show a significant decline of 57, 17% in the low achievement level and a significant increase of 40, 92% in the high achievement level. Therefore, the findings indicate that learners who were exposed to the use of graphic calculator performed significantly better on test than their counterparts.

4.3 Descriptive analysis per level of knowledge

The result of epistemological mathematical knowledge is viewed as a cognitive model explaining the constructs of a certain piece of knowledge and technology tools. The mathematical knowledge of an individual tends to respond to perceived mathematical problem situations and their solutions. The pre-test and the post-test questions are outlined using the APOS framework, action is then regarded as a physical or transformation of mathematical objects with the use of technology tools in response to an external situation, this means an action is viewed as a process of mathematical thinking using technology.

The theoretical analysis indicated the type of mental structures of Action, Process, Object, and Schema are relevant to learning the concept of Data Handling using technology tools, that is, the graphic calculator.

4.3.1 Transformation of Mathematical objects through Action process

According to APOS theory, the learning process occurs through the construction of mental structures and it is through reflection that learners can construct mathematical knowledge. The results of the study have brought about the genetic decomposition to which Actions are interiorised into numerical and graphical representation. Learners are expected to show action conception through determining the median and range given a formula, and process conception through identifying the five number summary and representing the data in a box-and-whisker plot.

As a result of this study, the learners' approach to answering the questions on the pre-test and the post-test indicated the learners' Action or Process conception in Data Handling (cf. Appendix C: Extracts, E1 to E6). Only 93 learners received an intervention, and their approach in answering the question in both the pre- and the post-test was Action oriented as Actions are externally guided, that is, the use of a formula in determining the median and the range.

Learner 28 (cf. E1 and E2) showed the ability to apply Action conception by determining the median and the range using a formula in a given data set, and from the given data set the learner arranged the data set in ascending order, but had not yet interiorised it into a Process and hence could not identify the upper quartile and the lower quartile in the five number summary. The learner identified [Q3=46 and Q1=73] instead of Q1=46 and Q3=73. However, the learner was able to represent the data graphically in a box-and-whisker plot, but failed to identify the outlier in the plot, hence there was no process conception.

Another learner, Learner 39 (cf.E3), showed no Action and Process conception skills in the pre-test, however, in the post-test, Learner 39 (cf. E4) could apply Action conception. The learner took the given data set and determined the median and calculated the range using a formula, and interiorised the Action into a process as the learner managed to identify the five-number summary and represent it graphically in a box-and-whisker plot, however, the learner could not identify the outlier.

Out of 93 learners who received the intervention, another learner, Learner 47 (cf. E5), was able to determine the median and the range of a given data set; but failed to identify the five number summary in the pre-test. However, in the post-test, Learner 47 (cf. E6) managed to identify the five-number summary and clearly represented graphically in a box-and-whisker plot, but could not identify the outlier. The Process conception as an interiorisation of Action makes it possible for this learner to repeat those Actions.

Conception does not lie in the individual or the mathematical problem, but rather with the logical relationship between the two (Dubinsky, 1997; Oktac, Trigueros & Romo, 2019). Learners may be considered to have developed mathematical knowledge in Data Handling, and may be functioning under the Action conception.

4.3.2 Process and Object conception

The interaction between the individual and the technology tool occurs by free discovery or when learners are guided by instructions to allow randomised mental interiorisation of mathematical concepts and technology processes (Leckson, Deonarain, & Jose, 2021). Furthermore, an individual can make a logical relationship between the mathematics constructs and technology constructs, which leads to the development of Schema development. The mental Schema of a mathematical concept is formed cognition enhanced by the manipulation of technology tools. Learners used a graphic calculator as a technology tool in learning Data Handling.

The learners developed Action and Process conceptions that enable them to determine the median and the range given a formula. The object conception enables learners to be aware of processes and realises the mental structure transformation, which enables the learners to work with the numerical and graphical representation of data.

Learner 28 (cf.E7 and E8) failed to determine the modal score and estimate the mean of a grouped data in the pre-test, however, in the post-test the learner was supposed to use [*f.m*] which would enable the learner to estimate the mean of grouped data. The development of Schema involves various interpretations of data in a given data set and representing the data graphically in a histogram.

Learner 39 (cf. E9 and E10) showed in Process conception level; the processes are not encapsulated into a cognitive object, as the learner failed to differentiate the estimation of the mean of grouped data and mean of ungrouped data. The learner was guided by instruction on how to operate the technology tool during the intervention, which enabled the learner to estimate the mean and represent the grouped data graphically. Furthermore, with the aid of a technology tool, the object conception and process conception occurred concurrently and the learner could make a connection between the process and object conception, where the encapsulation of mental structures is derived from a technology tool.

Learner 47(cf. E11 and E12) showed no ability to process conception and object conception in the pre-test. However, the learner showed the ability to apply Action conception in Question 1, but could not interiorise it into process. In the post-test, the learner showed the ability of both the Object and Process conception derived from the use of a graphic calculator.

4.3.3 Schema

Schema was developed as learners could make a logical relationship between determining measures of tendency and dispersion to represent and interpret data. Organised actions, processes, and objects are congruent with those mathematical ideas in Data Handling. This includes various interpretations of Data Handling; these learners were able to link the relationship between representing data using numerical values and graphically. In Question 2, learners were given grouped data and were able to analyse it using numerical values, which enabled them to show the process and the object conception, hence the graphic calculator enabled the learners to explore multiple representations. Furthermore, in Question 2.4, all learners had the capability of establishing a link between numerical and graphical representation of data, hence learners were able to represent the data graphically. By doing so, learners were able to reconstruct those mental structures to show the ability of a schema in representing grouped data graphically and estimating the mean.

In conclusion, the test was designed in such a way that it would be able to address the development of the mental structures and enable learners to make a connection between these constructs and the technology tool. Learners were expected to show the ability to develop the mental constructs through the learning process. They were able to show the ability of action conception in both the pre-test and the post-test by determining the measures of dispersion and tendency using a given formula. They needed to understand the mathematical language and convert it into mathematical expressions. Action was interiorised into process conception, and learners showed an ability to identify the five number summary and represent them in a box-and-whisker plot. Learners were guided by instruction on how to operate the technology tool (GC), and the object conception and the development of schema were enhanced by the manipulation of the technology tool.

4.4 Analysis of the questionnaire

The focus group was the experimental group, however, learners in the comparison group were also given a questionnaire, as well as the teachers in both the experimental and the comparison group. Table 4.8 demonstrate the scale of agreement to disagreement in the questionnaire.

Table 4.8: Rating scale of agreement and disagreement of learners in the experimental group

Item	SA (%)	A (%)	SD (%)	D (%)
1. Learning DH using GC helped me to focus on the learning process (P).	44,4	47,8	0	7,8
2. I spend unnecessary time on long and repetitive calculations when using pen-and-paper (A).	24,4	36,7	5,6	33,3
3. The use of GC enables me to use multiple representations: tabular, algebraic, and graphical simultaneously (P).	34,4	38,9	1,1	26,7
4. The use of GC enables me to develop new thinking skills and mathematical understanding of DH (P).	46,7	40,0	4,4	8,9

5. The use of GC enables me to develop mathematical understanding of reasoning and other level of application concepts (P).	31,1	48,9	14,4	5,6
6. I am a confident user of GC (A).	17,8	37,8	27,8	16,7
7. The use of GC in learning DH motivates me to work on challenging problems (A).	38,9	47,8	11,1	2,2
8. The use of GC in learning DH gives me an opportunity to work with real-life problems (P).	24,7	40,4	28,1	6,7
9. Learning DH is more interesting when using GC (A).	54,4	37,8	5,6	2,2
10. The use of GC in learning DH should be incorporated into the South African curriculum (P).	58,9	24,4	11,1	5,6

There are 93 completed questionnaires for the experimental group who were exposed to the use of a graphic calculator in learning data handling, and 92, 5% of learners agreed that the use of a GC helped them in the learning of data handling, and 7, 8% disagreed.

Furthermore, 61, 1% of learners agreed that they spent unnecessary time on long and repetitive calculations using pen-and-paper, however, 38, 9% of learners disagreed that they spent unnecessary time on calculations and drawing graphs if they did not use a graphic calculator. Furthermore, 73,3% found that the use of a graphic calculator enables them to use multiple representations and 26,7% disagreed; 86,7% of learners agreed that a graphic calculator enabled them to develop mathematical thinking, and 80% agreed that it helped to develop mathematical thinking, while 33,3% disagreed. 55,6% of learners believed that they are confident users, and 62,4% found the use of a graphic calculator in learning data handling interesting; 86,7% of learners agreed that the use of a graphic calculator motivates them to work with challenging questions. In conclusion, 57, 2% learners agreed that graphic calculators should be incorporated into the South African curriculum.

Table 4.9: Rating scale of agreement and disagreement of learners in the comparison group

Item	SA (%)	%A	%SD	%D
1. Learning DH using the traditional approach does not help me focus on the learning process (A-R).	12,8	27,7	36,2	23,4
2. Long and repetitive calculations diminish/ take away the joy of learning DH (A).	38,3	31,9	21,3	8,5
3. Learning DH using the traditional method does not give me an opportunity to work with real-life problems (A).	17,0	29,8	34,0	19,1
4. The use of technology tools, such as GC will help me to engage with challenging problems (P).	38,3	36,2	12,8	12,8
5. The use of technology tools, such as GC enables learners to be better at interpreting graphs and tables (P).	27,7	42,6	19,1	10,6

Learners in the comparison group completed a questionnaire, 43 questionnaires were completed; out of the completed only 40,5% learners agreed that learning data handling using conventional method does help them on focusing in learning;70,2% found that long and repetitive calculations took away the joy of learning data handling. Furthermore, 53,1% of learners disagreed that learning data handling using the traditional method does not allow learners to work with real-life situations; 74,4% of learners agreed that the use of technology tools helps learners to engage in more challenging problems and 70,3% agreed that learning data handling aided by the use of technology tools help learners to better interpret tables and graphs.

Table 4.10: Rating scale of agreement and disagreement of teachers in experimental group

Item	%SA	%A	%SD	%D
1. Learners should be allowed to use GC to create graphical representations after they have learned to create graphs by hand (P).	50	25	25	0
2. Regular use of GC will help learners to become better at interpreting tables and graphs (P).	50	50	0	0
3. The use of GC provides learners with an opportunity to share their ideas (P).	0	100	0	0
4. Teachers should decide when it is appropriate for learners to use GC (P).	75	0	25	0
5. The South African curriculum should incorporate the use of technology tools such as GC from lower grades (P).	0	25	50	25

As teachers observed the lesson during the intervention in the experimental group, 75% agreed that learners should be allowed to use graphic calculators in learning data handling and other mathematical topics. In addition, 100% found that regular use will help learners to become better interpreters of tables and graphical representations. Notably, 100% agreed that the use of a graphic calculator allows learners to share ideas, and 75% agreed that teachers should decide when it is appropriate for learners to use graphic calculators, and 25% agreed that the use of graphic calculators should be incorporated in the South African curriculum.

Table 4.11: Rating scale of agreement and disagreement of teachers in the comparison group

Item	%SA	%A	%SD	%D
1. Learners should be allowed to use GC to create graphical representations after they have learned to create graphs by hand (P).	66,67	33,33	0	0
2. Regular use of GC will help learners to become better at interpreting tables and graphs (P).	0	100	0	0
3. The use of GC provides learners with an opportunity to share their ideas (P).	0	66,67	0	33,33
4. Teachers should decide when it is appropriate for learners to use GC (P).	66,67	33,33	0	0
5. The South African curriculum should incorporate the use of technology tools such as GC from lower grades (P).	0	33,33	33,33	33,33

Teachers in the comparison group were not aware of how learners in the experimental group were taught, however, they were also given a closed-ended questionnaire. All teachers in the comparison group (100%) agreed that learners should be allowed to use graphic calculators in learning data handling and other mathematical topics. Furthermore, 100% found that regular use will help learners to become better interpreters of tables and graphical representations. Only 66, 67% agreed that the use of a graphic calculator allows learners to share ideas, and 66, 67% strongly agreed that teachers should decide when it is appropriate for learners to use graphic calculators, and 33, 33% agreed that the use of graphic calculators should be incorporated in the South African curriculum.

In summary, teachers and learners in both the experimental group and comparison group had different perceptions and attitudes towards the inclusion of a graphic calculator as a tool for learning in Data Handling in Grade 10. A high percentage of learners in the experimental group agreed that the use of a graphic calculator in learning Data Handling supports their learning and enhances their mathematical thinking and problem-solving skills. The graphic calculator allows the learners an opportunity to use multiple representations, and as a result, learners can deepen their mathematical understanding of Data Handling. About 81,77% of the learners who were exposed to the use of graphic calculators agreed that not only does the graphic calculator enables them to use multiple representations such as tubulars, charts, and algebraic computations, but also helps them to focus more on their learning by developing a mathematical understanding of reasoning and an opportunity to work with challenging problems. Furthermore, learners have developed a positive attitude towards the content area and the inclusion of the graphic calculator, 73, 9% of the learners enjoyed and felt comfortable working with Data Handling problems and they were capable of switching between multiple representations.

