USE OF SCIENTIFIC CALCULATORS IN THE TEACHING AND LEARNING OF SCHOOL MATHEMATICS: THE CASE OF ONE SECONDARY SCHOOL IN LUSAKA, ZAMBIA

BY

Mashekwa Mashekwa

A Dissertation Submitted to the University of Zambia in partial fulfillment for the award of degree of Master of Education (Mathematics Education)

The University of Zambia

Lusaka

2021

AUTHOR'S DECLARATION

I, **Mashekwa Mashekwa**, do hereby declare that this dissertation entitled: "Use of Scientific Calculators in the Teaching and Learning of school Mathematics: The case of one secondary school in Lusaka, Zambia" represents my own work and that all the resources used or presented have been indicated and acknowledged by means of complete reference and that the dissertation has not previously been submitted for a Master's degree at the University of Zambia or any other university.

Signed: ..... Date: .....

CERTIFICATE OF APPROVAL

This dissertation is approved as fulfilling the requirement for the award of the Master of Education degree in Mathematics Education by the University of Zambia. Examiners' Signatures Date

Examiner.....Date:…… Signature:.....

Examiner.....Date:…… Signature:.....

Examiner.....Date:…… Signature:.....

Chairperson, Board of Examiners…….Date ….……..Signature:……..

Supervisor.....Date:…… Signature:.....

DEDICATION

I dedicate this work to my first-born daughter Mukubesa Mashekwa, my second born Muzwamasimu Mashekwa, my last born Namakando Mashekwa and my wife Mrs. Mashekwa Brenda Mwanza for all the love, support and encouragement given to me throughout my studies. I also dedicate this research work to my uncle Mr. Mashekwa Namakando for his inspiration, encouragement and the foundation he laid many years ago. It was his greatest desire to see to it that I get all necessary education, and for me to have attained this higher education I owe it to him. I will always cherish his love and care. Not forgetting his wife Mrs. Mashekwa Mutinta Shaluzani for her unconditional support during my study period. May the Almighty God keep and bless you all. I love you.

ACKNOWLEDGEMENTS

Writing a dissertation is a very challenging task, but through the support and contributions of many people it was made possible. To all those who supported me morally, financially, materially, in terms of time and expertise I would like to extend my sincere thanks. Firstly, I would like to thank my supervisor Dr. Priestly Malambo of the School of Education, UNZA for the expert guidance, encouragement, assistance and patience during the course of my study. Without his support and professional guidance this work would not have been completed. I also wish to thank Dr. Kaiko Mubita, Dr. Bernard Chileshe and Mr. Manyando Mulonda for their guidance during my studies. Secondly, I would like to thank Munali Boys Secondary School Administration then, for the support and understanding shown to me during the time I was pursuing my studies at UNZA when in fact I should have been at work. I also wish to thank my course mates in the Master of Mathematics Education class for the academic year 2018-2020, particularly, Mizinga Shelly, Tafeni Spiwe, Mubanga Steve, Musonda Jonathan, Chingala Catherine, Sinzala Gift and Hambale Emad for sharing with me fruitful insights and encouragement during the years of my study. Furthermore, I sincerely thank all the participants without whom this study could not have been a success. Last, but not least, I would like to express my profound gratitude and appreciation to my family for their support and encouragement. I would like to deeply thank my wife Brenda Mwanza, for her love and understanding during those stressful moments. I sincerely wish you all God's Blessings.

ABSTRACT

The use of scientific calculators in the teaching and learning process of secondary school Mathematics in the Zambian education system began in 2001. Since then, there has been lack of the Zambian context research evidence regarding the use of scientific calculators in the teaching and learning process. In this regard, the present study was intended to contribute to the knowledge about the use of scientific calculators by learners and teachers of Mathematics in secondary schools. A qualitative approach and specifically a case study design was used because it provided a systematic way of acquiring in-depth understanding of the phenomenon which was being investigated. The sample comprised of 8 teachers and 24 learners of secondary school Mathematics. The teachers were selected using a homogeneous purposive sampling technique while the learners were chosen through self-selection sampling technique. In respect of data collection, participant observation schedules, unstructured interviews, focus group discussions and a performance test were utilized. Data accessed through observations, interviews and group discussions were analyzed thematically while the data derived from the performance test was analyzed through exploration of learners' answers to specific test questions. Analysis of the data showed that teachers of Mathematics supported the use of scientific calculators in the teaching and learning process of Mathematics. Teachers argued that calculators made learners to be over dependent on the gadget even in instances where simple computations are involved and had a salient effect of robbing learners of the necessary ability to think mathematically. Furthermore, learners demonstrated occasional lack of ability to effectively use scientific calculators, for example, in topics such as indices and fractions. This discovery suggested that learners are rarely taught the major functions of a scientific calculator or even how to operate calculators. Moreover, it was found out that teachers also lacked capacity to adequately and appropriately use the functions of scientific calculators. It is therefore recommended that schools adopt unique models of scientific calculators whose functions are easy to use by learners. In addition, subject association programs could provide opportunities for teachers to familiarize themselves with the use of scientific calculators in teaching of Mathematics.

Keywords: Scientific calculator, teaching and learning Mathematics, performance, Zambia.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background

Mathematics is considered by society as the engine for scientific and technological development of many nations. There is a general agreement in many societies that every child should study Mathematics at school to acquire skills for adult life (Orton, 1992). As a result of this, great changes have taken place in Mathematics curriculum throughout the world due to the realisation that Mathematics is a practical subject **(**Gunstein & Lipsey, 2001).

Mathematics education started way back during the ancient civilization (Gillings, 1972). Mathematics was part of the education system in most of the ancient civilization including ancient Greece, the Roman Empire, Vedic society and ancient Egypt (Gillings, 1972). During this time, formal education was only available to male children with sufficiently high status, wealth or caste. The first Mathematics text books to be written in English and French were published by Robert Recorde beginning with the Grounde of Artes in 1540 (Frank & Victor, 2011). However, there are many different writings on Mathematics and Mathematics methodology that date back to 1800 BCE mostly located in Mesopotamia where the Sumerians were practicing multiplication and division (Frank & Victor, 2011).

By the 20^{th} century, Mathematics became part of the core curriculum in all developing countries such as Kenya, Ghana and Zambia. During this period, Mathematics education was established as an independent field of study **(**Gunstein & Lipsey, 2001). However, during all this time, the main tools used in the study of Mathematics were mainly paper and pencil. Complicated topics such as trigonometry were done with the help of logarithm tables. The first tables of trigonometric functions known to be made were by Hipparchus and Menelus (Boyer, 1991). The table produced by the Indian mathematician Aryabhata is considered the first sine table ever constructed (Boyer, 1991). Tables of common logarithms were used until the invention of computers and electronic calculators to do rapid multiplications, divisions and exponentiations, including the extraction of n^{th} roots. Several studies (Hunter, 1994; McCoy, 1996) on the use of instructional technology, such as calculators, have shown that this technology helps in improving special visualisation skills, critical thinking ability, understanding of connections among graphical, tabular, numerical, and algebraic representation and improvement of learners' confidence in Mathematics. Early digital computers were developed during World

War II in part to produce specialized mathematical tables for army artillery. From 1972, with the launch and growing use of scientific calculators, most mathematical tables went out of use in the United States (Sarah, 2011).

From the classroom perspective, the United States of America was one of the first countries to introduce the use of calculators in Mathematics education**.** In 1974, the National Council of Teachers of Mathematics (NCTM) issued a far-reaching statement urging that calculators be used in schools (NCTM, 2000). Aside from the computational value of calculators, a host of expectations for their usage could be listed (Suydam, 1976, p. 12) to aid algorithmic instruction; facilitate concept development; reduce the demand for memorisation; enlarge the scope of problem solving; provide motivation; and encourage discovery, exploration, and creativity. Calculator usage in Mathematics classrooms in the United States was introduced in 1975 with a focus on the attitudes of learners, educators, and national organisations towards Mathematics (Sarah, 2011). This was particularly in order to lessen the tedious work of processing computations mentally. At this point that easy access to calculators prominently begun to affect the lives of average learners and teachers. Another milestone for learners using calculators occurred as cities, such as Chicago, began to provide free calculators for all learners (Seán et al, 2008). Teachers saw calculators as a chance to increase learners' motivation by using more "real-life" problems (Pendelton, 1975). Around the same period, Canada also introduced the use of calculators in Mathematics education.

In Africa, countries that started using calculators in the teaching of Mathematics included Kenya, Ghana, South Africa and Nigeria. The use of scientific calculators in the Kenya Certificate of Secondary Education (KCSE) was approved in 2005 by the Kenya Ministry of Education for their application in the classroom situation (Mbugua, Muthoni & Okere, 2011). Scientific calculators were introduced in the Mathematics curriculum for solving tedious and lengthy computations at secondary school level. It was for the view that calculators will allow learners to learn more quickly and efficiently while keeping them engaged in what they are learning (Mbugua, Muthoni & Okere, 2011). According to Briggs (1977), the incorporation of technology during the teaching and learning process propels the learners' attention by seizing and stimulating their interest in the subject. In Ghana, the most recent issues in the new educational reforms of which implementation started in September, 2007 included the use of calculators. Research evidence in Ghana shows that the use of calculators motivates learners, gives confidence to those anxious about Mathematics and helps learners develop fluency in

number because they can give repeated practice and rapid experience of many examples (Churcher, Boinde & Asiedu, 2016).

Zambia could not be left behind as technology was taking the centre stage worldwide. The introduction of scientific calculator in Mathematics in the Zambian education system began in 2001 when the curriculum was revised. However, it was not until 2003 when the 2001 grade 10 cohort reached Grade 12 that the first examinations were written using scientific calculators. In 2003, instructions to candidates allowed both the use of mathematical tables and scientific calculators (Examination Council of Zambia, 2003). By 2005, the instruction to candidates was very specific, that only the silent electronic calculator (non-programmable) was allowed in Mathematics 4024/2.

1.2 Statement of the problem

In 2001, Zambia through the Ministry of Education introduced the use of scientific calculators in the teaching and learning of Mathematics. Previously, learners at senior secondary school level were using logarithm tables to evaluate certain mathematical problems in topics such as logarithms and trigonometry.