Learners in the comparison group were not exposed to the use of a graphic calculator and continued learning using the conventional approach. Some learners believed that learning using a conventional method does not give them time to think about the problem but they only focus on the long algebraic calculation of the problem. A total of 43, 65% of the learners agreed that the conventional approach does not allow them an opportunity to focus on their learning. However, 72, 4% believed that inclusion of technology tools such as a graphic calculator will allow them to work with challenging problems, and as a result, the technology tool will enable them to develop problem-solving skills and gain more knowledge. Learners have a negative attitude towards the content area because they spend more time focusing on a long repetitive calculation and that takes away the joy of learning mathematics.

Teachers from both the experimental group and the comparison group agreed that the inclusion of a technology tool in a classroom, such as a graphic calculator has a positive impact on their learning, not only by improving the learners’ performance but also by enabling learners to deepen their mathematical understanding in the content area and other mathematical content areas. About 77, 5% of teachers agreed that a graphic calculator should be considered during teaching and learning Data Handling and other mathematical content areas, and that the South African curriculum should incorporate the use of a graphic calculator.

4.5 Triangulation of Results

Table 4.12: Triangulated Data: Effects of using a graphic calculator as a cognitive tool in learning Grade 10 Data Handling

	Skills Development	Cognitive Development	Attitude
EFFECTS OF USING A GRAPHIC CALCULATOR	• Problem-solving strategies: ability to solve challenging problems	• Make a connection between graphical and numerical representation, and how they are related to the concept	• Learners understand and feel comfortable in the presence of Data Handling problems
	• Visualisation: learners find it easy to visualise numerical calculations, tables, and graphs with the calculator's display	• The learners' application of graphical strategies is stimulated	• Learners find the lesson to be interesting and enjoyable
	• Exploration	• High level of thinking and understanding	• Learners are motivated to work with challenging problems
	• Ability to switch between multiple representations	• Development of statistical knowledge and understanding	• Inclusion of a graphic calculator allows them an opportunity to focus more on their learning

The performance of the learners in the experimental group for the pre-test and the post-test was recorded to be statistically significant at $p<0,005$, that is $p=0,000$ with a large effect size of 0,958 in the post-test. This indicates that the intervention improved the learners' performance and enhancing their knowledge of understanding Data Handling. In comparison with the learners who did not have access to the use of a graphic calculator in learning, their performance in the pre-test and the post-test was recorded to be insignificant at p>0,005, that is p=0,039, this implies that the formalist approach did not contribute to the improvement of the performance in the comparison group. As a results, the comparison group's teaching and learning method provides no benefits in conceptual development, that is to say, the method of learning Data Handling in the comparison group is influenced by rote learning which leads to learning with no understanding due to memorisation.

Therefore, this study found that the integration of a graphic calculator as a tool of learning allows learners an opportunity to move from the formalist approach and learn with understanding, thereby developing visualisation, exploration and problem-solving skills. The inferential statistics in the experimental group are in line with the descriptive results of the study. The descriptive statistics results revealed that learners in the experimental group progressed from a low level of achievement to a high level of understanding with an increased rate of 40, 92%. This implies that the use of a graphic calculator in learning enhanced the learners' mathematical thinking and understanding (see Table 4.6). Similarly, the formalist approach to learning did not support mathematical thinking and understanding, as well as visualisation and problem-solving skills. There was a slight improvement in levels of achievement as illustrated in Table 4.7, however, the comparison group results were proved to be insignificant (p=0,039>0,005), this resulted from the formalist approach of learning that influences learning through memorisation without understanding.

Both groups required learners to learn by sharing ideas, discussion, and group work. Learners in the experimental group worked in groups as there was a limited number of graphic calculators, hence they needed to learn in groups, in order to encourage cooperative learning and learner-centred approach, however, some of the learners in the comparison groups chose to work as individuals, and they learned by recalling what the teacher had said during the lessons or recalled what they had written in their notes, and focused on getting once answer for a given problem. Learners in the experimental group were able to switch between representations using the calculator, hence learners in the experimental group were able to make a connection between the algebraic computation and graphical computation, but in the comparison group, learners struggled to switch from algebraic computation to graphical computation.

Figure 4.2.1 shows that there was a development in all levels of achievement, and learners in the experimental group consistently used graphical and numerical representations to solve problems. However, there was no consistent improvement of results in the comparison group, for example, a 0,73% increase was recorded from low level to high level of achievement, which implies that the learners in the comparison group did not develop statistical knowledge and understanding. The intervention did not only enhance the learning of learners in the experimental group, but it also had an impact on their attitude towards the content area and other mathematical content areas. From the questionnaire results (see Table 4.8), it was reported that 73,9% of learners find learning Data Handling with the use of a graphic calculator interesting and it motivates them to work with more challenging problems so that they will be able to use more than one problem-solving strategy. Learners in the experimental group agree that a graphic calculator enables them to focus on learning and that it should be integrated into teaching and learning Data Handling and other content areas in mathematics.

The pre-test results reported that the comparison group performed at 6, 25% at a high level of achievement and the experimental group at 5, 32% (see Table 4.6 and 4.7), which implies that the comparison group performed at a rate of 0, 93% higher than the experimental group. However, in the post-test, a decline of 0, 73% in the comparison group was evident, and the experimental group increased by 40, 92%, a large attrition value in the comparison group could have contributed to the decline in the number of learners who performed at a high level of achievement. Furthermore, rote learning was employed during teaching and learning in the comparison group, which did not influence problem-solving skills and conceptual understanding, therefore the performance was poor in the moderate and high levels of achievement. Therefore, a conclusion can be drawn that the inclusion of a graphic calculator supports the learning of Data Handling, learners can use more than one problem-solving strategy when solving problems, and they are also able to visualise, switch between multiple representations, and enhance their mathematical thinking.

4.6 Chapter Summary

Inferential statistics and descriptive analysis were employed to analyse data in this study. In inferential statistics, a paired t-test was used to show the effectiveness of the intervention, that is, the use of a graphic calculator in learning data handling. The experimental group was exposed to the intervention and improved as the mean score was 13, 14 with a standard deviation of 4,649 and the standard error was recorded as 0,487. Learners who were not exposed to the intervention had a score of 8, 53; a standard deviation of 5,865; and a standard error of 0,894; they showed a slight improvement in their post-test. Learners in the comparison group have shown an insignificance difference with $t = -2,134$, and $p = 0, 39$ not significant since $p>0, 05$. The results of the experimental group that received the intervention showed a significant impact with $t = -14,179$; and $p= 0,000$ significant since $p<0,005$ and a large effect size of $d>0, 8$ which indicate that the significant difference did not occur by chance; the treatment was effective.

Furthermore, descriptive statistical analysis of the learners' level of achievement and understanding as summarised in Tables 4.6 and 4.7 has revealed that there was a great improvement between the pre-test and the post-test. On the other hand, the comparison group showed no improvement in high achievement levels. The use of a graphic calculator has assisted learners who scored at low achievement level to improve in the post-test and at all levels of achievement. The results from the questionnaire have also revealed that a great percentage of learners exposed to the intervention believed to be confident users of graphic calculators and agreed that the graphic calculator allows them to work with more challenging problems, not only in data handling, but also believe that it could be used in other mathematical topics. Teachers agree that learners should be allowed to use graphic calculators and 57% believe that it should be incorporated into the South African curriculum.

In conclusion, the theoretical framework has revealed that learners who were exposed to the intervention showed the ability to apply Action in a given mathematical problem, but could not interiorise it to a Process in a pre-test. However, in the post-test, learners could apply Action and Process conception, and could make the connection between Object and Process conception during the use of a graphic calculator as a technology tool. The constructs of the mental structure led to the development of the Schema. The findings of inferential statistics and descriptive statistical analysis support the alternate hypothesis that learning that is aided by a graphic calculator enhances understanding of data handling.

CHAPTER 5

Interpretation of Data and Discussion

5.1 INTRODUCTION

Interpretation of data and discussion aims at summarising the findings of the study, expanding on the hypothesis and responding to the research questions, and also presenting the limitations of the study and layout the recommendations for future research. This study aimed to investigate the effects of using a graphic calculator (GC) in learning Data Handling Grade 10, hence the study argues that the use of a graphic calculator enhances learners' conceptual understanding and problem-solving skills in learning Data Handling Grade 10. Previous research has yielded positive results on the effectiveness of the use of a graphic calculator as a tool of instruction and learning mathematics (Kee & Sam, 2004; Parrot & Leong, 2018; Roschelle & Singleton, 2008; Burril, 1996; Kor & Lim, 2004; Jung-Chih & Yung-Ling, 2015; Ye, 2011; Abu-Naja, 2008), and it is quite helpful to the development of conceptual understanding, visualisation, and achievement not only in data handling but in other mathematical topics as well. The results in this study are in agreement with the findings from previous studies that have recommended the use of a graphic calculator as a cognitive tool for mathematics learning.

5.2 HYPOTHESIS

This study bears the following null hypothesis: there is no difference between learning supported by graphic calculator technology and conventional learning. And in support of the null hypothesis, the directional hypothesis states that learning that is aided by a graphic calculator enhances understanding of Data Handling. The paired T-test was used to compare the difference in mean scores of both the comparison and the experimental group, and to determine the statistical difference between the mean scores of the experimental group and the comparison group.

The mean difference between the pre-test and the post-test in the comparison group was 1, 48, and were not statistically significant with p=0, 39>0, 05. Therefore, there was no difference between the achievement for the pre-test and the post-test scores of learners in the comparison group, hence the t-test revealed that there was no improvement between the pre-test and the post-test. Comparing the mean scores of the pre-test and the post-test of the experimental group, the mean difference was 7, 38 and was statistically significant with p=0,000<0, 05, this means that most learners scored higher in the post-test than in the pre-test. Looking at Figures 4.1.1 and 4.1.2, the plots which represent the post-test are positively skewed. However, they indicate that 50% of the learners in the experimental group scored higher than 75% of learners in the comparison, hence there is a slight improvement in the post-test in comparison with the pre-test for learners in the comparison group.

The paired t-test in this study has shown a statistically significant difference of p<0, 05, that is p = 0,000 in the experimental group compared to the comparison group which showed a difference of p>0, 05, that is p=0, 39 it is not statistically significant. The instructional tool, which is the use of a graphic calculator contributed greatly and that led to a significant improvement for learners in the experimental group. In contrast, conventional learning had no significant effect on learning Data Handling for learners in the comparison group. Applying the paired t-test to compare the mean values of the pre-test and the post-test between the comparison and the experimental group, the comparison group showed a mean difference of 1,488 (as illustrated in Table 4.2) in the pre-test and post-test and were not statistically significant (p= 0,039>0,005). In the experimental group, the variance between the pre-test and the post-test is a mean difference of 7,385 (as illustrated in Table 4.3) were statistically significant (p=0,000<0,005). Looking at box-and-plot in Figure 4.1.1 for the pre-test between the experimental and comparison group were statistically the same, in comparison with the post-test as illustrated in Figure 4.1.2 shows that the data is positively skewed. This indicates that the post-test showed an improvement.

The statistical difference between the comparison and the experimental group in the post-test result has demonstrated that learners who were not exposed to the use of a graphic calculator in learning Data Handling (M= - 1,488; SE = 0,698) while the results of the learners who were exposed to the use of graphic calculator in learning Data Handling (M= -7,385; SE= 0,521), this difference was significant at (t= 14,179), p=0,000 that is p<0,005 and represented a large effect size d=0,958 that is d>0,8 which emphasises that the use of a graphic calculator has contributed greatly to the learning of Data Handling as compared to the conventional learning. The intervention has effectively contributed to a significant enhancement in the experimental group, whereas the conventional learning had no significant impact on the learning of Data Handling. Therefore, this has led to the rejection of the null hypothesis and supports the directional/alternative hypothesis, that is, learning that is aided by graphic calculator/technology tool enhances the learners' understanding of Data Handling.

5.3 RESPONDING TO THE RESEARCH QUESTIONS

The primary research question posed in this study was: Does the use of graphic calculators have an effect on learning Grade 10 Data Handling?

The use of a graphic calculator in learning does not merely help learners improve their mathematics performance, as well as contributing significantly to their conceptual knowledge and understanding and obtains a better level of metacognitive awareness, and the graphic calculator is regarded as an efficient tool for learning as compared to the conventional learning (Tajuddin, Tarmizi, Konting, & Ali, 2009). Furthermore, graphic calculators are designed to facilitate active learning and to minimise time spent doing long repetitive calculations and graphs which are tedious and time-consuming, and have a positive impact on the learners' attitude towards the content area and other mathematical content areas (Kee & Sam, 2004; Reznichenko, 2007).

The analysis shows that the learners who were exposed to the use of a graphic calculator improved in their achievement level on the post-test as compared to the pre-test (see Figure 4.2.1) and were significant as the variance of the mean score was (M= -7,385; SE = 0,521), while on the other hand the levels of achievement were statistically the same between the pre-test and the post-test for the learners who were not exposed to the use of graphic calculators. In the post-test, learners in the experimental group have shown an ability to establish a link between numerical, tabular, and graphical representations, for example, they were able to work with ungrouped data and make an analysis using numerical values, such as the quartiles and the five-number summary, and represent them graphically. Secondly, they were able to make a mean estimation using grouped data and ungrouped data. This shows that learners were able to use multiple representations in the graphic calculator. Learners also developed a positive attitude towards the learning area, 92,5% of learners in the experimental group believed that the use of a graphic calculator helped them in learning Data Handling and it helped them to develop their mathematical thinking.

Further, learners find it easy to visualise tabulation and graphical representation on the calculator’s display. They developed the ability to learn Data Handling and the mathematical skills, such as problem-solving and also developed mental structures. This study provides answers to the two supporting research questions, as addressed below.

The two supporting research questions are addressed below.

5.3.1 How can graphic calculators be applied in learning Grade 10 Data Handling?

A paired t-test was used to determine the statistical difference for the mean scores for both the pre-test and the post-test, the statistically significant difference of $p<0, 05$, that is, $p = 0,000$, and $p>0, 05$, that is, $p = 0, 39$ between the experimental group and the comparison group affirm that the use of a graphic calculator enhances the learners’ understanding of Data Handling. The pre-test results of the learners in both the experimental and the comparison groups were statistically the same. Learners in both groups could not establish a link between the numerical and the graphical representation, and a lack of comprehension of the mathematical language led to the failure of mathematical computation, this was influenced by the formal traditional learning, for example, learners failed to identify the five-number summary in a given data set and could not represent that graphically.

The post-test results in the experimental group have improved significantly, and this shows that learning with the use of a graphic calculator took place, because learners were able to establish a link between the numerical and graphical representation and understood the mathematical language. This implies that the ability to learn was influenced by the use of the graphic calculator and this led to a high level of thinking and understanding, and the development of problem-solving.

Related to the APOS theory, this study has demonstrated a model of theoretical analysis (see Figure 2.8.1) that can be used to forecast the mental structures needed to learn the concept, and in this case, Data Handling. In this study, learners in the experimental group learned Data Handling using a graphic calculator as an instructional tool. This was intended to assist learners to develop conceptual understanding, and it is evident as it has been summarised in Tables 4.6 and 4.7 Learners in the experimental group have shown a great improvement in the post-test in contrast to the pre-test, there was an increase of 40,92% of learners performed in high achievement in the post-test. Therefore, the study avers that learning aided by instructional treatment (graphic calculator technology tool) helps learners to succeed in their learning (Dubinsky, 1994).

Mudrika (2016) states that during the learning process, through the construction process, learners can create new mental objects, new processes, and new schemes in the form of generalisation, interiorisation, encapsulation, coordination, and reversal. The performance of the learners related to these concepts (Action, Process, Object and Schema) was evaluated on the post-test to determine the effectiveness of the instructional tool, which is the graphic calculator; the APOS theory focuses on the ability to describe how an individual learns a specific mathematical concept, in this instance, Data Handling and the potential of showing the mental constructs as a learner moves through various stages of cognitive development. Learners faced with mathematical problems need to convert the mathematical language into the mathematical expression to show the Action conception. For example, when learners are required to determine the median and the mean, they should understand that the median is a middle value and the mean is an average of a data set. Secondly, learners can use the appropriate technology tool, in this instance graphic calculator. Both Process and Object conception can occur concurrently with the manipulation of the technology tool. The mental structures (Action, Process, and

Object) and other related mechanisms play an important role in the development of a Schema.

Every problem posed during the lesson and on the post-test required a learner to realise that they understood it through defining the problem and that led to the occurrence of mental action in learners. Learners understand the definition of measures of tendency and dispersion and using the given formula in a problem, actions are interiorised into process, they can estimate, calculate and the measures of tendency and dispersion, in this case, an existing schema is used as the basis for mental process, because when learners respond to the given problems, they construct mental processes as a means of understanding the concept. Learners try to perfect the problems as they respond to the given questions as they can represent the data numerically and graphically, which can be viewed as construction through coordination and reversal; by doing so, learners can be said to be in the process of constructing a new mental construct.

During the intervention, learners were taught Data Handling using a technology tool, a graphic calculator, and it was evident that learners were able to develop the mental structures at the process, object and schema levels. The ability of learners to represent data graphically facilitates the growth of mental structures at the process and object levels, while the ability to represent data numerically aids the object conception. The schema links the relevant actions, processes, and objects.

5.3.2 What are the effects of using graphic calculator as a cognitive tool in learning Data Handling?

Instruction of Data handling is highly influenced by formalist tradition, mathematical concepts are learned by rote learning and learners are trained through memorising the concepts (Makina & Wessels 2009; Meletiou-Marvrotheris, Paparistodemou, & Stylianou, 2009) which prepares them to search for one correct answer to the problem without having to understand and integrate it with other concepts. Learners in the comparison group could not easily recall the concepts and the teacher had to keep giving them answers to most of the questions throughout the lesson. The memorisation of the concept hinders the development of conceptual understanding and problem-solving skills, and learners cannot develop other mental structures during their learning process, because they rely on a given formula to perform a computation.

Cognitive technology use varies in what it is intended for. A graphic calculator is a cognitive tool that supports learning of Data handling and other mathematical concepts and it can support the learners' cognitive growth, mathematical thinking and understanding. Cognitive technologies are used to study the effect of technology tools in mathematics learning (Pea, 1987; Reznichenko, 2007). Previous studies have demonstrated that the use of a graphic calculator in mathematics learning provides learners with visualisation and exploration, enhances the learners' cognitive understanding, removes long calculations and other difficult tasks, and it takes less time (Chen & Lai, 2015; Graham & Thomas, 2000; Kee & Sam, 2004; Groves& Obregon, 2009; Reznichenko, 2007). In support of this, this study avers that learning with the use of graphic calculators has promoted conceptual understanding, visualisation, and exploration as learners were able to visualise the graphs, tables, and numerical representation with the calculator's display, and reduced the time spent on calculations and manipulations.

Learning Data handling using a graphic calculator in the experimental group encouraged a high level of thinking and understanding, and also created an environment that promoted mathematical thinking; thus, the graphic calculator has a great effort to take on some tasks in order that learners can concentrate on learning and understanding the concept. The appropriate use of a graphic calculator allows learners to move from formula-based approaches and repetition of tasks to real data situations (Burrill, 1996), and with the appropriate and proper use of a graphic calculator and through the facilitator's guidance, learners can work individual learning or cooperative learning. Intervention revealed that using of a graphic calculator leads to high achievement which shows learners' conceptual understanding and problem-solving. This indicates that the use of a graphic calculator had a positive impact on learners in the experimental group.

Questions in the learners' questionnaire for learners in the experimental group were grouped in such a way that they determine the learners' attitude towards the use of a graphic calculator and its effects. Previous studies have been conducted to assess the efficacy of the graphic calculator and the learners' perception of this technology tool (Groves & Obregon, 2009; Reznichenko, 2007). In support of these studies, this study has revealed that learners in the experimental group showed a positive attitude towards the use of a graphic calculator and their perception towards the content area and the subject, learners are confident users of the graphic calculator and that has motivated them to focus more on their learning. In addition, this study has revealed that learners were able to use multiple representations of the graphic calculator when working data and enables them to develop new thinking skills which is a build-up from the mathematical basic skills. In contrast, learners in the comparison group seem to differ as they associate understanding with doing the tasks manually because it helps them to understand. In addition, teachers believe that learners should be allowed an opportunity to use graphic calculators in learning Data Handling and other mathematical topics.

5.4 EVALUATING THE STUDY OBJECTIVES

5.4.1 Determine how graphic calculator support learning of Data Handling in Grade 10

Learning Data handling supported by the use of a graphic calculator has contributed greatly to the learners' high achievement and the development of the mental structures. Learners were able to move from the formalist approach of learning to technology learning which enhanced their mathematical thinking. They moved from the repetition of tasks that influenced memorisation to understanding the mathematical language used in data handling, by understanding the relationship between the numerical and graphical representation of data in the content area. The use of a graphic calculator in learning data handling did not only contribute greatly to the learners' high achievement as compared to the learners in the comparison group, but had a great influence on enhancing the learners' problem-solving skills and mathematical thinking.

5.4.2 Determine the effects of using graphic calculators in learning Data Handling

This study has revealed the improvement from low level of understanding to a high level of understanding in learning data handling (Tables 4.6 and 4.7). The learners have shown the ability to learn data handling enhanced by the graphic calculator which led to the high level of mathematical thinking and understanding. Secondly, there was improved visualisation and exploration skills because access to a graphic calculator in the experimental group allowed multiple representation and manipulation of data; it also removed long calculations and other difficult tasks reduced the time spent on simple calculations and manipulations. Therefore, this helped learners to focus more on learning and their conceptual understanding was enhanced.

Learners lack statistical thinking because learning of data handling is greatly influenced by the formalist approach to learning, and this has contributed greatly to the learners' negative attitude towards the content area and other mathematical topics. However, this study has revealed that the integration of a graphic calculator in learning data handling influences how learners perceive data handling and other mathematical contents/ topics. Idris (2004) states that the use of a graphic calculator has a positive impact on the learners' self-confidence, and reduces mathematical anxiety during problem-solving. Therefore, this study asserts that learners who utilise the graphic calculator during problem-solving are motivated and can direct their attention to enhancing their mathematical thinking and high achievement.

5.4.3 Compare the cognitive development of learners supported and that of learners not supported through the usage of a graphic calculator

According to Reznichenko (2007), many studies have revealed positive results of the use of a graphic calculator as a tool of learning. However, the research must go beyond the effectiveness and address the impact that it has on the actual learning process and how it functions as a cognitive technology. This study does not only focus on the effectiveness of the graphic calculator, but also addresses how it functions as a cognitive tool. Learners do not lose basic mathematical skills during learning using a graphic calculator. However, it takes less time by minimising routine calculations and gives learners an opportunity to focus on their learning. With the appropriate use of a graphic calculator, learners can avoid long calculations and dedicate more time to focusing on conceptual understanding, developing higher order thinking skills, and learning relevant application, and a graphic calculator can undertake cognitive processing on behalf of the learner (Tajuddin, Tarmizi, Konting, & Ali, 2009). This study has revealed that the graphic calculator can support mental computation and mathematical thinking. It also shows that the learners' ability to learn data handling was enhanced by the use of the graphic calculator which led to a high level of thinking and conceptual understanding. This was illustrated in Figure 4.2.1 which shows a great number of learners in the experimental group have improved in post-test result because the number of learners who excelled at a high level improved by 40,92%. The study has revealed that learners who were exposed to the use of graphic calculators had the potential to develop mental structures in comparison to those who learnt data handling utilising the traditional method of learning, and the development of mental structures influenced the development of mathematical knowledge in data handling.

5.5 Implications of the study

5.5.1 Theoretical Implications

Learning occurs only when the learners' minds form a mental structure in accordance with the given mathematical concept; if the expected mental structures are not formed, learning does not occur, or learning about the concept does not work (Syamsuri & Santosa, 2021). A misconception or lack of understanding of a mathematical concept needs to be described through mental structures. Therefore, a learning treatment that promotes mastery and understanding of a mathematical concept is required. This study has revealed that learning Data Handling with the use of a graphic calculator has encouraged learners to develop mental structures and make a connection between multiple representations that the graphic calculator can provide. Learners were able to understand the mathematical language and convert it into a mathematical expression. Data Handling requires a learner to make sense of the mathematical language used before performing a mathematical computation, which shows the Action conception. With the appropriate use of a graphic calculator, learners were able to make a connection between the calculator's multiple representations, hence the process and the object conception occurred at the same time, and the schema conception is enhanced by the manipulation of the graphic calculator.

5.5.2 Methodology Implication

This study draws from the positivist philosophy which holds that all knowledge is based on sensory experiences and can only be obtained using scientific methods. In this study, an experiment was done through the application of an intervention. Following the empiricist tradition, the results were obtained through inferences and descriptively. This study followed a quantitative approach, where an intervention was only implemented in the experimental group and the comparison group did not receive the intervention. This was for comparison purpose, that is, to ensure that the intervention has impacted learning. A test can be administered only to learners who were taught. Therefore, while intervention occurred in the experimental group, teaching had to take place as usual in the comparison group. Therefore, lessons in the usual conventional teaching and learning way were observed in the comparison group. For the triangulation purpose, questionnaires were distributed to both the experimental and comparison group at the end of the post-test. The data analysis through the paired t-test addressed the significance of the intervention and the questionnaire addressed the perspectives and attitudes of teachers and learners. The significant difference has led to the rejection of the null hypothesis; therefore, the findings of the study support the alternative hypothesis, furthermore, the evidence provided by the achievement test and the questionnaire supports the alternative hypothesis. The positivist philosophy strives to investigate, confirm, and predict law-like patterns. This study affirms that using technology tool as a tool for learning and teaching contributes greatly to the development of cognitive growth.