Since the introduction of scientific calculators in Mathematics education in Zambia, however, there are still questions surrounding the use of scientific calculators: How appropriately do learners use scientific calculators in Mathematics? Are secondary school learners formally taught how to use scientific calculators? How accessible are calculators to the learners? What are the challenges faced by both the teachers and learners in using scientific calculators? So far, no study has been conducted in the Zambian context to assess the use of scientific calculators in the teaching and learning of Mathematics at senior level since its introduction in 2001. This study, therefore, was meant to establish how scientific calculators are used in the teaching and learning of Mathematics in one selected secondary school in Lusaka District.

1.3 Aim

The aim of the study was to assess the use of scientific calculators in the teaching and learning of Mathematics in one of the secondary schools in Lusaka District.

1.4 Specific Objectives

The study was guided by the following objectives:

1. To establish how secondary school teachers and learners used scientific calculators in the teaching and learning of Mathematical concepts in Lusaka district.
2. To determine the challenges teachers and learners of Mathematics faced as they used scientific calculators in the teaching and learning of Mathematics in Lusaka district.
3. To establish the teachers' and learners' perceptions regarding the effective ways of using scientific calculators in the teaching and learning of Mathematics in Lusaka District.

1.5 Research Questions

The study was guided by the following research questions:

1. How were scientific calculators used by teachers and learners in the learning and teaching of Mathematical concepts in Lusaka district?

2. What challenges did teachers and learners face in the use of scientific calculators in the teaching and learning of Mathematics in Lusaka district?
3. What are teachers' and learners' perceptions regarding the effective ways of using scientific calculators in the teaching and learning of Mathematics in Lusaka District?

1.6 Significance of the study

There are several reasons why this study is significant. To begin with, the findings of the study would be of significance to policy-makers and teachers who are the implementers of curriculum. The study could also equip learners with the skills necessary for appropriate use of scientific calculators in solving Mathematical problems. Furthermore, the study could help policy-makers to understand the risks and benefits associated with the introduction of new technology in Mathematics Education. The findings from this study would also be used to inform Mathematics teachers on the best practices (pedagogical strategies) of using scientific calculators as well as the need for effective training of learners in their use in order to improve Mathematics computational skills and performance.

1.7 Limitations of the Study

The use of a larger sample size was a limitation as it would have required a bigger room to conduct the performance test. Another limitation faced by the study was that some learners who were selected to be part of the sample withdrew at the time of administering the test. This non-response by some participants could have led to loss of information and underestimation of some aspects of scientific calculator use. The results of this study may not be applicable to other schools because of certain factors such as geographical location and catchment area of grade 10 learners. The results may not also be generalized to other schools because only one school was used in a case study.

1.8 Theoretical Framework and Conceptual Framework

This section covers the theoretical and conceptual frameworks of the study. Adom, Hussein and Adu-Agyem (2008; 147) assert that "the overall aim of the two frameworks is to make research findings more meaningful and acceptable to the theoretical constructs in the research field and ensures generalisability. They assist in stimulating research while ensuring the extension of knowledge by providing both direction and impetus to the research inquiry."

1.8.1 Theoretical Framework

This study was guided by Constructivist Theory, with particular attention to social constructivism in Mathematics education. Constructivism is an approach to learning that holds that people actively construct or make their own knowledge and understanding, and that reality is determined by the experiences of the learner (Elliott et al., 2000; Jayeeta, 2015). In elaborating constructivists' ideas, Arends (1998) states that constructivism believes in personal construction of meaning by the learner through experience, and that meaning is influenced by the interaction of prior knowledge and new events.

Social constructivism is a variety of cognitive constructivism that emphasizes the collaborative nature of much learning. This theory was developed by post-revolutionary Soviet psychologist Lev Vygotsky. According to Vygotsky (1978:57),

> *Every function in the child's cultural development appears twice: first, on the social level and, later on, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies*

> *equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals.*

Vygotsky was also best-known for his concept of Zone of Proximal Development (ZPD). The ZPD has been defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978: 86). Vygotsky stated that learners should be taught in the ZPD. The ZPD is a useful concept for teachers. To ensure that learners are learning in their zone of proximal development, teachers must provide new opportunities for students to work slightly beyond their current skills and provide ongoing, scaffolded support to all learners. A good teacher or more-knowledgeable-other (MKO) identifies a learner's ZPD and helps them stretch beyond it. Then the MKO gradually withdraws support until the learner can perform the task unaided.

Advocates of social constructivism theory argue that knowledge is acquired during the sharing of experiences. Therefore, knowledge is collectively constructed (Ernest, 1991; Smith, 1991). In a constructivist classroom, learner autonomy and initiative are accepted and encouraged. By respecting learners' ideas and encouraging independent thinking, teachers help learners attain their own intellectual identity. The social constructivist teacher values learner reflection and cognitive conflict and encourages peer interaction. Studies have indicated that teachers who frequently use calculators in the teaching and learning of Mathematics hold a constructivist teaching philosophy (Becker, 2000 & Burke, 2001). Their role in the classroom is to help learners to build their knowledge and to facilitate opportunities for collaborative work and problem solving.

In the context of this study, the implication of constructivism in a Mathematics classroom is that learners can take an active role in learning as teachers provide them with activities and knowledge of the world through experiencing those things and reflecting on those experiences. Use of the scientific calculator in the learning and teaching of Mathematics exposes learners to such experiences as they interact among themselves and with their teachers. Through both interpsychological interaction and intrapsychological activities, learners come to learn other functions (with the teacher's guidance) of a scientific calculator that would enable them solve mathematical problems. The learners use the calculator to investigate different solutions of a

mathematical problem (Kissane, 1999). A study by Orton (1992) noted that calculators can be used in an exploratory and investigatory way that helps learners to develop their own way of understanding of arithmetic. Therefore, learners are not seen as passive absorbers of knowledge but as active participants in their own learning as they obtain new skills through the use of scientific calculator (Tajuddin, Tarmizi, Konting & Ali, 2009). Using a scientific calculator is one way in which learners are engaged in their own learning, as they operate the calculator to come up with mathematical solutions.

Since the constructivist theory is all about a learner-centered approach to learning, it is most suitable for this study as it encourages learners to be active participants while learning. Scientific calculators are devices that require manipulations and thus learners may construct new knowledge while performing mathematical computations.

In the context of the study, calculators play a role in providing the scaffolds for our learners to simply arrive at correct answers. Sometimes learners may find it difficult to solve complicated mathematical problems such as questions involving trigonometry. They may understand all the formulae and steps required to solve such a given problem but may not be able to reach at the correct answers because of difficult arithmetic calculations involved. Thus, a scientific calculator as a being a mediating tool in the learners' ZPD plays that scaffold role. It is for this reason that this theory is most relevant for this study**.**

1.8.2 Conceptual Framework

A conceptual framework for the use of scientific calculators in the Mathematics classroom describes the interactions among the students and teacher. It is the teacher's responsibility to give instructions and guidance to the learners who in turn carry out those instructions in solving Mathematical problems by the use of scientific calculators. This has influence on the learners' performance, attitude and time management in the learning of Mathematics. An illustration of the conceptual framework is shown in Figure 1.

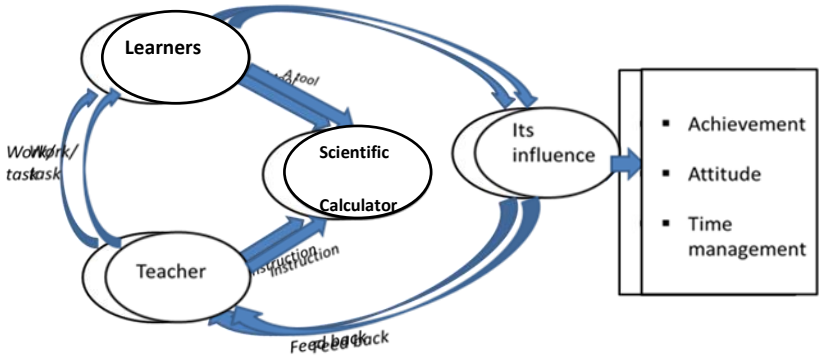


Figure 1: Conceptual Framework

1.9 Delimitation of the study

The research was conducted in one of the secondary schools in Lusaka urban. If the study was to be conducted among schools in rural areas where learners do not have much access to scientific calculators, the results could have been different. Age was not considered as it was assumed that all learners behaved in the same way when using scientific calculators. The study only concentrated on senior secondary school learners (Grade 12).

1.10 Operational Definition of Terms

The following terms mean what is explained below in relation to the focus of the study

(a) **Scientific calculator** is a tool not only to perform mathematical computations but also for learning Mathematics.
(b) **Learners** refers to children of school-going age attending secondary school in Zambia
(c) **Learning** refers to a process that leads to change in behaviour. It occurs as a result of experience and increases the potential for improved performance and future learning**.**
(d) **Teaching** means an interactive process, primarily involving classroom activity which takes place between teacher and learners.
(e) **Performance** is what can be observed and measured during instruction or training. In this study, learners' performance is used to measure conceptual understanding.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents literature which is related to the study. This chapter highlights the literature from several studies related to this study. The first section will explore the influence of the scientific calculator. The second section will discuss the use of scientific calculator in the teaching and learning of Mathematics. The third section will look at the myths about the use of scientific calculator. The four section will bring about the availability of scientific calculator while the fifth section will discuss scientific calculator and technology in Mathematic. The last section will summarized the reviewed literature. These five sections are important to this study because they present related findings that demonstrate the use of scientific calculators at different levels in other countries.