5.5.3 Pedagogical Implications

This study has revealed that learning using a technology tool, a graphic calculator, is more effective than learning influenced by the formalist approach. The use of a graphic calculator in learning Data Handling has encouraged a learner-centred approach. It allows visualisation and exploration. It also empowers learners to do multiple representations, for example, representation as charts, tables and other numerical measures, such as mean, median, mode, and range. Furthermore, learners are led to a high level of thinking, therefore, the learners are motivated to focus on their learning. The ability of learning was enhanced by the use of a graphic calculator, the study also revealed that the use of a graphic calculator allowed the learners to develop a positive attitude towards the Data handling content area and other mathematical-related content areas.

In the implementation of the intervention, time always remained a constraint. More time is required for the learners to familiarise themselves with other features of the calculator to use for Data handling, and also realise the benefits of the calculator, not just as a tool but as a tool that can enhance their cognition. More time is also needed for the learners to learn at their own pace where the teacher guides them step by step to allow a learner-centred approach and the ability to construct their own ideas. The lack of availability of the resources should not be the reason for the facilitator not to encourage learner-centred activities, and a high level of thinking and understanding. For example, participating learners in the experimental group were compelled to share the graphic calculator during learning as the facilitator could not provide for every learner. However, the South African curriculum does not allow the use of programmable calculators. The intervention in this study has revealed that access to the use of a graphic calculator, proper guidance, and clear direction on how to operate the graphic calculator as an instructional tool of learning can enhance cognitive growth and conceptual understanding through this cognitive tool.

5.6 Conclusion

5.6.1 Conclusion from Literature

Studies have revealed that research must go beyond the effectiveness of the graphic calculator and address fundamental questions about the actual process of how it functions as a cognitive tool for learning mathematics. Furthermore, it should impact the performance of the learners in all spheres of mathematical problem-solving. Teachers need to choose the appropriate activities that will not only allow the use of a graphic calculator but also lead to a high level of thinking and understanding. The use of a graphic calculator allows the comprehension of the relationship among graphical, tabular, numerical, and algebraic representations, learners find it easy to visualise graphical and numerical representations on the calculator's display.

Graphic calculators as a cognitive tool enable learners to take the traditional tasks to another level by avoiding the sequence calculations that will take more time which can be used to develop the learners' understanding and their cognitive growth. In addition, a graphic calculator is an 'all-round tool' that can be used to enhance the learners' learning and has a positive impact on the learners' ability to solve problems, encourage visualisation, and exploration. Understanding and cognitive growth of the concepts are influenced by the development of stages of mental structures, and once a learner has developed all the stages of mental structures, they can make a connection of understanding of the concepts.

5.6.2 Conclusion from Quantitative methodology

The implementation of the intervention had a great influence on the performance scores of the learners in the achievement test. The inferential statistics have shown a significant difference of $p= 0{,}000$; $p<0{,}005$ in the experimental group, and this shows that the graphic calculator supports the learning of Data Handling. Descriptive analysis has also shown a great improvement in all levels of achievement from the pre-test to the post-test in the experimental group as compared to the comparison group, and as the increase in the experimental group is attributed to the treatment/intervention, it was found that there was a slight improvement in the level of achievement in the comparison group. Furthermore, the response to the questionnaire has also shown that learners in the experimental group have developed a favourable attitude towards the use of a graphic calculator as a tool for mathematics learning. Learning with a graphic calculator encourages a learner-centred approach. When compared to the comparison group, learners were able to generate graphs effortlessly and quickly.

5.7 Limitations to the study

General conclusions cannot be made in this study because the selected Grade 10 learners from Vhembe West and Vhembe East, and the conditions and the setting of the schools in the selected Districts might not be the same as that of the other schools in different parts of the country. In addition, this study only focuses on one concept of mathematics, that is, Data Handling. However, the inferences drawn from this study can also be used to suit another mathematical concept. Other external factors such as learners withdrawing to be part of the research and absenteeism have contributed greatly to the attrition in the post-test, mainly in the comparison group. Limitations may help in the recommendation of future research. However, regardless of the limitations, this study has revealed positive outcomes in using a graphic calculator as a cognitive tool for learning Data Handling.

5.8 Recommendations

This study investigated the effects of using a graphic calculator as a cognitive tool for learning Data Handling Grade 10. The graphic calculator was implemented to enhance or support learning in Data Handling. The implementation anticipates to assist learners to develop a positive attitude towards the subject, as well as assisting teachers and subject specialists in mathematics with techniques to support the learning of Data Handling. This study has revealed that the use of a graphic calculator had an effect on learners, thereby improving from low achievement to high achievement which led to a high level of mathematical thinking and understanding. In addition, the study revealed that the use of a graphic calculator allows learners an opportunity to develop different stages of mental structures through the APOS theory. To fully assess the possible results on how learners interact with the technology tool, a different setting for research is required. Furthermore, the graphic calculator should be allowed to play a central role in learning mathematics, and its use be permitted during the writing of tests and examination.

5.9 Recommendation for further Research

Both teachers and learners need to have a positive attitude towards the use of graphic calculators in learning mathematics, the use of a graphic calculator enhances the learners' conceptual understanding and the development of cognitive growth. Some of the teachers in the experimental group were sceptical about implementing a graphic calculator in learning Data Handling, mainly because they were not exposed to it, and it is not permitted during the writing of tests and examinations. Furthermore, learners in the comparison group are still struggling to make a connection between the graphical and numerical representation of data. Therefore, this study recommends the use of a graphic calculator as a cognitive tool in classroom problem-solving, tests, and examinations. Furthermore, teachers and learners should uphold a positive attitude towards the usage of a graphic calculator in classroom problem-solving. Many studies that have reported the positive outcome of the intervention are mostly in developed countries. Therefore, further research is recommended and the focus should be on the South African curriculum.

REFERENCES

Abu-Naja, M. (2007). Abu-Naja, M. (2008). The Influence of Graphic Calculators on Secondary School Pupils' Ways of Thinking about the Topic" Positivity and Negativity of Functions". International Journal for Technology in Mathematics Education, 15(3).

Ary, D., Jacobs, L.C. & Sorensen, C.K. (2010). *Introduction to Research Education* (8^{th} Ed). Wadsworth, Cengage Learning, USA.

Asiala, M., Brown, A., DeVries, D. J., Dubinsky, E., Mathews, D., & Thomas, K. (1997). A framework for research and curriculum development in undergraduate mathematics education. Maa Notes, 2, 37-54.

Bansilal, S. (2014). Using an APOS Framework to Understand Teachers' Responses to questions on the Normal Distribution. University of Kwa-Zulu Natal, South Africa. *Statistics Education Journal*, 13(2).

Beckers, J. & Van Niekerk, R.W. (2021). Mathematics teachers' perceptions on the use of Graphic calculators and other digital tools. Elndhoven University of Technology. Netherlands

Berger, B. (1997). A Mediating Role for the Graphic Calculator. University of Witwatersrand, South Africa.

Berry, J. & Graham, T. (2005). On high-school students' use of graphic calculators in mathematics. *ZDM*, 37(3), 140-148.

Berry, J., Graham, T., & Smith, A. (2005). Classifying Students' Graphic Calculator Strategies. *International Journal for Technology in Mathematics Education, 12(1)*

Chagwiza, C.J. (2019). *Exploration University Students' Mental Constructions of the limit concept in relation to sequence and series*. University of KwaZulu Natal. South Africa.

Chen, J. & Lai, Y. (2015). A Brief of Research on the use of Graphic Calculator in Mathematics Classroom. National Chiayi University. Taiwan. *International Journal of Learning, Teaching and Educational Research*. 14 (2), 63-172

Clark, J., Kraut G., Mathews, D. & Wimbish, J. (2007). *The Fundamental Theorem of Statistics: Classifying Student Understanding of Basic Statistical Concepts.* Hollins University, Roanoke Virginia.

Cohen, L, Manion, L, & Morrison, K. (2007). *Research Methods in Education*. 6th edition, Routledge Publications. New York.

Cohen, L, Manion, L. & Morrison, K. (2005). *Research Methods in Education*. 5th Edition. Taylor & Francis e-Library. New York.

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education*.8th Edition, Routledge, New York.

Department of Education. (2011). National Curriculum Statement (Curriculum Assessment Policy: Mathematics) (Grade 10-12). Department of Basic Education South Africa.

Department of Education. (2011). National Curriculum Statement: Curriculum and Assessment Policy (CAPS). FET (Grade 10-12) Mathematics. Department of Basic Education South Africa.

Department of Mathematics & Science Education, Faculty of Education. Universiti Malaya. 2nd National Conference on Graphing Calculators.

Dror, I.E & Harnad, S. Eds. (2008). *Cognition distributed: How cognitive technology*

Dubinsky, E., & McDonald, M.A. (2001). APOS: A constructivist theory of learning in undergraduate mathematics education research. In *The teaching and learning of mathematics at university level,* pp.275-282. Springer, Dordrecht.

Dubinsky, Ed. & McDonald, M. A. (2002). *APOS: A Constructivist Theory of Learning in Undergraduate Mathematics Education Research*. Georgia State University, USA.

Eyyam, R. & Yaratan, H.S (2014). Impact of the Use of Technology in Mathematics

Fidelity and General Education Research Journals. *Journals of Special Education*, SAGE.

Franklin, C., Kader, G, Mewborn, D.S, Moreno, J, Peck, R, Perry, M & Scheaffer, R. (2005). A curriculum framework for K-12 statistics education. GAISE report.

Gage, J.A. (2005). Is the graphic calculator a useful mediating tool for students in the early stages of forming a concept variable? The Open University.

Graham, T., Headlam, C., Honey, S., Sharp, J. & Smith, A. (2003). The use of graphic calculators by students in an examination: what do they really do? *International Journal of Mathematical Education in Sciences and Technology, 34(3). 319-334*

Groves, S & Obregon, D (2009). The Graphic Calculator as a Thinking Tool: Perspective from the classroom. Deakin University; Western Visayas College of Science and Technology, Philippines.

Grzadzielwski, A.A. (2005). The validity of student self-report about the effectiveness of graphing calculators in an undergraduate mathematics classroom. University of Washington.

Hangzhou Normal University. China.

Hiebert, J., Stigler, J. & Manaster, A.B. (1999). Mathematical features of lessons in the TIMMS Video Study. ZDM, 31(6), 196-201.

Idris, N. (2004). Exploration and Entertaining Mathematics: Why Graphic Calculator?

Idris, N., Nor, M.N., Chew, C.M., Lim, H.L. & White, A. (2010). *Comparative studies on the integration of graphing calculator in mathematics assessment in Australia, Singapore, and Malaysia*. Malaysia: Mc Graw Hill.

Inkpen, K.M. (1999). Designing handheld technologies for kids. *Personal Technologies* 3, 81-89.

International Group for the Psychology of Mathematics Education, Vol. 4, pp.257264 (Teacher Factor in Integration of Graphic Calculators into Mathematics Learning). Melbourne: PME.

Inzunsa, S. & Quintero, G. (2007). The information and communication technologies as cognitive tools in the teaching and learning Probability and Statistics. Proceeding of the International Systems, Technologies and Applications, Orlando FL,

Kamid, K, Huda, N, Rohati, R, Safari, S, Iriani, D. & Anwar, K. (2021). Development of Mathematics Teachings Based on APOS Theory: Construction of Understanding the concept of Students Straight Line Equation. *Ta'dib,* 24(1), pp.81-92.

Khobo, R.J. (2015). *The effect of using computers for the teaching and learning of mathematics to Grade 10 learners at the secondary school*. (Doctoral dissertation, University of South Africa. Department of Mathematics Education.

Kissane, B., McConne, A., & Ho, K.F. (2015). Review of the use of technology in mathematics education and related use of CAS calculators in external examinations and in post-school tertiary education settings. Perth, WA: School Curriculum and Standard Authority.

Kothari, CR (2004). *Research Methodology Methods and Techniques*. 2nd Edition. New Age International Publishers. India.

Krishnana, S. & Idris, N. (2013). The Use of Graphic Calculator in a Matriculation Statistics Classroom: A Malaysian Perspective. *Technology Innovations in Statistics Education*, 7(2), *1-13.*

Leong, K.E & Parrot, M.A.S. (2018). Impact of Using Graphing Calculator in Problem Solving. University of Malaya. Malaysia. *International Electronic Journal of Mathematics Education*. *13, 139-148.*

Lessons on Student Achievement and Attitudes. Eastern Mediterranean University. *Journal of Social Behaviour and Personality: an international journal, 42(1), 31S42S*.

Maharaj, A. (2013). An APOS Analysis of Natural Science Students' Understanding of Derivatives. School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal. South Africa. *South African Journal of Education*, 33(1), 1-19

Makina, A., & Wessels, D. (2009). The role of visualisation in data handling in Grade 9 within a problem-centred context. Pythagoras, 2009(69), 56-68.