2.2 Influence of the Scientific Calculator

A calculator is a device for performing both mathematical computations as well a tool in the learning for Mathematics. Since technology is recognised as an essential component of the instructional process, the advent of calculator technology has influenced the teaching and learning of Mathematics in a profound way (Dunham & Dick, 1994; Demana & Waits, 2000). From a study in South Africa, Suydam (1976) made a valid point that the use of a calculator enables the teaching of concepts like estimation, long division and decimals taught before fractions. According to Suydam, this would be more difficult for learners to do without a calculator. The use of scientific calculator forms an important foundation for the grasping of the fraction concept. This study differs with that of Suydam (1976) in the sense that it focused on the use of scientific calculator in the teaching and learning of Mathematics at senior secondary school. It entails that by the time the learners reach senior level, they will have understood the application of a calculator in certain areas of Mathematics. A research by Humbree and Dessart (1986) concluded that, apart from improving learners' aptitudes, the calculator develops learners' conceptual thinking as well as helping them to achieve mathematical abilities and self-confidence. This was supported by Maxwell et al**.** (2004) and NCTM (2000). Under the technology principle, Ellington's meta-analysis research of 2006, Mbugua, Muthoni and Okere (2011) as well as research by Ochanda and Indoshi (2011), concluded that the merits of the use of a calculator in teaching and learning clearly outweighed

the demerits of using a calculator. Contrary to these findings, studies by McNamara (1995) concluded that the use of a calculator neither do good nor bad for school children. This clearly shows that no study pointed out that the use of scientific calculator is harmful to learners in the teaching and learning process. Therefore, this study has attempted to unravel the truth about the type of influence scientific calculators have on learners towards Mathematics in the Zambian context.

2.3 The Use of Scientific Calculators in the Teaching and Learning of Mathematics

A study carried out by the National Council of Teachers of Mathematics (NCTM) in 2000 in the United States supports the advancement of technology in the classroom, and asserts that the use of technology often allows for problem solving to occur in greater depth. The study showed that scientific calculators are not just tools for performing computations; they have great potential as instructional aids for the development of Mathematics concepts and understanding, especially when learners are proficient in their use. A study carried out by Ochanda and Indoshi (2011) indicates that the calculators should be used frequently for the learner to exploit the benefits that come with their use, such as improved attitude towards the subject and time management due to the fact that calculators are faster to use in computations as compared to the traditional pen-paper technique of computation. Ellington (2003: 456) stated that; "To get the greatest benefit from calculator usage within the classroom, calculator use should not be confined to the mere checking of work; it should have a pedagogical influence in the Mathematics classroom." These studies do not show how learners use a scientific calculator and the challenges that come with its usage other than its benefits. It is for this reason that this study established the use of scientific calculator from the time it was introduced in the Zambian Mathematics syllabus.

In spite of these benefits, the use of calculators in Zambia is not widely exploited in secondary schools. This has prompted the researcher to establish more information about the use of calculator in mathematics education. It appears to reap outlined benefit of the calculator, there is need to establish more information about how exactly the gadget is used in the Zambian education system.

In a survey carried out to identify mathematical skills commonly used in occupations, it was identified that 98% of respondents used the calculator in their jobs (Saunders, 1998). To this effect, Masese (2016: 22) argued that "if the calculator is so readily required in the real world

then it seems prudent that learners get the opportunity to apply this learning tool in classrooms." Some researchers pointed out the technological advantage offered by the calculator; its ability to reduce the time spent on mathematical computations leading to increased amount of time spent on learning and understanding mathematical concepts, and discovering and observing patterns (Pomerantz, 1997). Since this had not been established in the Zambian education system, this study sought to establish if scientific calculators aided learners' time management while they performed mathematical computations.

2.4 Myths he use of Scientific Calculator

Studies conducted by Pomerantz (1997) and Risser (2011) in the United States showed that the effective use of a calculator in the classroom, regardless of the positive reports from research, was hindered by people's attitude towards the calculator rather than on the merits or demerits of the calculator. The merits and demerits were labelled as myths rather than facts. Learners were able to increase the volume of calculations in a given time because calculators made computation faster. Ochanda and Indoshi (2011) observed that scientific calculators were seen as simple tools which the learner could use to save on time, especially where large volumes of calculations were involved. Mbugua, Muthomi and Okere (2011) emphasised that the calculator was an essential learning tool and should be availed to the learners all the time. In the use of scientific calculator and exposure of learners to the device, Mabra (2013:14) stated that:

> *Too much exposure to calculators and the student will not understand the actual meaning of an exponent in an equation or expression. Too little exposure and the student will not learn to use a tool that will make them more efficient. Obviously somewhere in the middle is the ideal amount of exposure, but where? For example, when graphing quadratic functions in Integrated Algebra, there is no reason after doing a few by hand that the students should not be able to use the calculator to quickly create a table. The basics of most concepts in math are learned in middle school. Clark says "middle school Mathematics determines student success at the high school level." Any concepts that students do not master in the middle school level will result in students having difficulty in the high school level. In particular, students need to acquire problem-solving methods and critical skills that will help in the learning of higher-level Mathematics.*

The focus of the current study differs from previous studies in that it focused on how scientific calculator is used in the teaching and learning of Mathematics in Zambian senior secondary schools. The study by Mabra (2013) focused on the manipulation of scientific calculators by learners only. This study would demonstrate the effective use of a scientific calculator in the teaching and learning of Mathematics by both teachers and learners. The study would investigate the attitudes of learners and teachers towards the use of the tool.

2.5 The availability of Scientific Calculator Usage

A survey done by DES/NCCA revealed that the revised Irish Primary School Mathematics Curriculum provided for the use of calculators in Mathematics from Fourth to Sixth classes (DES/NCCA, 1999a, 1999b). However, the study did not clearly show whether the school bought scientific calculators for learners to use of primary school Mathematics. This current study looked at secondary school Mathematics. From learners' responses, it was revealed that the calculator was available to almost all the learners since it was a small percentage that never had (Mbugua, Muthomi, Okere, 2011). On the contrary, teachers' views showed that calculators were not available to all learners. Learners often used scientific calculators and more so in examinations and believed that they finished their work faster and it made Mathematics easier. With this understanding calculators may not be available to all learners, the current study established whether scientific calculators were available to all learners in the teaching and learning of Mathematics in Zambian classrooms.

Given the affordability of the simple hand-held calculator, it is hardly surprising that it is easily available in the workplace and at home. However, some controversy has surrounded its use in the classroom as teachers, parents and learners have felt that calculator usage might cause a diminution of Mathematics skills (Close, et al., 2003a). Close's study is referring to the general use of a calculator regardless of the type or model. On the contrary, the current study looked at a specific type of calculator that learners and teachers must use as an aid in mathematical computations in certain topics. In Ireland, it was indicated that 24% of learners were taught by teachers who reported calculator usage at least once a week (Close, et al., 2003b). This situation is different from other countries like Australia, Canada, England, Iceland, Netherlands and Singapore where over 80% of learners used calculators in Mathematics classes almost every day (Beaton, et. al., 1996). The current study has established the importance of the availability and affordability of scientific calculators in a Mathematics classroom.

2.6 Scientific Calculators technology in Mathematics

Since technology is recognized as an essential component of the instructional process, the advent of calculator technology has influenced the teaching and learning of Mathematics in a profound way (Dunham and Dick, 1994; Demana and Waits, 1990; Fey and Good, 1985). In the study done by Goos and Bennison (2008), it was found that a majority of teachers agreed that technology makes calculations quicker, helps students understand concepts, enables real-life applications and allows students to see the link between different representations. Their study is important in the sense that it investigated the benefit of technology in mathematics education. However, the study did not specify the level of learners involved in the study. It did not also indicate the extent to which calculators were used by teachers and learners. The current study looks at the use of scientific calculators at senior secondary school Mathematics.

The study by Rebecca (2013) indicates that in 2007 the Trends in International Mathematics and Science Study (TIMSS) explored three different aspects of calculator use that ages at which different types of calculator are introduced into teaching in England Basic calculators (not scientific or graphical) are first introduced into teaching in England during Key Stage 2, between ages 7 and 11, for use where appropriate. Key Stage 3 and 4 learners are also required to use calculators as appropriate. The Key Stage 3 and 4 programmes of study do not specify what type of calculators should be used; however, at the most advanced level the programmes do require that learners have familiarity with graphical calculators. The study focused on the use of calculator in general at lower grades and the type of calculator was not specific that learners needed to use. There is need for the learners to be guided on what type of calculator is of help only at an advanced stage where graphical calculators were specified which was not the case with this current study.

According to Rebecca, Calculator use was also investigated in the TIMSS 2003 study. Between the 2003 and the 2007 studies five countries displayed a significant increase in the usage of calculators in the Grade 4 classroom: Armenia, Hong Kong, Latvia, Lithuania and the Russian Federation. New Zealand was the only country to display a significant decrease in calculator use at this level. At Grade 8, three countries displayed a significant increase in the usage of calculators in the classroom: Jordan, Malaysia and Slovenia. In contrast, four countries displayed a significant decrease in the usage of calculators at this level: Bahrain, Ghana, Serbia and the United States. The study explored the important use of calculators at grade 4 and grade 8 levels but not at senior secondary school level.

2.7 Summary

In summary, the literature reviewed has shown that there is still debate about whether calculators increase efficiency in doing Mathematics among senior secondary school learners. The researcher has also observed that several gaps still exist in the literature. This points to the need for carrying out a study of this nature. The gaps include documenting the extent to which the use of scientific calculators influences the performance of learners in Mathematics in Zambian schools, the applications for which scientific calculators are used and the observable practices regarding the use of scientific calculators in the teaching and learning of Mathematics in the context of Zambian education system.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter is the description of the research paradigm, research approach and design, study site, population, sample, sampling techniques used, data collection instruments and Data Presentation and Analysis procedures. Furthermore, highlights relating to how the data were analysed, trustworthiness and credibility and ethical considerations are presented.

3.2 Research Approach and Design

This research was qualitative and it utilized a case study design. Creswell (2010:56) states that the aim of qualitative research studies is to engage in research that probes for a deeper understanding of a phenomenon rather than to search for causal relationships. Qualitative research sets out to penetrate the human understanding and the construction thereof. The design provided a systematic way of understanding the problem at hand (Use of Scientific Calculators in the Teaching and Learning of School Mathematics: The case of one secondary school in Lusaka, Zambia) in greater depth. This is because the case study design provides for a variety of participant perspectives and uses multiple data collection techniques (Gillham, 2000). The design is also appropriate when a researcher is dealing with a research problem whose questions are designed to elicit different types of data, either qualitative or quantitative (Creswell, 2012). In the context of this study, the design enabled the researcher to elicit qualitative data from different sources, including observations, unstructured interviews, focus group discussions, and performance tests (Myers, 2009).

3.3 Study Site

The study was carried out at a public secondary school in Lusaka District of Zambia. The school was selected using convenience sampling because it was easily accessible to the researcher. It was also chosen because, in the recent past, it recorded poor performance in Mathematics in the School Certificate Examinations as compared to other schools, despite being in the capital city (ECZ, 2015). It was expected that children in an urban area would perform better than those in rural areas because urban schools had easy access to teaching and learning resources than rural schools. Therefore, one expected more learners in town schools

to have scientific calculators than those in rural schools and, ostensibly, do better. The school under study was chosen on the basis that it was underperforming in Mathematics at national examinations level despite the introduction of scientific calculators (ECZ, 2015). Other than that, the school was one of the oldest schools in Lusaka District and, as such, was expected to be established and have good learning facilities that would lead to good performance in Mathematics.

3.4 Population

In this study, the population consisted of all Grade 12 learners who were doing Mathematics, together with all the teachers of Mathematics in Lusaka District because, at that level, the learners were mature enough and had experience from Grades 10 and 11 in handling scientific calculators. On the other hand, the study opted to include teachers because they were the ones guiding learners in the use of scientific calculators during Mathematics lessons.

3.5 Sample

In determining the sample size, the researcher considered the purpose of the inquiry, what was at stake, what was useful, what was credible, and what could be done with available time and resources (Patton, 1990). Being a qualitative study, only a small sample was typically required. Therefore, the sample comprised of 8 Mathematics teachers and 24 Grade 12 learners. The Mathematics teachers were given identification codes, namely CA, CB, CD, up to CH. Learners were code-named L1 to L 24. Table 1 shows a summary of sample size used in this study.

Table 1: Sample size

Serial Number	**Participant**	**Sample size**
1.	Teachers of Mathematics	8
2.	Learners of Mathematics	24
Total		**32**

Table1 shows the number of participants who took part in the study through unstructured interviews, focus group discussion, in lesson observations and performance test in this study.

The work experience of Mathematics teachers was considered to be important because it contributes to learners' Mathematics achievement. Table 2 shows the years of experience of the teacher participants.

Table 2: Work experience of teachers

Serial No.	Years in Service	Frequency	Percentage (%)
1.	Less than 5 years	0	0
2.	5-10 years	1	8
3	10-15 years	2	38
4.	15-20 years	3	31
5.	20 years and above	2	23
	Total	**8**	**100**

Table 2 summaries the number of Mathematics teachers who participated through unstructured interview and lesson observations.

3.6 Sampling Techniques

Since the study was qualitative in nature, it utilized non-probability sampling techniques to select participants. Homogeneous purposive sampling was used to select teachers of Mathematics at the selected secondary school and, since the school only had a few teachers of Mathematics teaching Grade 12 classes. All the eight teachers participated in the interviews but only three of the teachers were selected for lesson observations depending on the outcome of the interviews. Self-selection sampling technique was used to select pupils for this study because the researcher wanted the learners to take part in the study on their own accord. The researcher used this technique to select learners who took part in the focus group discussions, and later sat for a test. These learners came from the classes taught by teachers who were observed while teaching. This was done for the purpose of triangulation.

3.7 Data Collection Instruments

This section presents data instruments used in the collection of data. These include: lesson observations, unstructured interviews guides, focus group discussion guides and performance test. These instruments are discussed in detail in the following sub-sections:

3.7.1 Unstructured Interviews

An unstructured interview guide was utilized to collect data from Mathematics teachers of Grade 12 learners. Recording of data was done by audio-recording and note-taking was used as backup. The interview guide consisted of a list of open-ended questions related to the issues under study (see Appendices D and F). In this study, the unstructured type of interviews allowed the researcher to pose open-ended questions and the interviewees to express their own opinions freely. This required both the interviewer and the interviewee to be at ease because it was like a discussion or brainstorming on the given topic. The direction of the interview was determined by both the interviewee and interviewer.

3.7.2 Lesson Observation

According to Creswell (2010:83) explains that "observation is a systematic process of recording the behavioural patterns of participants, objects and occurrence without necessarily communicating with them. Observation is an everyday activity whereby we use our senses (seeing, hearing, touching, smelling, tasting) but also our intuition to gather bits of data". McMillan and Schumacher (2010:208) allege that "observation is used to describe the data that are collected, regardless of the technique employed in the study.

Observation was used to collect information on how teachers and learners interacted in the classroom and how the scientific calculator was used". Riding on the argument by Leedy and Ormrod (2005:145) that "observations in a qualitative study are intentionally unstructured and free-flowing", the researcher was free to shift focus from one thing to another as new and potentially significant objects and events presented themselves. The advantage of the observations in this research is that they presented an opportunity to gain insight into the problem. The researcher gained insight into the participant's views, developed relationship with them, and allowed the researcher to hear, see and begin to experience reality as participants did. The researcher too learned from own experience and own reflections, which form part of the emerging analysis. The researcher took time to develop an observation schedule that comprises of what the researcher was looking for in line with the research objectives.

To observe a lesson, the researcher took a back seat (though he could move around once in a while to see how the learners were working). He took note of the number of learners who were present, how many of them had scientific calculators, and the types of calculator they had. The

researcher also paid attention to computation of numerical problems, learners' skills in handling the device and the role played by the teacher in guiding the learners in the use of the scientific calculator in the Mathematics classroom. The researcher used an observation schedule (Appendix H) in order to gather information in a systematic manner.

3.7.3 Focus Group Discussion

The other method of data collection that was used in this study was focus group discussion. 24 learners were put in three groups of 8. The during the focus group discussion, learners were asked about their perceptions, opinions, beliefs and attitudes towards the use of scientific calculators in teaching and learning Mathematics at secondary school. Questions were asked in an interactive group setting where participants were free to talk with other group members (see Appendix D). In the context of this study, the focus group discussions helped clarify and shed more light on issues raised and not clarified in the interviews. The method was particularly utilized because it was economical on time, focused on particular issues, and yielded insights that would not otherwise be available in a straightforward interview. The focus group discussions also produced large amounts of data and were useful for triangulation with the information obtained through interviews and observation (Morgan, 1988).

3.7.4 Performance Test

The researcher also administered a performance test to the 24 learners. The test consisted of items for which the use of a scientific calculator was reasonable and necessary, that is, challenging calculations (see Appendix G). The administration of the test helped the researcher observe certain behaviours among learners concerning the use of scientific calculators. The researcher took note too of the effectiveness and practical deficiencies in using scientific calculators in the items that required their aid.

3.8 Data Collection Procedure

The researcher was made to explain to the teachers of Mathematics the purpose of the research and to establish a rapport with them. The researcher also reassured the teachers of their confidentiality. The teachers participated in unstructured interviews. From the issues that arose from teachers CA, CB and CC, the researcher got interested in and followed the teachers to their respective classes and observed lessons. The interviews were audio-recorded and note-taking was done to enable the researcher capture the occasions in their totality. The lessons

from the three teachers were observed on trigonometry. Observations on how learners and teachers used the scientific calculator in Mathematics lessons were conducted (see Appendix: H). The lessons observed were video-recorded and notes were taken. From the three classes, the researcher explained to the learners the purpose of the study, the items on the tests and to let them feel free to take part. The learners volunteered to take part in focus group discussions and test. Each group consisted of 8 members. The researcher was made to explain to the learners the importance of them participating in the research and assured them of confidentiality. Lastly, the same learners were subjected to a test consisting of the items that required the use of a scientific calculator.

3.9 Data Presentation and Analysis procedures

This section explains how data was presented, analysed and interpreted.

3.9.1 Data Presentation

With the understanding that qualitative data is usually subjective, interpretive, descriptive, holistic and copious (Hancock, 1988), the researcher based the structure of the presentation of the research findings around the categories or themes that emerged from the study. The following strategy were used during presentation:

- The themes or categories were presented as sections with relevant sub-sections.
- Quotes were used to demonstrate and/or inform or support findings arising from the verbatim.

3.9.2 Data Analysis

The analysis of data was done by following the trends in the patterns that emerged in the course of the research. When interviewing participants, the researcher listened to narratives about the use of scientific calculators in teaching and learning of Mathematics in secondary schools. Hence, the researcher was able to collect multiple interpretations with all their contradictions, rather than finding the 'correct' interpretation (Yin, 1994). The analysis of data firstly dealt with the description of each case based on the data collected via the different instruments. The data from unstructured interviews, lesson observations and focus group discussions were analysed and interpreted thematically. The Braun and Clarke (2006) assert that thematic analysis is a qualitative research method that can be widely used across of research questions

for identifying, analyzing, organizing, describing and reporting themes found within the data set. This means that the researcher analysed the data by grouping statements that were similar into themes. Following Creswell (2014), the researcher categorised thematic analysis into related topics, and identified major themes to provide descriptions of the phenomena under study. Data from the performance test was analysed by examining the learner's answers and the idea was to determine how effective they were in the use of scientific calculators for those questions which required the need of scientific calculators.

3.10 Credibility and Trustworthiness

Trustworthiness was an essential consideration in this study. According to Padgett (1998) cited in Chileshe (2018), a trustworthy study is one that is carried out fairly and ethically. Trustworthiness of the qualitative data was ensured by assessing credibility, transferability and dependability. To ensure credibility of this study, the inclusion of member checking into the findings, that is, gaining feedback on the data, interpretations and conclusions from the participants themselves was used. Transferability of the study was realised through detailing of research methods, contexts and assumptions underlying the study. Dependability of this study was enhanced through triangulation, member checks, observation and peer examination.

3.11 Ethical Consideration

In order to protect those involved in research, ethical issues were considered by maintaining confidentiality anonymity and respect for the participants. Wimmer et al. (1994) identified the principles of confidentiality and respect as the most important ethical issues requiring compliance on the part of the researcher. These basic ethical requirements demanded that the researcher respected the rights, values and decisions of participants. In this study, values of the participants were respected and informed consent was obtained voluntarily from the participants before engaging them in the study. Before embarking on data collection, the researcher first applied for ethical clearance from the Ethics Committee of the University of Zambia. He then asked for permission from the District Board Secretary (DEBS) for Lusaka in order to visit the targeted secondary school (see Appendix A). The researcher was also requested the head of the selected secondary school in order to collect data from the learners and teachers (see Appendix B). Consent forms for both teachers and learners were given (see Appendices C and E).

3.12 Summary

This chapter explained the research methods that were used to collect data from teachers, head of department and learners. Qualitative techniques were employed in order to collect information from 8 secondary school teachers and learners using thematic categorisation procedures. This research design involved the use of unstructured interviews, focus group discussions and performance test in order to get detailed information. Lastly, all ethical considerations and limitations of the study were explained.