Makwakwa, E. (2012). Makwakwa, E. (2012). Exploring problems encountered in the teaching and learning of statistics in grade 11 (Doctoral dissertation).

Mathematics Science Education Board. (1990). Reshaping School Mathematics, Washington DC: National Research Council. *The Science Teacher, 58(1), p.84*

Mathews, D. & Clark, J. M. (2003). Successful Students' Conceptions of Mean, Standard deviation, and the Central Limit Theorem. https://www.researchgate.net/publication/253438034

Meel, D. E. (2003). Models and theories of mathematical understanding: Comparing Pirie and Kieren's model of the growth of mathematical understanding and APOS theory. CBMS Issues in Mathematics Education, 12(2), 132-181.

Meletiou-Mavrotheris, M., Paparistodemou, E. & Stylianou, D. (2009). Enhancing Statistics Instruction in Elementary Schools: Integrating Technology in Professional Development. *The Mathematics Enthusiast*: 6(1), 57-58.

Mitchelmore, C.M. & Cavanagh, M. (2012). Students' difficulties in operating a graphic calculator. *Mathematics Education Research Journal*. 12(3):254-268.

Mudrikah, A. (2016). Problem-Based Learning Associated by Action-Process-Object-Schema (APOS) Theory to Enhance Students' High Order Mathematical Thinking Ability. International Journal of Research in Education and Science, 2(1), 125-135.

Muijs, D. (2004). *Doing Quantitative Research in Education with SPSS*. Sage Publication. London.

Mukavhi, L. Brijlall, D. & Abraham, J. (2021). An APOS Theory-Technoscience Framework to understand Mathematical Thinking. *Journal of Critical Reviews*. *8(2), 126-135.*

Mutodi, P. & Ngirande, H. (2014). The Influence of Students' Perceptions on Mathematics Performance. A case of Selected High School in South Africa. *Mediterranean Journal of Social Sciences*. 5 (3), 431.

Naidoo, J. & Mkhabela, N. (2017). Teaching Data Handling in foundation phase: Teachers' experience. *Research in Education, 97(1), 95-111*

National Council of Teachers of Mathematics (2015). Strategic use of Technology in Teaching and Learning Mathematics. A Position Council of Teachers of Mathematics.

National Education Collaboration Trust. (2016). The status of ICT in Education in South Africa and the way forward.

Ndlovu, L. & Ndlovu, M. (2020). The effect of graphing calculator use on learners' achievement and strategies in quadratic inequality problem solving: Pythagoras, *41(1), a552: https://doi.org/10.4102/pythagorus. V41i1.552*

Ndlovu, M. (2021). Paradigms in Mathematics Teacher Professional Learning Research: A Review of South Africa's Literature for 2006-2015. *Mathematics Teaching and Professional Learning in sub-Sahara Africa. 167-187*

Ndlovu, M. (2021). Paradigms in Mathematics Teacher Professional Learning Research: A Review of South Africa's Literature for 2006-2015. In: Luneta, K (Eds.) Mathematics Teaching and Professional Learning in sub-Sahara Africa. Research in Mathematics Education. Springer, Chm. https://doi.org/10.1007/978-3-030-82723-6_11

Nelson, M, Cordray, D.S, Hulleman, C.S, Darrow, C.L. & Sommer, E.C. (2012). A Procedure for Assessing Intervention Fidelity in Experiments Testing Educational and Behavioral Interventions. *Journal of Behavioral Health Services & Research*. Volume 39 (4).

Oktac, A, Triguesros, M & Romo, A. (2019). APOS Theory: connecting research and teaching. Douglas College, Faculty of Science & Technology, Canada. FLM Publishing Association. 39 (1).

Pea, R.D. (1987). Cognitive Technologies for Mathematics Education. In A. Schoenfeld (1987). *Cognitive Sciences and Mathematics Education*, Hillsdale, NJ: Erlbaum, 89122.

Pehkonen, E. (2007). Problem solving in mathematics in Finland. WG2, Topic 8, 9.

Penglase, M. & Arnold, S. (1996). The Graphics Calculator in Mathematics Education: A Critical Review of Recent Research. The University of Newcastle. Mathematics *Education Research Journal*. *8 (1), 58-90.*

Person, P. (2011). How Teachers can use TI-Nspire CAS with laptops in an upper secondary course. *The Electronic Journal of Mathematics and Technology*, *8(4), 257-273*

Pirie and Kieren's Model of the Growth of Mathematical Understanding and APOS Theory. *CBMS Issues in Mathematics Education*. Volume 12(2), pp. 132-181

Reznichenko, N. (2007). Learning Mathematics with Graphic Calculator: A study of students' experiences. *Online Submission*.

Rhea, M.R. (2004). Determining the Magnitude of Treatment Effects in Strength Training Research Through the use of Effect size. *Journal of Strength and Conditioning Research*.18 (4), 918-920.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context.* Oxford University Press.

Roschelle. J. & Singleton, C. (2008). *Graphing Calculators: Enhancing Math Learning For All Students*. SRI. International, USA.

Schema (APOS) Theory to Enhance Students' High Order Mathematical Thinking Ability. *International Journal of Research in Education and Science (IJRES)*, 2(1), 125-135.

Shaughnessy, M, Garfield, J, & Greer B. (1996). International handbook of mathematics education, 205-237.

Sullivan, GM & Feinn, R. (2012). Using Effect size- or Why the p Value is not enough. *Journal of Graduates Medical Education.* 4(3), 279-282

Swanson, E., Wanzek, J., Haring, C., Ciullo, S., & McCulley, L. (2013). Intervention fidelity in special and general education research journals. The Journal of Special Education, 47(1), 3-13.

Syamsuri, S. & Santosa, C.A. (2021). Thinking structure of students' understanding of Probability Concept in Term of APOS Theory. *MaPan: Jurnal matematika dan Pembelajaran, 9(1), 119-135.*

Tajuddin, N.M, Tarmizi, R.A, Konting, M. & Ali W.Z.W. (2009). Instructional efficiency of the integration of graphing calculators in teaching and learning mathematics. Institute for Mathematical Research. University Putra Malaysia. *International Journal of Instruction*. *2 (2), 12-27.*

Waits, B. K., & Demana, F. (2000). Calculators in mathematics teaching and learning: Past, present and future. In M. J. Burke (Ed.), *Learning mathematics for a new century* (pp. 516). Reston, VA: National Council of Teachers of Mathematics.

Wessels, H. (2011). Statistics in the South African School Curriculum: Content Assessment and Teaching Training. North West University, South Africa.

Wessels, H. (2011). Teachers' Professional needs in data handling and probability, *Pythagoras*, 32(1), Art#10, 9 pages. Doi:10.4102/*Pythagoras*.v32iq:10

Ye, L. (2009). Integration of graphing calculator in mathematics teaching in china. *Journal of Mathematics Education*, 2(2), 134-146.

APPENDICES

APPENDIX A: Lesson preparation

WORKBOOK

Lesson 1

Topic: Data Handling: Measures of central tendency of grouped and ungrouped data

Concepts and skills to be covered:

By the end of this lesson learners should be able to:

- Estimation of mean of grouped and ungrouped data
- Estimate where the median lies in grouped and ungrouped data Identify the modal value/ modal interval(s)

Resources: Textbook; Textbook, Graphic Calculator (Casio Fx-9750GII)

Prior Knowledge: Measures of central tendency in the Senior Phase

Introduction

Ask learners how we can find different averages for data, the focus of this lesson is on the three averages, they are called measures of tendency, looking at one value that can represent the whole data set. It is therefore a measure (value) that takes all the data into account but goes towards one value only (the data is tending towards one central value).

- Mean – sum of all values in the set of data then divide by the number of values
- Median – ensure that the data is in order (ascending order-Lowest to Highest), we can use a stem-and-leaf (stem-1st digit, the tens column; and the leaf-2nd digits, the units); then find the middle value. If there is an even set of values, add the two middle values and divide by 2.
- Mode- look for the value that appears most often. It is easy to do this ranked set of data

Instruct learners to work on their own

ACTIVITY 1: Ungrouped Data

1. Given data: ages of people working in an institution

   Determine the mean; median; and mode

   44 31 45 21 35 34 48 49 32 28

Work on your own

(i) Arrange in ascending order using stem-and-leaf

0 |
1 |
2 |
3 |
4 |
5 |

Given data: 44 31 45 21 35 34 48 49 32 28 21

0	
1	
2	
3	
4	

Mode =

Activity 2: Grouped Data

Given data: 32 learners wrote a test and these are the results

29 30 47 46 51 38 56 78

44 59 45 61 35 34 48 49

45 62 37 29 53 52 46 55

22 26 23 56 35 68 44 45

(i) Group the data using a stem-and-leaf

(ii) Draw a frequency table

(iii) Estimate the mean, identify where the median lies, and the mode

Stem-and-leaf

0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

(ii) Frequency Table

Interval	Frequency	Cumulative Frequency	Midpoint
0 ≤ x < 10			
10 ≤ x < 20			
20 ≤ x < 30			
30 ≤ x < 40			
40≤ x < 50			
50 ≤ x < 60			
60 ≤ x < 70			
70 ≤ x < 80			
80 ≤ x < 90			
90 ≤ x < 100			
TOTAL			

Lesson 2

Topic: Measures of Dispersion

Concepts and skills to be covered

By the end of this lesson learners should be able to:

- Measures of dispersion: range, percentiles, quartiles, interquartile and semi interquartile range.

Resources: Workbook, Textbook, Graphic Calculator

Prior knowledge: measures of dispersion covered in the Senior Phase

Introduction

Ask learners what is a range, tell learners that this is a measure of dispersion, meaning to spread. There are other measures of dispersion, such as, quartiles (dividing the data into four equal parts) and percentiles (dividing the data into 100 equal parts).

Instruct learners to do an activity, learners are expected to work on their own

Activity 1

1. Given a set of data:

44 31 45 21 55 34 48 49 32 65 80

(I) Determine the range

(II) Calculate the inter-quartile range

Stem-and leaf

Lesson 3

Topic: Five number summary; graphs to analyse grouped and ungrouped data

Concepts and skills to be covered

By the end of this lesson learners should be able to:

- Values of five-number-summary: minimum, lower quartile(Q1), median(Q2), upper quartile(Q3), and maximum
- Analysing grouped and ungrouped data using graphs: bar graphs; histogram; scatter plot

Resources: Work book, Textbook, Graphic calculator

Prior Knowledge: measures of dispersion

Activity 2

Given data: A car dealer ask 20 customers to rank his service on a scale of 1 to five. The results are as follows: 5 3 4 5 4 3 4 5 3 2

2 4 5 1 2 1 4 2 4 2

Draw a graph to represent the data above.

Grouped data

Given a set of data: 32 learners wrote a test and these are the results

29 30 47 46 51 38 56 78

44 59 45 61 35 34 48 49

45 62 37 29 53 52 46 55

22 26 23 56 35 68 44

(i) Arrange the data in a stem-and-leaf

(ii) Complete the frequency table

(iii) Represent the data in a histogram

Stem-and-leaf

0
1
2
3
4
5
6
7
8
9

Frequency table

Interval	Frequency	Cumulative Frequency	Midpoint
0 ≤ x < 10			
10 ≤ x < 20			
20 ≤ x < 30			
30 ≤ x < 40			
40≤ x < 50			
50 ≤ x < 60			
60 ≤ x < 70			
70 ≤ x < 80			
80 ≤ x < 90			
90 ≤ x < 100			
TOTAL			

Histogram

APPENDIX B: Assessment Task

Pre- and Post-test

School code: ……………………………………

Learner Code: ………….

Age: ………………..

Grade: ………………

Gender: ……………..

The objectives of this test are to: ……

- Enable learners to develop new thinking skills, reasoning, and mathematical understanding of Data Handling.
- Effects of Graphic calculator- to help learners to use and construct multiple representation, algebraic, tabular, and graphical representations

Instructions

- Answer all questions
- Show all calculations
- Write neatly and legible
- Answers will be treated confidentially
- This question paper is also an answer sheet

Total: 25 Marks

Duration: 1 Hour

Question 1

Sam is working at Gadget store, below is the data that shows the number of laptops that he sold for a period of 15 months.

43 48 62 52 46 90 58 37 48 73 84 68 54 34 78

1.1 Determine the median of the number of laptops sold. (2)

…………………………………………………………………………………………

1.2 Calculate the range of the data. (2)

…………………………………………………………………………………………

1.3 Calculate the interquartile range (IQR)

…………………………………………………………………………………………

1.4 Draw a box and whisker diagram for the data above. (3)

…………………………………………………………………………………………

1.5 Identify the outlier in a box-and-whisker diagram (1)

…………………………………………………………………………………………

Question 2

The age limit for entering Miss South Africa beauty pageant is between the ages of 20 and 28. Below is the ages of Miss SA Top 35 2020

21 27 24 27 20 24 23 24 23 24 24 23 21 25 27 21 24 25 24 24 23 21 24 25 22 25 26 24 23 24 25 23 23 23 21

AGES	FREQUENCY
$20 \leq A < 22$	6
$22 \leq A < 24$	8
$24 \leq A < 26$	10
$26 \leq A < 28$	11

2.1 Identify the interval in which the median lies. (2)

………………………………………………………………………

$$= \frac{1}{n}\sum$$

2.2 Write down the modal class for the data. (2)

2.3 Estimate the mean of the data. (2)

2.4. Represent the given data in a histogram. (2)

2.5. Calculate the percentage of contestants which are below the age of 24 (2)

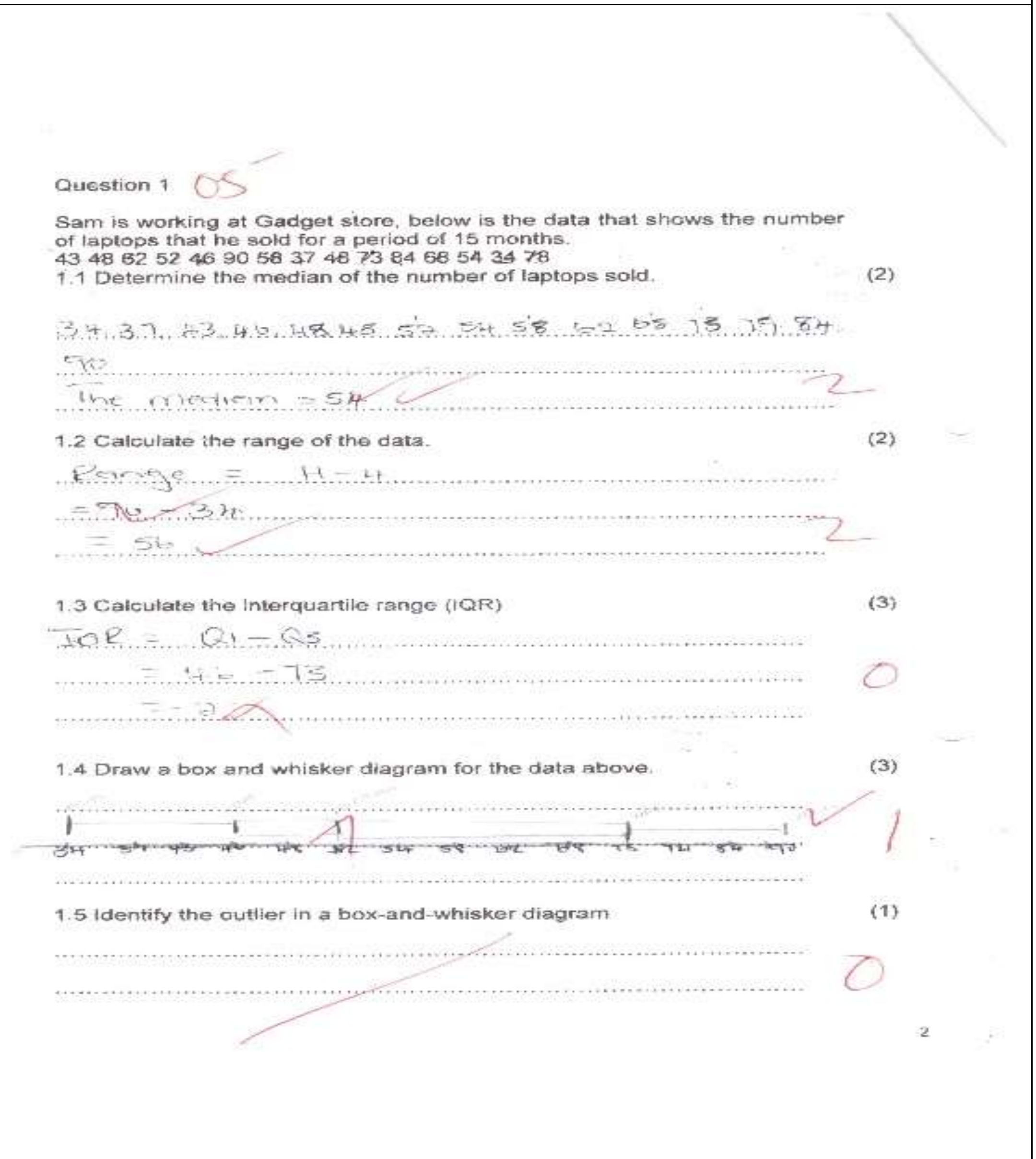
APPENDIX C: Pre- and Post-test Extracts

Extracts (E)

1. Action-Process conception mental structures (Question 1)

E1

L28 - Pre-test



Question 1 05

Sam is working at Gadget store, below is the data that shows the number of laptops that he sold for a period of 15 months.
43 48 62 52 46 90 56 37 46 73 84 66 54 34 78

1.1 Determine the median of the number of laptops sold. (2)

34, 37, 43, 46, 48, 48, 52, 54, 58, 62, 66, 73, 75, 84, 90

The median = 54

1.2 Calculate the range of the data. (2)

Range = H − L
= 90 − 34
= 56

1.3 Calculate the Interquartile range (IQR) (3)

IQR = Q1 − Q3
= 46 − 73
= −27

1.4 Draw a box and whisker diagram for the data above. (3)

1.5 Identify the outlier in a box-and-whisker diagram (1)

2

E2

L28: Post-test

Question 1 08

Sam is working at Gadget store, below is the data that shows the number of laptops that he sold for a period of 15 months.
43 48 62 52 46 90 58 37 48 73 84 68 54 34 78

1.1 Determine the median of the number of laptops sold. (2)

34, 37, 43, 46, 48, 48, 52, 54, 58, 62, 68, 73, 78, 84, 90

Median 54 — 2

1.2 Calculate the range of the data. (2)

Range = H - L

= 90 - 34

= 56 — 2

1.3 Calculate the interquartile range (IQR) (3)

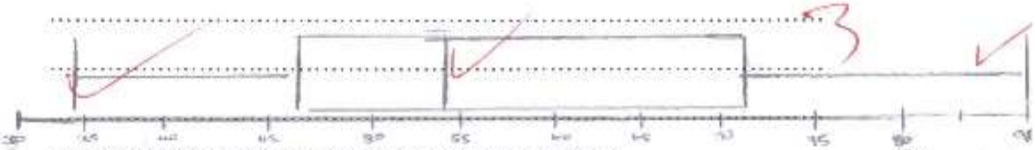
Interquartile = $Q_3 - Q_1$

= 44.5 - 45 - 73

= 27 — 1

1.4 Draw a box and whisker diagram for the data above. (3)

3



1.5 Identify the outlier in a box-and-whisker diagram (1)

The outlier in a box and whisker diagram is less equal to the negative side — 0

6

E3

L39: Pre-test

Question 1 00

Sam is working at Gadget store, below is the data that shows the number of laptops that he sold for a period of 15 months.
43 48 62 52 46 90 58 37 48 73 84 68 54 34 78

1.1 Determine the median of the number of laptops sold. (2)

Q² = 37 laptops

0

1.2 Calculate the range of the data. (2)

Range = H − L
78 − 43
= 35

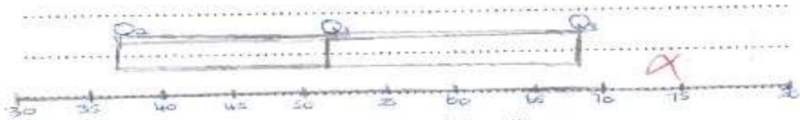
0

1.3 Calculate the interquartile range (IQR) (3)

IQR = Q3 − Q1
68 − 52
= 16

0

1.4 Draw a box and whisker diagram for the data above. (3)



0

1.5 Identify the outlier in a box-and-whisker diagram (1)

the outlier is Q3

0

2

E4

L39- Post-test

34, 37, 43, 46, 45, 46, 52, 54, 58, 62, 68, 73, 78, 84, 90

Question 1 10

Sam is working at Gadget store, below is the data that shows the number of laptops that he sold for a period of 15 months.
43 48 62 52 46 90 58 37 48 73 84 68 54 34 78

1.1 Determine the median of the number of laptops sold. (2)

54 2

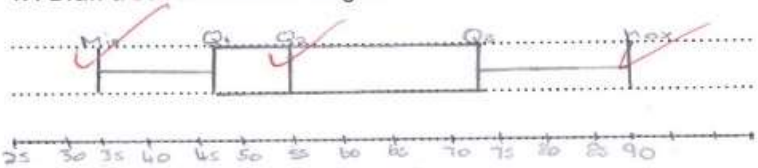
1.2 Calculate the range of the data. (2)

H – L
90 – 34
= 56 2

1.3 Calculate the interquartile range (IQR) (3)

Q3 – Q1
73 – 46
= 27 3

1.4 Draw a box and whisker diagram for the data above. (3)



3

1.5 Identify the outlier in a box-and-whisker diagram (1)

the box is bigger and stretching from Q1 to Q3 leaving a big space 0

6

E5

L47: Pre-test

Question 1 05

Sam is working at Gadget store, below is the data that shows the number of laptops that he sold for a period of 15 months.
43 48 62 52 46 90 58 37 48 73 84 68 54 34 78

1.1 Determine the median of the number of laptops sold. (2)

54 ✓ 2

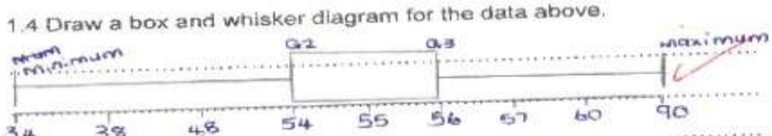
1.2 Calculate the range of the data. (2)

H-L
= 90-34
= 56 ✓ 2

1.3 Calculate the interquartile range (IQR) (3)

IQR = Q3-Q1
= 34+90
= 56 0

1.4 Draw a box and whisker diagram for the data above. (3)



1

1.5 Identify the outlier in a box-and-whisker diagram (1)

The are Minimum because of box-and-whisker is the highest quartile range 0

2

E6

L47: Post-test

Question 1 10

Sam is working at Gadget store, below is the data that shows the number of laptops that he sold for a period of 15 months.
43 48 62 52 46 90 58 37 48 73 84 68 54 34 78

1.1 Determine the median of the number of laptops sold. (2)

54 — 2

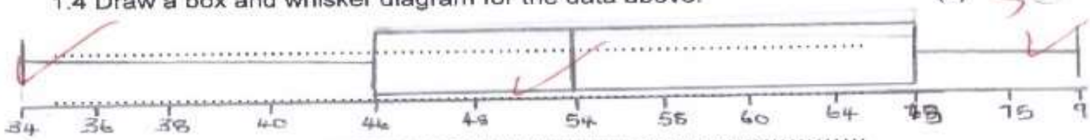
1.2 Calculate the range of the data. (2)

H − L
= 90 − 34
= 56 — 2

1.3 Calculate the interquartile range (IQR) (3)

IQR = Q3 − Q1
= 73 − 46
= 27 — 3

1.4 Draw a box and whisker diagram for the data above. (3) 3



1.5 Identify the outlier in a box-and-whisker diagram (1)

box and whisker on left hands is lower quartile and on right hand upper quartile on the data — 0

6

Process and Object conception (Question 2)

E7

L28 Pre-test

Question 2 0 |

The age limit for entering Miss South Africa beauty pageant is between the ages of 20 and 28. Below is the ages of Miss SA Top 35 2020
21 27 24 27 20 24 23 24 23 24 24 23 21 25 27 21 24 25 24 24 23 21 24
25 22 25 26 24 23 24 25 23 23 23 21

AGES	FREQUENCY
$20 \leq A < 22$	6
$22 \leq A < 24$	8
$24 \leq A < 26$	10
$26 \leq A < 28$	11

2.1 Identify the interval in which the median lies. (2)

20 21 21 21 21 21 22 23 23 23 23 23 23 23

23 24 24 24 24 24 24 24 24 24 24 25

25 25 25 25 26 27 27 27 28 The median = 24 |

2.2 Write down the modal class for the data. (2)

20 21 21 21 21 22 23 23 23 23 23
The modal = 23 24 24 24 24 24 24 24 24 24 24 25
25 25 25 25 26 27 27 28
35

857
35
= 24.48 0

2.3 Estimate the mean of the data. (3)

$$x = \frac{1}{n}\sum_{i=1}^{n} xi$$

Mean = 24 0

2.4 Represent the given data in a histogram. (5)

3

E8

L28: Post-test

....

Question 2 09

The age limit for entering Miss South Africa beauty pageant is between the ages of 20 and 28. Below is the ages of Miss SA Top 35 2020
21 27 24 27 20 24 23 24 23 24 24 23 21 25 27 21 24 25 24 24 23 21 24 25 22 25 26 24 23 24 25 23 23 23 21

AGES	FREQUENCY
$20 \leq A < 22$	6
$22 \leq A < 24$	8
$24 \leq A < 26$	10
$26 \leq A < 28$	11

2.1 Identify the interval in which the median lies. (2)

20 21 21 21 21 21 22 23 23 23 23 23 23 23 23
24 24 24 24 24 24 24 24 24 24 24 25 25 25 25
25 27 27 27 25 Median lies = 24 ✓ 1

2.2 Write down the modal class for the data. (2)

....