CHAPTER FOUR

PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents the findings of the study. It is divided into the introduction, general statistical information, how calculators are used in schools, challenges faced by learners in using calculators, and best practices for the use of calculators. The findings are presented according to the objectives of the study.

4.2 Work Experience of Teachers and Learner Performance

Teaching experience plays an important role in learners' achievement in Mathematics. Therefore, this study sought to find out the work experience of the teachers who were selected in the sample (see Table 2). Table 2 shows that out of the eight teachers who participated in this study, 7 teachers (88%) had taught for periods of more than 10 years. Only one teacher had taught Mathematics for less than ten years.

4.3 How secondary school teachers and learners use scientific calculators in the teaching and learning of Mathematics.

Objective 1 of this study was to establish how scientific calculators were incorporated into the teaching and learning of Mathematics in senior secondary schools. The study established various ways in which scientific calculators were used by both teachers and learners. The following were the findings of the study:

4.3.1 Scientific calculators selectively used for certain topics

Teacher CE interviewed indicated that scientific calculators were not used indiscriminately and that the use was guided by certain topics that required scientific calculators when they were teaching. They were mindful of the fact that not all topics required scientific calculators, even in the final examinations. To this effect, one of the participants stated that:

> *Mostly, learners are taught on how to use a scientific calculator when learning certain topics that require its aid not just teaching them how to use it. The topics that require the aid of scientific calculators as enshrined in the Mathematics*

syllabus are trigonometry, statistics, earth geometry, sequences, function graphs and mensuration. (Participant teacher CE)

The teacher participants further indicated the topics that required the use of scientific calculators. The information is shown in Table 3.

Table 3: Topics that required the use of scientific calculators

s/n	**Topics**	**Subtopics where calculators were needed**
1	Trigonometry	Throughout apart from special angles
2	Mensuration	Finding volume and area of solid shapes
3	Earth geometry	Finding the distance between the two places
4	Sequences and series	Calculating the n^{th} term and the sum of geometric progression
5	Statistics	Calculating the standard deviation
6	Quadratic equations	Solving equations involving the use of quadratic formula only

A teacher participant explained how she taught learners how to use a scientific calculator in Mathematics. She explained this as follows:

I do spend a few minutes talking about the scientific calculator before the main lesson is introduced. I teach the learners how to use the tool as I teach a topic that needs the use of a scientific calculator. (Teacher CF)

Another teacher participant stated:

Usually, when teaching trigonometry, I take time to teach them how to use a scientific calculator. I teach about the functions of the scientific calculator that are relevant to the topic I am teaching. (Teacher CH)

Yet another teacher participant added:

Most teachers overlook the fact that there are areas where learners are expected to comprehend concepts without the use of calculators. Yes, I do allow the use of calculator, e.g. finding the percentage error. Calculators are allowed.

The calculator was meant only in areas where one cannot calculate mentally, the tedious work of going to the log-book. I am sure the calculator was meant to replace the use of a logarithm-book. (Teacher CE)

4.3.2 Practical Classroom Usage of Scientific Calculators in Teaching and Learning of Mathematics

The researcher observed three trigonometry lessons taught by teachers CA, CB and CC. The observation was that the three teachers guided learners on the use of scientific calculators in their lessons. Teacher CA told the learners to get their scientific calculators and ensure that they were on degree mode. The teacher used sin 68 to demonstrate how the learners could use the scientific calculator in a practical way to solve a mathematical problem.

He instructed the learners,

" Make sure that your scientific calculator is in 'degree mode' them to press sin then 6 and 8, followed by the equal sign, display is 0.927183855".

The teacher followed this with questions for the learners to practice. However, it was observed that out of 46 learners, 9 had no scientific calculators (see Table 5 page 34).

In teacher CB's class, it was observed that learners and the teacher used scientific calculators when calculating for angles. It was noticed that 8 learners and the teacher did not have scientific calculators during the lesson. The teacher issued instructions to learners on how to calculate for an angle using the sin rule. Following the teacher's instructions, the learners managed to arrive at the correct answer. However, one learner got stuck as the scientific calculator he had displayed $\frac{407}{10}$ (in fraction form), instead of the expected answer 40.7 (in decimal form).

The learner asked about how to convert the answer to a decimal fraction.

"Sir, my scientific calculator has displayed the answer in a fraction form? Could this this be correct?"

Unfortunately, the teacher failed to help the learner because he too had no idea of converting a fraction to decimal fractions. It was a fellow learner who finally came to rescue the situation by converting the answer to a decimal fraction. In another example, some learners had challenges in computing $\frac{6}{sin108} = \frac{x}{sin30}$ instead of x $= \frac{6\sin30}{\sin108}$ =3.154386673. For example, a

learner keyed in $6\sin(30 \div 108)$ on a scientific calculator which displayed 0.02908870. Thus, the learner failed to find the correct answer even with the aid of a scientific calculator.

In teacher CC's class, it was observed that 9 learners didn't know how to change their scientific calculators to degree mode. All what they knew was to enter numbers and copy what the calculator displayed. At the same time, the teacher didn't have a scientific calculator and depended on learners for answers. There were also learners who did not seem to care about what the class was doing. All this happened when teacher CC wrote a question on the white board. Find the value of Cos 135^0. Three learners gave out their answer as -0.996087835 and the other two learners said -0.707106781. The teacher was perplexed on seeing two different answers. Since he had no scientific calculator, the teacher went to check on the learner whose answer was wrong. It was at this point that the teacher realised that the learners was using the scientific calculator in radian mode. The teacher said

"I know there are some of you who do not know how to change your calculators into degree mode". Those who are using "CASIO" scientific calculators are you able to see the button "mode"? Press the button three times. You will see "Deg 1 Rad 2 Grd 3". Press 1 and your scientific calculator will show "D" on the screen. For those using "SHARP", go to a button 'DRG' on the right top of your calculator. Observe what is happening on the screen display as you continue pressing the button. Press the button and stop when DEG is displayed". Now, find cos 135^0. (Teacher CC)

At this point all learners who had scientific calculator were able to get -0.707106781 as the correct answer.

In addition, participants observed that scientific calculators were very useful tools when used properly. In relation to this, one of the teacher participants explained:

> *If a calculator is well used, yes, it helps learners to do things faster and teaching becomes easier. Sometimes I rely on a calculator to find standard deviation in statistics. Using calculators gives a more accurate answer and is faster. Sometimes even before going to class I prepare the work for learners with the aid of a calculator. When preparing lesson plans, I use the device. In class, it helps the teacher to quickly cover a concept and move to another. In this way, most of the time is devoted to teaching the concept than on calculations. The*

learners too are able to solve problems involving bigger figures unlike in the past, before the calculators were introduced. (Teacher CD)

Table 4 shows the performance of learners in each question in relation to who they were using scientific calculators. Most of the questions in the test could be answered even without a scientific calculator. This was necessary to find out how learners used the gadget in answering the questions.

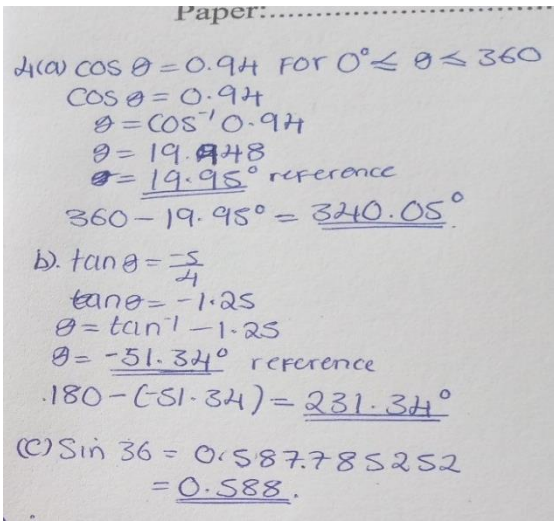
Table 4: Marks scored by learners in each question in the performance test

Question Number		**With access to scientific calculator**			
		Correct	%	**Incorrect**	%
1	a)	9	36.4	15	63.6
	b)	6	27.3	18	72.7
	c)	13	55.5	11	44.5
2	a)	7	27.3	17	72.7
	b)	4	18.2	20	81.8
3	a)	15	63.6	9	36.4
	b)	15	63.6	9	36.4
4	a)	17	72.7	7	27.3
	b)	2	9.1	22	90.9
	c)	13	55.5	11	44.5
5	a)	15	63.6	9	36.4
	b)	6	27.3	18	72.7
	c)	6	27.3	18	72.7

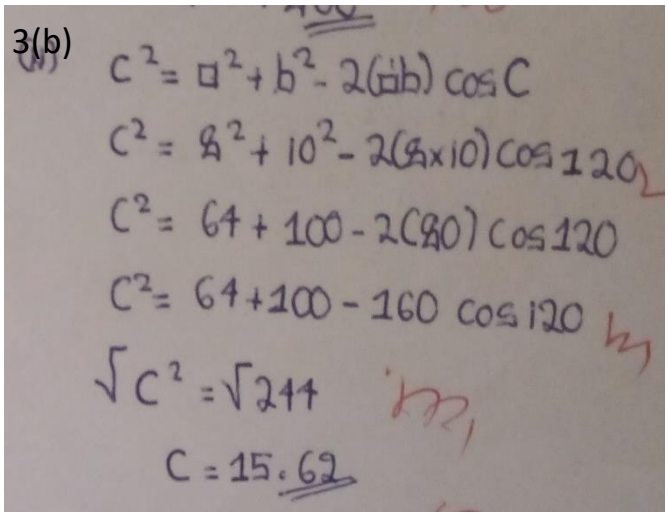
Table 4 indicates that majority of leaners did not do well in Questions 1(a), 1(b), 2(a), 2(b) , 4(b), 5(b) and 5(c). Conversely, the learners performed well in Questions 1(c), 3(a), 3(b), 4(a), 4(c), and 5(a) (at least half of the learners got these questions correct).