24 = modal class ✗ 0

....

2.3 Estimate the mean ($\bar{x}$) of the data. (3)

....

$\frac{829}{35} = 23,69$ 4

3

2.4 Represent the given data in a histogram. (5)

7

E9

L39: Pre-test

Question 2 05

The age limit for entering Miss South Africa beauty pageant is between the ages of 20 and 28. Below is the ages of Miss SA Top 35 2020
21 27 24 27 20 24 23 24 23 24 24 23 21 25 27 21 24 25 24 24 23 21 24 25 22 25 26 24 23 24 25 23 23 23 21

AGES	FREQUENCY
$20 \leq A < 22$	6
$22 \leq A < 24$	8
$24 \leq A < 26$	10
$26 \leq A < 28$	11

2.1 Identify the interval in which the median lies. (2)

$= 24 \leq A < 26$ ✓ 2

2.2 Write down the modal class for the data. (2)

$= 26 \leq A < 28$ ✗ 0

2.3 Estimate the mean of the data. (3)

$$x = \frac{1}{n}\sum_{i=1}^{n} xi$$

21+27+24+27+20+24+23+24+23+24+24+23+21+25+27 +21+24+25+24+24+23+21+24+25+22+25+26+24+23+25+23+23+23+21 / 6+8+10+11

$= \frac{803}{35} = 22,94$ ✗ 0

2.4 Represent the given data in a histogram. (5)

3

E10

L39: Post-test

2\.

Question 2 10

The age limit for entering Miss South Africa beauty pageant is between the ages of 20 and 28. Below is the ages of Miss SA Top 35 2020
21 27 24 27 20 24 23 24 23 24 24 23 21 25 27 21 24 25 24 24 23 21 24 25 22 25 26 24 23 24 25 23 23 23 21

AGES	FREQUENCY
$20 \leq A < 22$	6
$22 \leq A < 24$	8
$24 \leq A < 26$	10
$26 \leq A < 28$	11

2.1 Identify the interval in which the median lies. (2)

~~24≤ 22≤A<24~~

24≤A<26 ✓ 2

2.2 Write down the modal class for the data. (2)

26≤A<28 ✗ 0

2.3 Estimate the mean ($\bar{x}$) of the data. (3)

= 23,60 ✓✓✓ 3

2.4 Represent the given data in a histogram. (5)

7

E11

L47: Pre-test

Question 2 03

The age limit for entering Miss South Africa beauty pageant is between the ages of 20 and 28. Below is the ages of Miss SA Top 35 2020
21 27 24 27 20 24 23 24 23 24 24 23 21 25 27 21 24 25 24 24 23 21 24 25 22 25 26 24 23 24 25 23 23 23 21

AGES	FREQUENCY
$20 \leq A < 22$	6
$22 \leq A < 24$	8
$24 \leq A < 26$	10
$26 \leq A < 28$	11

2.1 Identify the interval in which the median lies. (2)

25 ✗ 0

2.2 Write down the modal class for the data. (2)

26 ≤ A < 28 ✗ 0

2.3 Estimate the mean of the data. (3)

$$x = \frac{1}{n}\sum_{i=1}^{n} xi$$

Mean = (6x22)+(24x8)+(10x26)+(11x28) / 6+8+10+11

= 892/35 = 25,4 ✗ 0

2.4 Represent the given data in a histogram. (5)

3

E12

L47:Post-test

10

Question 2

The age limit for entering Miss South Africa beauty pageant is between the ages of 20 and 28. Below is the ages of Miss SA Top 35 2020
21 27 24 27 20 24 23 24 23 24 24 23 21 25 27 21 24 25 24 24 23 21 24 25 22 25 26 24 23 24 25 23 23 23 21

AGES	FREQUENCY
$20 \leq A < 22$	6
$22 \leq A < 24$	8
$24 \leq A < 26$	10
$26 \leq A < 28$	11

2.1 Identify the interval in which the median lies. (2)

between 24 ≤ A < 26 — 2

2.2 Write down the modal class for the data. (2)

26 ≤ A < 28 — 0

2.3 Estimate the mean ($\bar{x}$) of the data. (3)

20+21+21+21+21+21+22+23+23+23+23+23+23+23+23+24+24+24+24+24+24+24+24+24+24+25+25+25+25+25+26+27+27+27
6+8+10+11

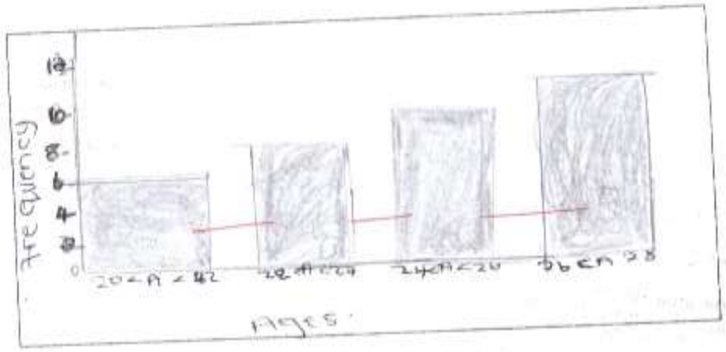
= 827/35 = 23,62 — 3

2.4 Represent the given data in a histogram. (5)

7

E13

L28: Pre-test



2.5 Calculate the percentage of the contestants which are below the age of 24. (2)

35 + 24 ÷ 100 % =

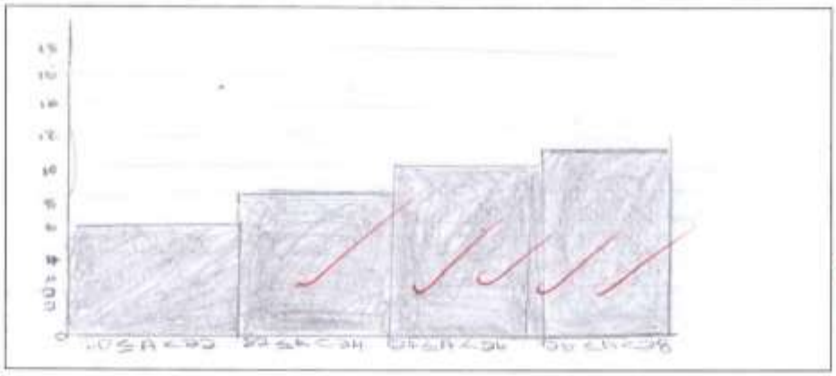
59 ÷ 100 %

= 0,59 %

4

E14

L28: Post-test



5

2.5 Calculate the percentage of the contestants which are below the age of 24. (2)

$100\% = 11 \times 24$

$\% = 0{,}31$

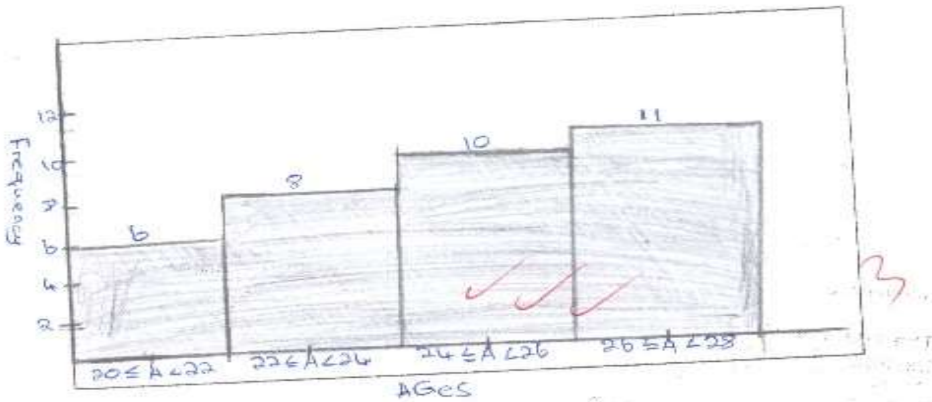
$0{,}37\%$

0

8

E15

L39: Pre-test



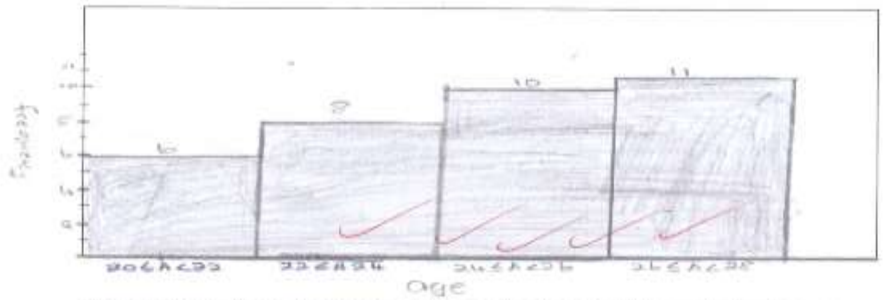
2.5 Calculate the percentage of the contestants which are below the age of 24. (2)

21+23+23+23+23+22+21+23+21+21+23+23+23
+22+21 = 310 =31.0

=

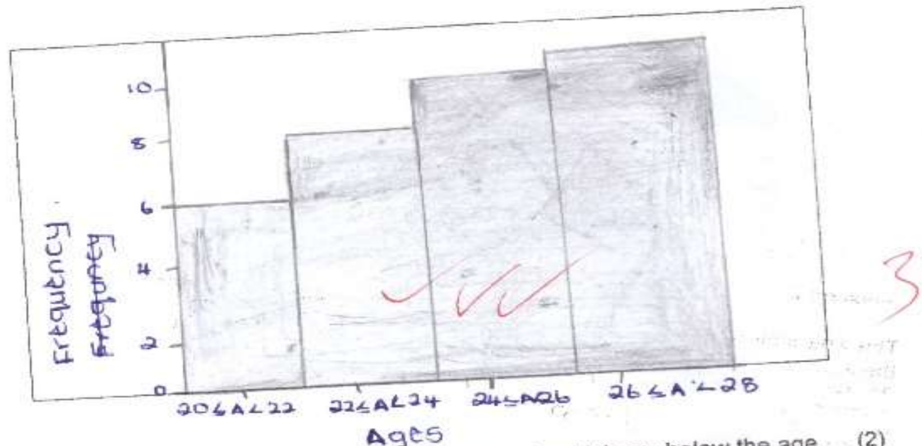
E16

L39: Post-test



2.5 Calculate the percentage of the contestants which are below the age of 24. (2)

8

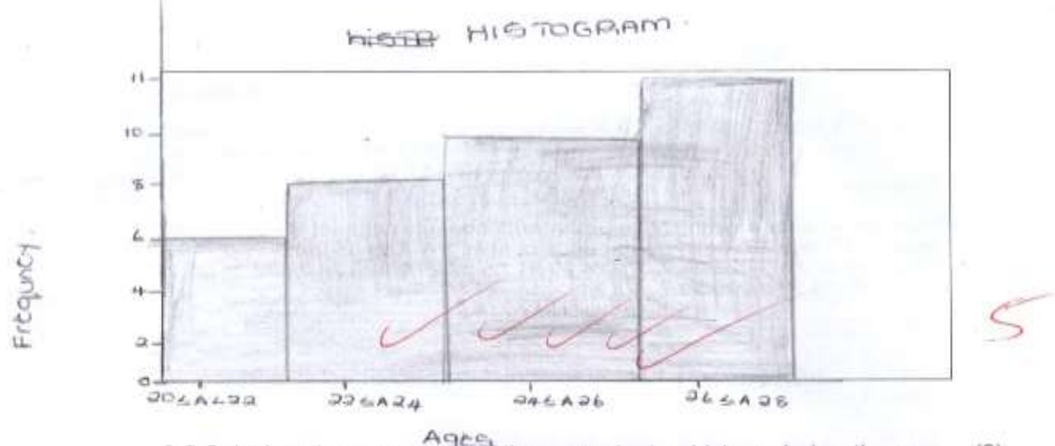


2.5 Calculate the percentage of the contestants which are below the age of 24. (2)

= 8

0

L47: Post-test



2.5 Calculate the percentage of the contestants which are below the age of 24. (2)

= 0,24

0

Minimum → 34
lower quartile → 46
Median → 54
upper quartile → 73
Maximum → 90

APPENDIX D: QUESTIONNAIRE (Learners in the experimental group)

Instruction

- Answer all questions
- Circle your answer from the given alternative
- Only circle the alphabet next to your answer
- Answers will be treated as private and confidential
- Answer as honest as possibly can
- Mark allocation is one mark per question

1. Learning Data Handling using graphic calculator helped me to focus on the learning process.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

2. I spend unnecessary time in long repetitive calculation when using pen- and-paper.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

3. The use of graphic calculators enables me to use multiple representations: tabular, algebraic, and graphical simultaneously