4.3.3 The Use of Scientific Calculator on Trigonometric Ratios

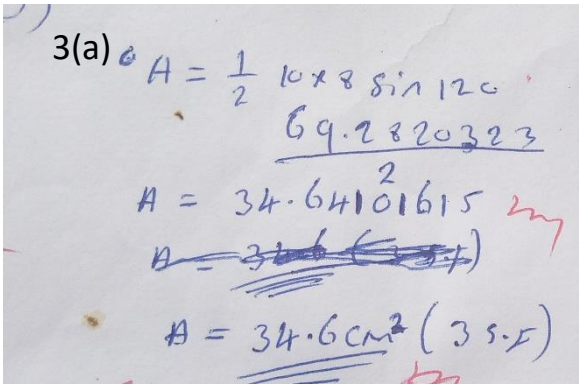
This demonstrates how learners were using scientific calculators to calculate for the length, angle and area of a non-right angled triangle. The Figure 2 shows how the learners L10 and L1 were using a scientific calculator on trigonometric ratios to arrive at the solutions



(a) Learner L10 with the aid of a scientific



(b) Learner L1's solution for question 3 (b).



(c)Learner L11 with the aid of a scientific

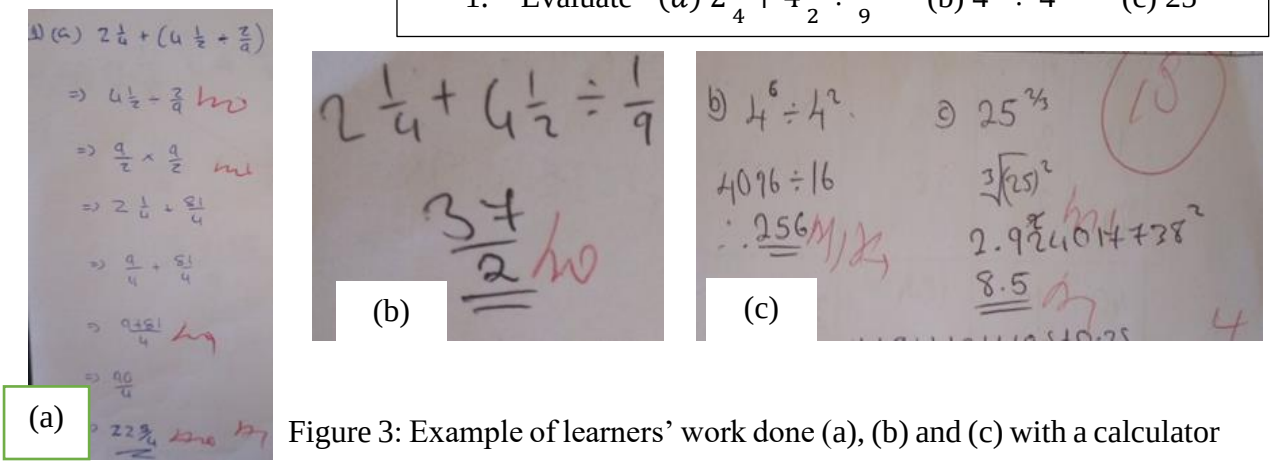
Figure 2: Example of learners' work done with the aid of a calculator

Figure 2 (a) shows part (a), (b) and (c) of question 4 worked example by L10 who demonstrated the use of scientific calculator for finding the angle within a given range. He managed to answer Questions 4(a) and (c) correctly but failed to get the expected final solution for (b). Figure 2 (b) shows how learner L1 was using a scientific calculator applying the cosine rule to find the length AB of a triangle, while learner L11 part (c) illustrated the use of a scientific calculator for finding the area of a given triangle in question 3(a). He systematically outlined how he used the gadget to arrive at the solution.

4.3.4 The Use of Scientific Calculator on Fractions and Indices

Figures 3 to 5 show some of examples of learners' work with correct and incorrect solutions. The examples also show different ways of solving questions with or without the aid of scientific calculator. Figure 3 part (a) shows an example of learner L14's work on Question 1 (a) with correct solution without the aid of a scientific calculator. Yet another learner L17 (Figure 3 part (b)) who attempted to use a scientific calculator directly (not step by step) in a wrong way could not find the correct solution. Figure 3 part (c) shows a learner L7 who correctly used scientific calculator to solve questions involving indices.

1. Evaluate $(a)\ 2\frac{1}{4} + 4\frac{1}{2} \div \frac{2}{9}$ (b) $4^6 \div 4^2$ (c) $25^{2/3}$



(a) (b) (c)

Figure 3: Example of learners' work done (a), (b) and (c) with a calculator

Figure 4 part (a) of question 1 shows worked example by learnerL11 who failed to use a scientific calculator but managed to answer Questions 1(b) correctly with the help of a calculator.

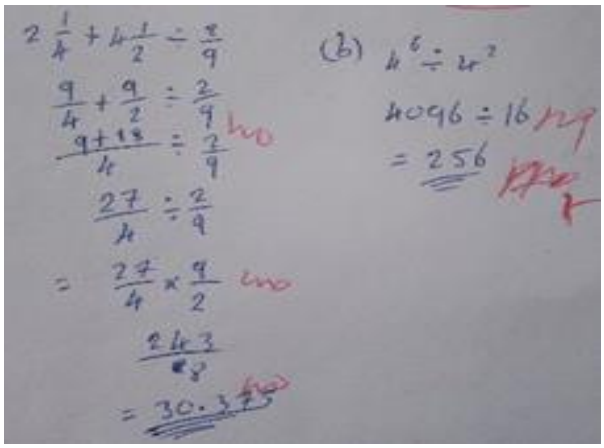


Figure 4: shows examples of learner L11's work with the aid of a scientific calculator

Figures 5 shows worked examples by learner L20 in part (a) and learner L13 in part (b) who could not get correct answers.

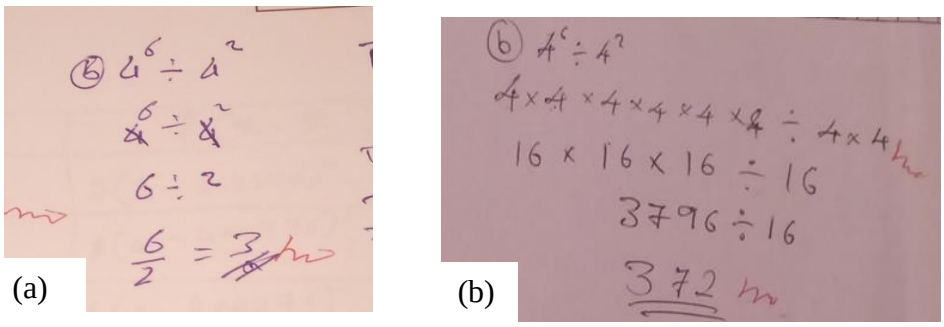


Figure 5: Examples of learner's work.

In Figure 5 part (a), learner L20 failed to compute the exponents even when he had a scientific calculator, though the calculation could still be done even without having a scientific calculator. In Figure 5 part (b), the learner was able to expand the exponents correctly but got the final answer wrong. The learner seemed to have made errors on multiplication (16 x 16 x 16 = 3796) and on the division (3796 ÷ 16) using the traditional method.

4.3.5 Use of Scientific Calculators for Paper 2 Questions

The study revealed that scientific calculators were mostly used in School Certificate Examinations for Paper 2 questions. When asked why scientific calculators were allowed in Paper 2 when it was not all topics required its aid, the participants referred to the voluminous amount of work which the candidates needed to do to answer the questions. One participant teacher had the following to say:

> *The teaching with the use of scientific calculators is focused on Paper 2 type of questions. In Paper 2, questions are in big figures, mostly requiring the use of scientific calculators unlike in Paper 1 which tests mostly mental and higher order thinking.* (Teacher CG)

Another participant teacher explained:

> *It's up to the learner to use a calculator for Paper 2 in the final [examination]. Learners know that they are supposed to use calculators. Calculators make the work easier and faster. Most of the learners say they fail to finish in Paper 1 because they do not use scientific calculators.* (Teacher CH)

4.3.6 Indiscriminate Use of Scientific Calculators

The study revealed that learners used calculators even for simple arithmetic problems. Some teacher participants had labelled this dependence as abuse of the scientific calculators. The abuse was found to be widespread. A participant described how learners depended heavily on scientific calculators, as follows*:*

> *I do allow learners to use calculator just in certain situation. The reason is, I will give you an example from one of my grade12 learners in my class who wrote examinations. I wrote 21 by 2, this child rushed to a scientific calculator. To me, that was promoting laziness in thinking in that child because 21 by 2 is not a complicated problem. Occasionally it takes more time to type in the expression than to evaluate it mentally. I started telling pupils that I will be allowing them to use calculators when it was necessary because I wanted to promote critical thinking in their minds. I told the pupils: The calculator is just thinking on your behalf. It is doing the calculations, not you. You, your mind is just pressing the numbers that the concept requires you to calculate, but not the calculation itself. So, on that one, I always do discourage my pupils from using calculators. I do allow them to use calculators when it is necessary. (Teacher CD)*

Another participant added:

> *There is abuse in the use of the calculator. In fact, the calculator is worsening the performance of the learner who does not know how to use it. The learners heavily depend on the calculator even for simple calculations that need to be done mentally. We have agreed with other members in the department never to allow learners to use calculators during lessons that do not need the aid of scientific calculators in the examinations (for example matrices).*
>
> *The learners should know when to use a scientific calculator. Teachers do encourage the learners to do Mathematics without the use of calculators. Calculator promotes laziness. In some cases, the calculator may delay where the brain can give the answer instantly. Calculators*

are only needed when the mathematical problem involves bigger figures, as such one with a calculator tends to work faster. (Teacher CG)

4.4 The Challenges Teachers and Learners of Mathematics face as They Use Scientific Calculators in the Teaching and Learning of Mathematics

This section presents the results of the study on the challenges teachers and learners that use of scientific calculators provide during instruction in Mathematics. The study also presents the challenges experienced during teaching and learning of Mathematics as a result of using scientific calculators. The following themes came out as challenges: teachers do not teach the use of scientific calculators, inadequate number of scientific calculators, missing out on important mathematical concepts and over dependence on scientific calculators.

4.4.1 Teachers do not Teach the Use of Calculators

Participants explained the challenges they had been facing in the use of scientific calculators in solving mathematical problems. The study established that teachers did not teach the learners the technical aspects of using scientific calculators. One participant revealed that:

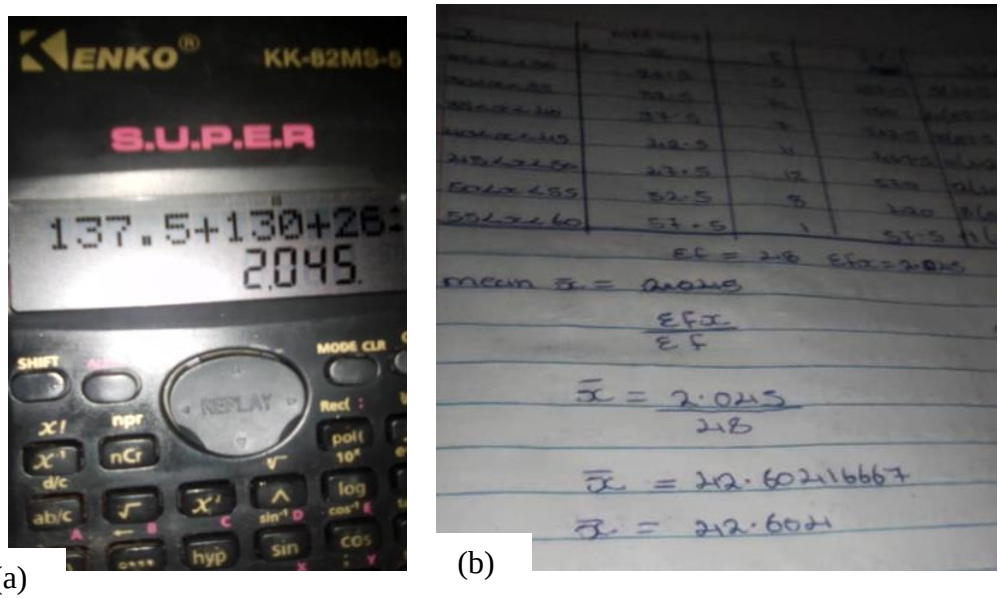
Learners are not taught how to use a calculator as a tool; instead, they are just guided on how to use the calculator when solving a particular question. There is no specific time that I teach learners the basic functions of a calculator, not until we come to topics that require the use of the device. I then teach learners the content in the topic with the aid of a calculator to solve mathematical problems. (Teacher CE)

In addition, one learner said:

We were not taught how to use calculators, even the types of calculators to buy. We just learnt how to use calculators when solving questions that require their use. There is no time that our teacher specifically taught us the functions of a calculator. We just found ourselves using calculators when it came to trigonometry. (Learner L4)

Learner L4's view about the challenges learners have in handling scientific calculators is what the researcher observed during lesson (the researcher was free to shift focus from one thing to another as new and potentially significant events presented themselves). A learner was trying

to calculate $\sum fx$ in order to find the mean of a given set of data. A scientific calculator displayed $137.5 + 130 + 26 \rightarrow = \mathbf{2,045.}$ Figure 6 part (a) shows the display by a scientific calculator while Figure 4 part (b) shows how the learner misread the figure from the scientific calculator *as* $\mathbf{2.045}$.



(a) (b)

Figure 6: An example of how a learner misread a calculator's display

4.4.2 Inadequate Number of Calculators

The research revealed that there were inadequate number of scientific calculators amongst learners. It was observed that some learners did not have calculators at all. Table 5 shows the number of learners with and without scientific calculators.

Table 5: Leaners with or without scientific calculators during Mathematics lessons

Class	**Number of learners with calculators**	**Number of learners without calculators**	**Total**
A	37	9	46
B	36	8	44
C	39	12	51
Total	**112**	**29**	**141**
Percentage	**79%**	**21%**	**100%**

Table 5 indicates that there were 46 learners in class A; 9 of these did not have scientific calculators. In class B, 8 learners out of 44 did not have scientific calculators while in class C, 12 learners out of 51 had no scientific calculators. In teacher CC's class, some of the learners who did not have scientific calculators could not ask from their friends who had. These learners did not participate fully in the lessons and their teacher did nothing to help the situation. In corresponding to this, one of the participants, who took part in the interview, explained that:

> *To begin with, these calculators are not provided by the school. It's the parents' responsibility to buy the calculators, so the challenge is that not all pupils come with calculators. As a result, those who have no calculators tend not to participate in lessons. If you are going to teach about the use of a calculator, they will use their friends' calculators to know how to use a calculator. In short, they don't participate actively. If you ask them to come with calculators, some will do that. The learner wants to use the friend's calculator, while the friend has a Casio and another different model of calculator. If you need to have your own calculator, and also the type of calculators, there is a problem with these learners where a coma is considered to be a point. What you find most of the time when marking, the answer is, for example, 200,00 which is wrong. Even when you have 1.000, that's the biggest challenge I have.* (Teacher CF)

Another participant explained the challenges experienced in the use of a scientific calculator:

> *Schools do not provide calculators and not all learners can afford them. Learners who cannot afford to buy scientific calculators have to depend on borrowing and those who borrow usually do not understand very well how to use the calculators. This has affected the participation of learners during Mathematics lessons. The other thing is that there are different models of calculators. There are situations where learners get stuck while using a calculator and as a teacher you find yourself in that situation where you cannot help the learner because you too are not familiar with the version. This discourages learners from doing Mathematics and as a teacher too, you feel bad for not being able to help the learner.* (Teacher CE)

Another teacher participant added:

> *The other thing which is a challenge is non-availability of scientific calculators to the learners. Most of the learners do not have calculators at the time they need to use them to learn Mathematics. Because not all parents are able to buy their children the required calculator.* (Teacher CA)

From Teacher CC's lesson, it was observed that some learners were sharing scientific calculators with friends; others, however, did not have anyone to share with or they were too shy to ask from their classmates. Another observation was that one learner had a non-scientific calculator, shown in Figure 7. In some instances, learners could not change their scientific calculators to degree mode.

Figure 7: A non-scientific calculator used by a learner during trigonometry lesson

4.4.3 Missing Out on Important Mathematical Concepts

Missing out on important mathematical concepts and procedures came out as a problem during the interviews with teachers. The skills of computing mathematical problems are lost or easily forgotten. A teacher participant had this to say:

> *Learners just punch the numbers on calculators that gave them the correct answers without showing the methods. Learners tend to miss out on important concepts like 'BODMAS'* $6 - 5 \times 2$. *The learner will just enter the figures and the correct answer is displayed. The learner will not know the concept of BODMAS, the concept of distributive law is lost. For example, the concept of* $11 \times 12 = 11(10 + 2)$ *will not be understood when a calculator is used. Not only that, learners will also fail to comprehend the laws of exponential function mentally. Using a*

scientific calculator to solve any mathematical problem will cause the learner to become mentally lazy and incapable of knowing the basic Mathematical skills. (Teacher CG)

The results from the performance test showed that learner L1, who had access to a scientific calculator, was unable to convert mixed fractions to improper fractions so that he can directly use a scientific calculator or use traditional method (see Figure 8).

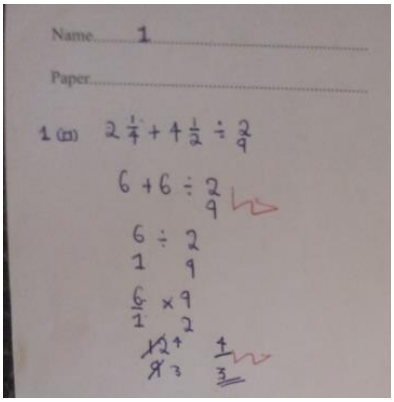


Figure 8: An example of a learner who failed to convert mixed fractions to improper fractions

It was expected that learner L1in figure 8 would convert the fraction to improper fractions and thereafter use a scientific calculate or pencil-and – paper.

4.4.4 Over-dependence on Scientific Calculators

Another problem reported by the participants was that learners depended heavily on scientific calculators whenever they were solving mathematical problems. Learners testified that they found Mathematics more interesting when they used scientific calculators. This information is shown in Table 6.

Table 6: Dependency on the scientific calculator

Category	**No of respondents**	**Percentage (%)**
Dependent on calculators	17	65
Not dependent on calculators	9	35
Total	**26**	**100**

The results in Table 6 indicate that the majority (65%) of the learners depended on scientific calculators to do Mathematics; only 35% stated that they did not depend on the use of scientific calculators. One of the learner participant explained:

> *There is a dependence on the use of the calculator. I find it difficult and frustrating when I have to do Mathematics without a calculator. The use of calculators makes me do work faster and it saves time, especially when faced with bigger figures.* (Learner L11)

One learner stated that:

> *The challenge is that, without a calculator, computation is difficult to do in Mathematics. It is, therefore, not easy to do Mathematics in the absence of a calculator especially where bigger figures are concern.* (Learner L15)

Another learner said:

> *We found Mathematics challenging to solve without a calculator in Paper 1 because we are used to doing Mathematics with a calculator. So, in the event that we are told not to use calculators in a test, we find it difficult and struggle with mathematical computations. It is not easy to multiple decimal numbers without a calculator.* (Learner L 9)

A teacher participant said:

> *I don't allow the use of calculators because learners do not perform well in Paper 1 where calculators are not permitted. Also, in case a calculator develops a fault, a learner that heavily relies on calculator will start panicking. This is one of the reasons why learners don't perform well in Mathematics. Learners still lack the concept of integers; even for simple calculations, such as 2 minus 4, learners will rush for a calculator.* (Teacher CA)

4.5 The teachers' and learners' perceptions regarding the effective ways of using scientific calculators in the teaching and learning of Mathematics in Lusaka District

The researcher sought to find out the effective ways that teachers and learners employed when teaching certain topics in Mathematics with the aid of scientific calculators. These approaches help learners to do Mathematics bearing in mind that it was not everything they learnt that needed the use of scientific calculators. This study yielded suggestions that would lead to the effective ways of using scientific calculators in the teaching and learning of Mathematics in Zambian secondary schools. The effective ways included the use of scientific calculators on allowed topics, the use of common types of calculators and the inclusion of the topic in the examination syllabus from Examination Council of Zambia.