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

4. The use of graphic calculator enables me to develop new thinking skills and mathematical understanding of data handling.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

5 The use of graphic calculator enables me to develop mathematical understanding reasoning and other level of application concepts.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

6. I am a confident user of graphic calculator.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

7. The use of graphic calculator in learning Data Handling motivates me to work on challenging problems.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

8. The use of graphic calculator in learning Data Handling gives me an opportunity to work with real-life problems.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

9. Learning Data Handling is more interesting when using graphic calculator.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

10. The use of graphic calculator in learning Data Handling should be incorporated in South African Mathematics curriculum.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

APPENDIX E: QUESTIONNAIRE (Learners in the Comparison Group)

Instruction

- Answer all questions
- Circle your answer from the given alternative
- Only circle the alphabet next to your answer
- Answers will be treated as private and confidential
- Answer as honest as possibly can
- Mark allocation is one mark per question

1. Learning Data Handling using traditional method does not help me to focus on the learning process.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

2. Long and repetitive calculations diminish/ take away the joy of learning Data Handling.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

3. Learning Data Handling using traditional method does not give me an opportunity to work with real-life problems.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

4. The use of technology tools, such as Graphic Calculator, will help me to engage with challenging problems.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

5 The use of technology tools, such as Graphic Calculators enable learners to be better in interpreting graphs and tables.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

APPENDIX F: QUESTIONNAIRE (Teachers in the Experimental & Comparison Group)

Instruction

- Answer all questions
- Circle your answer from the given alternative
- Only circle the alphabet next to your answer
- Answers will be treated as private and confidential
- Answer as honest as possibly can
- Mark allocation is one mark per question

1. Learners should be allowed to use Graphic Calculators to create graphical representation after they have learned to create the graphs by hand.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

2. Regular use of Graphic Calculator will help learners to become better in interpreting tables and graphs.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

3. The use of Graphic Calculator provides learners with an opportunity to share their ideas.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

4. Teachers should decide when it is appropriate for learners to use graphic calculators.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

5 The South African Mathematics Curricular should incorporate the use of technology tools such as Graphic calculator from lower grades.

A. Strongly Agree

B. Agree

C. Strongly Disagree

D. Disagree

APPENDIX G: Ethical Clearance Certificate

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2021/02/10

Ref: **2021/02/10/59838981/35/AM**
Name: Ms M RAMBAO
Student No.: 59838981

Dear Ms M RAMBAO

Decision: Ethics Approval from 2021/02/10 to 2024/02/10

Researcher(s): Name: Ms M RAMBAO
E-mail address: mpho.rambao@gmail.com
Telephone: 081 304 1033

Supervisor(s): Name: Dr M Masilo
E-mail address: masilmm@unisa.ac.za
Telephone: 012 429 6154

Title of research:

THE EFFECTS OF USING GRAPHIC CALCULATOR IN LEARNING GRADE 10 DATA HANDLING

Qualification: MEd Mathematics Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2021/02/10 to 2024/02/10.

*The **medium risk** application was reviewed by the Ethics Review Committee on 2021/02/10 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the UNISA College of Education Ethics Review Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
8. No field work activities may continue after the expiry date **2024/02/10**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2021/02/10/59838981/35/AM** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Kind regards,

Prof AT Motlhabane
CHAIRPERSON: CEDU RERC
motlhat@unisa.ac.za

Prof PM Sebate
EXECUTIVE DEAN
Sebatpm@unisa.ac.za

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

APPENDIX H: LDoE Research Approval

CONFIDENTIAL

LIMPOPO

PROVINCIAL GOVERNMENT

REPUBLIC OF SOUTH AFRICA

OFFICE OF THE PREMIER

Office of the Premier

Research and Development Directorate

Private Bag X9483, Polokwane, 0700, South Africa

Tel: (015) 230 9910, Email: mokobij@premier.limpopo.gov.za

LIMPOPO PROVINCIAL RESEARCH ETHICS

COMMITTEE CLEARANCE CERTIFICATE

Meeting: April 2021

Project Number: LPREC/26/2021: PG

Subject: The Effects of Using Graphic Calculators in Learning Grade 10 Data Handling (Statistics)

Researcher: Rambao M

Dr Thembinkosi Mabila

Chairperson: Limpopo Provincial Research Ethics Committee

The Limpopo Provincial Research Ethics Committee (LPREC) is registered with National Health Research Council (NHREC) Registration Number **REC-111513-038.**

Note:

i. **This study is categorized as a Low Risk Level in accordance with risk level descriptors as enshrined in LPREC Standard Operating Procedures (SOPs)**

ii. **Should there be any amendment to the approved research proposal; the researcher(s) must re-submit the proposal to the ethics committee for review prior data collection.**

iii. **The researcher(s) must provide annual reporting to the committee as well as the relevant department and also provide the department with the final report/thesis.**

iv. **The ethical clearance certificate is valid for 12 months. Should the need to extend the period for data collection arise then the researcher should renew the certificate through LPREC secretariat. PLEASE QUOTE THE PROJECT NUMBER IN ALL ENQUIRIES.**

APPENDIX I: Principal's permission

P O BOX 747

ELIM HOSPITAL

0960

08 March 2021

The Principal

………………….

Name of School

Dear Sir/Madam

PERMISSION TO CONDUCT A RESEARCH

Research Title: The effects of using a Graphic Calculator as a cognitive tool in learning Grade 10 Data Handling.

This letter serves a request of your permission to conduct a research project.

My name is Rambao Mpho, a student at the University of South Africa studying towards a Master's Degree in Mathematics Education. The purpose of the study is to investigate the effects of using Graphic Calculator and how it can support or enhance the learning of Data Handling in Grade 10.

I therefore request a permission to conduct research in your school as it has been selected to represent your district in Limpopo, and it is classified as the comparison group. Your role in this study will involve allowing the researcher to carry out pre-test and posttest in one of the Grade 10 Mathematics classrooms. Further, I request permission to administer a questionnaire to both learners and teachers after the pre- and post-test. The research will be conducted during school hours, during mathematics periods for a period of two weeks. Both teachers' and learners' participation are voluntary and all information will be treated with confidentiality and anonymity in order to ensure that no bad effect will be caused to the participants by the study. Letters will be sent to the institution to inform them on the findings of this study. Any questions or queries regarding the study may be directed to the researcher (contact no: 078 5930 243; email: mpho.rambao@gmail.com)

Yours sincerely

Rambao M

(Please complete the consent form below and return it to me)

Permission to conduct research

I ……………………………….. the principal of……………………………

understand the context of the research study and I grant permission that the research study may be conducted at the school. I am fully aware that the teacher and learners' participation is voluntary, and all information will be treated with confidentiality and anonymity in order to ensure that no harm will be caused to the participants by the research study; participants will be granted the right to withdraw when they wish to do so, and may also refrain from answering questions when they see it necessary.

Principal's signature: …………………………

Date: ……………………………………………..

APPENDIX J: Teacher's Consent (Experimental group)

College of Education

UNISA

Dear Sir/Madam

Re: Request for your participation in a research study

Research Title: The effects of using a Graphic Calculator as a cognitive tool in learning Grade 10 Data Handling.

This letter serves to request your permission to conduct a research project.

My name is Rambao Mpho, a student at the University of South Africa studying towards a Master's Degree in Mathematics Education. The purpose of the study is to investigate the effects of using Graphic Calculator and how it can support or enhance the learning of Data Handling in Grade 10. Your school has been classified as the experimental group, your interaction with the researcher will involve allowing the researcher to administer a pre- and post-test in your classroom, and assist in carrying out the experimental instrument; learning Data Handling using Graphic Calculator and administer the questionnaire to the learners.

The research will be conducted during school hours, during mathematics periods, for a period of two weeks. Your participation is voluntary, and you will be granted with permission to withdraw from this research study if you wish to do so. I therefore request you to sign the consent form provided to accept my request to participate.

I will appreciate your cooperation in this regard.

Yours sincerely

Rambao M

(Please complete the consent form below and return it to me)

Teacher's Consent (Comparison group)

College of Education

UNISA

Dear Sir/Madam

Re: Request for your participation in a research study

Research Title: The effects of using a Graphic Calculator as a cognitive tool in learning Grade 10 Data Handling.

This letter serves to request your permission to conduct a research project.

My name is Rambao Mpho, a student at the University of South Africa studying towards a Master's Degree in Mathematics Education. The purpose of the study is to investigate the effects of using Graphic Calculator and how it can support or enhance the learning of Data Handling in Grade 10. Your school has been classified as the comparison group, your interaction with the researcher will involve allowing the researcher to administer a pre- and post-test in your classroom, carry out a lesson in Data Handling as the researcher observes the lesson, and assist the researcher to administer the questionnaire to the learners. You will be required to complete a closed-ended questionnaire about your views on the use of graphic calculators in learning grade 10 Data Handling.

The research will be conducted during school hours, during mathematics periods, for a period of two weeks. Your participation is voluntary, and you will be granted with permission to withdraw from this research study if you wish to do so. I therefore request you to sign the consent form provided to accept my request to participate.

I will appreciate your cooperation in this regard.

Yours sincerely

Rambao M

(Please complete the consent form below and return it to me)

Teacher’s participation consent

I …………………………………….understand the context of the research study, and I am fully aware that my participation is voluntary, and I am aware that anonymity and confidentiality will be adhered in this study. I have been informed I may withdraw my consent to participate from the study if I wish to do so. I therefore agree to participate in the research study.

Participants signature: …………………..

Date: …………………………..

APPENDIX K: Parent/ Guardian Consent

College of Education

UNISA

Dear Sir/Madam

Re: Request for your child to participate in a research study

Research Title: The effects of using a Graphic Calculator as a cognitive in learning Grade 10 Data Handling.

This letter serves to request your permission to conduct a research project.

My name is Rambao Mpho, a student at the University of South Africa studying towards a Master's Degree in Mathematics Education. The purpose of the study is to investigate the effects of using Graphic Calculator and how it can support or enhance the learning of Data Handling in Grade 10. Your child's role in this research study will be to participate in learning Data Handling using Graphic. A pre- and post-test will be administered to track the performance of your child, furthermore questionnaire will be given to your child to find out their views and experience on using Graphic Calculator during the lessons

The research will be conducted during school hours, during mathematics periods, for a period of two weeks. Your child's participation is voluntary, and they will be granted with permission to withdraw from this research study if they wish to do so. I therefore request you to sign the consent form provided to accept my request to participate.

I will appreciate your cooperation in this regard.

Yours sincerely

Rambao M

(Please complete the consent form below and return it to me)

Participation consent

I……………………………………parent/guardian of………………………..

understand the context of the research study, and I am fully aware that my child's participation is voluntary, and I am aware that anonymity and confidentiality will be adhered in this study. I have been informed I may withdraw my consent for my child to participate from the study if I wish to do so. I therefore agree on my free will that my child will participate in the research study.

Parent's signature: …………………..

Date: …………………………..

APPENDIX L: Learner's Assent Form

College of Education

UNISA

Dear Learner

Re: Request for your child to participate in a research study

Research Title: The effects of using Graphic Calculator in learning Grade 10 Data Handling.

This letter serves to request your permission to conduct a research project.

My name is Rambao Mpho, a student at the University of South Africa studying towards a Master's Degree in Mathematics Education. The purpose of the study is to investigate the effects of using Graphic Calculator and how it can support or enhance the learning of Data Handling in Grade 10. I request you to participate in this research study, your role is to participate in learning Data Handling using Graphic Calculator, and your participation will be observed during the lesson. A pre- and post-test will be administered to track your progress, further, a questionnaire will be administered to find out your views and experience of learning Data Handling using Graphic Calculator.

The research will be conducted during school hours, during mathematics periods, for a period of two weeks. Your participation is voluntary, and you will be granted with permission to withdraw from this research study if you wish to do so. I therefore request you to sign the assent form provided to accept my request to participate.

I will appreciate your cooperation in this regard.

Yours sincerely

Rambao M

(Please complete the consent form below and return it to me)

Participation Assent.

I………………………………………… understand the context of the research study, and I am fully aware that my participation is voluntary, and I am aware that anonymity and confidentiality will be adhered in this study. I have been informed I may withdraw my assent to participate from the study if I wish to do so. I therefore agree on my free will that I will participate in the research study.

Learner's signature: …………………..

Date: …………………………..

EDITORIAL CERTIFICATE

Author: Ms Rambao Mpho

Document title: THE EFFECTS OF USING A GRAPHIC CALCULATOR AS A COGNITIVE TOOL IN LEARNING GRADE 10 DATA HANDLING

Date issued: 02/08/2022

This document certifies that the above manuscript was proofread and edited by Prof Gift Mheta (PhD, Linguistics).

The document was edited for proper English language, grammar, punctuation, spelling and overall style. The editor endeavoured to ensure that the author's intended meaning was not altered during the review. All amendments were tracked with the Microsoft Word "Track Changes" feature. Therefore, the authors had the option to reject or accept each change individually.

Kind regards

Prof Gift Mheta (Cell: 073 954 8913)