4.5.1 Use of Scientific Calculators on Allowed Topics

The study revealed that the use of scientific calculators was allowed in certain topics in the syllabus. A participant teacher explained:

> *If you allow learners to use calculators, then it must be on a topic where calculators are needed. Learners should not be allowed to use calculators on topics that don't need its use. Learners should be encouraged not to use scientific calculators on topics that mostly are examined in Paper1. Teachers should prepare work in such a way that a lesson will not need the use of a calculator in order to avoid heavy dependency on the calculators.* (Teacher CB)

Another participant explained:

> *I don't allow learners to have calculators when the lesson doesn't require its use. No calculator on the desk during such lessons so that learners are not tempted to use it.* (Teacher CD)

Most learners complained that they did not finish on time when answering paper 1 questions because they didn't have calculators. The restriction came as a result that learners should apply knowledge and the basic concepts of Mathematics.

A teacher participant narrated:

> *I allow learners to use scientific calculators because those who use calculators are more accurate and display the correct answers. On how to answer examination questions in Paper2 using a scientific calculator, learners must be guided as they learn Mathematics. Learners should be discouraged from using calculators on topics that are examined in Paper 1 because the nature of questions in this paper do not require the use of a scientific calculator. Teach learners the basic functions of a scientific calculator, not just telling them to solve questions. Teach and demonstrate each key. Teach when and how a scientific calculator is supposed to be used. Show the learners topics that require the use of scientific calculators. We should give guidelines in regard to the use of scientific calculators. The reason why the use of scientific calculators should be controlled is not to spoil the learners.* (Teacher CA)

4.5.2 Use of Common Types of Calculators

This study revealed that learners needed to use the same model of scientific calculators. The finding of the study was that learners used different models of calculators. In some cases, the learners did not even fully understand the functions on the key pad. In this regard, a participant teacher said:

> *All the learners should be encouraged to have the same type of scientific calculator. This is important because it makes it easy to guide the learners. In addition, teachers may not be in the position to know the operations of all models of calculators.*
>
> *As things are at the moment, learners are not advised on the type of calculator to use. It is important for the school to agree on one model of scientific calculator to be used. This will even help teachers to teach well and guide learners on the use of the device.* (Teacher CH)

A check on the school acceptance letters revealed that a scientific calculator is not even one of the items learners were required to bring to school. In the light of this finding, the participants

suggested that schools should consider including and specifying a particular model of scientific calculator to be used in Mathematics classes in the acceptance letter.

Using observation method, the researcher noted that the most commonly used types of scientific calculators are those shown in Figure 9.

Figure 9: Models of scientific calculators used by learners in the school studied

4.5.3 Inclusion of the Topic (calculator) in the Examination Syllabus prepared by the Examinations Council of Zambia

The inclusion of questions in the final examinations that involved the application of functions on scientific calculator would motivate learners to buy calculators since schools could not afford to provide calculators to all the learners. A participant teacher explained that:

> *I feel the Examinations Council of Zambia should include questions based on the use of calculators in the final exams so that teachers and learners take the use of calculators seriously. This will help learners to know how to make use of the scientific functions on a calculator, such as the exponential functions.* (Teacher CB)

Another teacher pointed out that:

> *The inclusion of questions [in the final examinations] will sharpen the use of operations on the scientific calculator. My experience of teaching Mathematics at senior secondary school level has revealed that many people (teachers) have issues to do with the use of the calculator properly. I have observed that the knowledge of a scientific calculator is not taken*

seriously because we as teachers assumedly know the answers by virtue of learning them at college. (Teacher CE)

However, another teacher felt that the Examinations Council of Zambia was already including questions that involved the use of calculators in the final examinations. This teacher said:

A calculator is already an aid to the learners and the Examinations Council of Zambia examiners know the topics where learners would use the concept of powering numbers, for example, the sum of the first n terms in a Geometric Progression. So, I would say topics are already there; there is no need for the Examinations Council of Zambia to include questions in the final examinations but locally, as a school, we can give learners tests and quizzes based on the use of calculators in order to sharpen their skills in calculating complex numbers within specified period of time. (Teacher CB)

In general, it was noted that the inclusion of a topic in the examination syllabus will encourage learners to buy their own scientific calculators and teachers to put more effort in teaching important functions of the device.

4.6 Summary

The findings of this study indicated that most of teachers were very positive towards the use of scientific calculator in the teaching of Mathematics. They indicated that scientific calculators save much time during instruction and learners are able to spend more time on high order thinking. The teachers, however, expressed fears that too much use of the calculator by learners in secondary schools made them lazy. The study revealed that teachers did not allow learners to use scientific calculators during Mathematics lesson indiscriminately, only in topics that required its use and were examined by the Examinations Council of Zambia. It was revealed that topics such as Trigonometry, Mensuration, Sequences (Geometric Progression), Earth Geometry (distance between two points), the use of quadratic formula and Statistics (standard deviation) needed the use of the scientific calculator.

This study also revealed that learners felt motivated whenever they were solving mathematical problems with the help of scientific calculators. Indiscriminate use of scientific calculators,

however, made learners depend heavily on the device, so that even on simple computations, learners wanted to use a scientific calculator. This trend led to learners missing out on developing important mathematical skills, such as addition, multiplication and division of integers and; solving algebraic fractions and computations of bigger figures. However, learners complained that teachers did not spend much time on teaching them the functions of scientific calculators. Much of what they knew was self-taught and only found themselves using or learning the operations of the scientific calculator during trigonometric lessons.

This study revealed that, when scientific calculators are used appropriately in the teaching and learning of Mathematics, they can enhance learning and make Mathematics interesting.

CHAPTER FIVE

DISCUSION OF FINDINGS

5.1 Introduction

The purpose of this chapter is to discuss the findings presented in the previous chapter. This will help to answer the research questions which seek to investigate the use of scientific calculators in the teaching and learning of school Mathematics in Zambian secondary schools. The chapter covers the relationship between teacher experience and learner performance, how learners in Zambian secondary schools use scientific calculators, the challenges experienced in the use of the scientific calculator and how scientific calculators can practically be used in a Zambian Mathematics classroom.

5.2 Work Experience of Teachers and Learner Performance

Many researches have expressed that a teacher's years of experience positively relate to learners' performance. According to Wenglinsky (2002:45), "many studies have agreed to find a positive correlation between students' high level of achievement and teaching experience". There is also an axiom that "*Experience is the best teacher"*. Therefore, it can be said that teacher experience is one of the important factors that lead to learners' achievement in Mathematics. According to Rice (2010:1), "The idea is that experience, gained over time, enhances the knowledge, skills, and productivity of workers." The current study revealed that, among the teachers who were interviewed, none had been teaching Mathematics for less than five years. It can, therefore, be assumed that since all the teachers were experienced in teaching Mathematics, they were capable of guiding learners appropriately in the use of scientific calculator. This assertion is supported by Croninger and Rathbun (2003) who stated that, among several teacher attributes, teaching experience plays a more important role for learner achievement.

5.3 Secondary school teachers' and learners' use of scientific calculators in the teaching and learning of Mathematics

This section discusses how scientific calculators were used in Mathematics lessons and the most important topics on which the device must be used to enhance teaching and learning of Mathematics. It also discusses the common habits that arose from the performance test.

5.3.1 Scientific Calculators Were Only Used for Certain Topics

A suitable use of scientific calculators is a way of increasing the amount and quality of learning afforded learners during the period of their Mathematics lessons in school. Most teachers who took part in this study expressed their opinions based on their teaching experiences. They indicated that they only taught learners how to use a scientific calculator at the time when learners were learning topics that needed the use of calculators. This implies that many teachers felt that teaching learners the basic functions of a scientific calculator only became important when topics dictated so. This study has shown that although scientific calculators were needed in topics such as mensuration, sequences, earth geometry and geometric progression, the teaching of how to use a scientific calculator was only done when trigonometry was introduced. For other topics, learners had to learn calculator functions from the more knowledgeable others. This brings to light the fact that the use of scientific calculators encourages collaborative and cooperative learning and this is in tandem with Pomerantz (1997) who reported that calculator use also promotes group work and communication among peers and classmates. The consequence of this interaction is the exchange of ideas and conjectures. It is not that learners were allowed to use scientific calculators anyhow, but teachers controlled its usage.

This study indicates that the prevailing situation in the secondary school studied was to allow the use of scientific calculators during classroom learning activities on topics that needed its aid as a tool. Among the learners, there was an indication that they felt motivated when solving mathematical problems with the aid of scientific calculators. Some learners in fact categorically stated that the use of scientific calculators should be allowed in any learning situation where Mathematics was concerned. This implies that the use of scientific calculators increased the confidence of learners to approach and do Mathematics without fear. This was evident in learners' attitude towards the subject and their performance in the test, where at least 60% of them scored a grade above the pass mark of 40%. The learners' ability to present their work neatly [as it is seen from figure 2 part (a) and part (b) where learners presented their work in an orderly manner and neatly] also clearly showed that they were confident and did not suffer from Mathematics anxiety.

This study has shown that scientific calculators can improve classroom teaching and learning dynamics, boost learners' confidence levels and enhance understating of mathematical concepts and problem-solving ability in learners (this was seen when teacher CA was teaching on trigonometry, that learners had hands on in computing mathematical problems with the aid

of a scientific calculator). That is not to say that the traditional paper and pencil is no longer important but learners should strike a balance between the two (Ochanda & Indoshi, 2011). Whereas calculators can do low-level tasks of computation (because they cannot think), the high level thinking still has to be done by the learner. Therefore, learners should not entirely rely on scientific calculators, but learn to use their knowledge first before getting assistance from the scientific calculator. This is in line with Karpie (2013) who stated that teachers usually introduce topics to the learners first without a calculator and then add the assistance of the calculator after the topic has been mastered. Since it is important to use the scientific calculator in an appropriate way, teachers indicated that learners were only allowed to use the tool in certain topics. This is in line with the assertion by Ochanda and Indoshi (2011) that when used appropriately, scientific calculators do not pose any challenge to learning mathematical manipulations and computations. Instead, scientific calculators can facilitate an active approach to teaching and learning, where the teacher is able to move from one concept to the other very quickly and easily, while learners focus on the steps involved in problem-solving. In this regard, it can be stated that if teachers only allowed use of the scientific calculator on deserving topics, learners were both allowed more time on higher order thinking and rescued from tedious calculations associated with paper and pencil.

Another finding was that scientific calculators offered learners a way of performing calculations that was more efficient and precise than paper and pencil methods alone. This is seen in figure 3 part c of question 1 (b), the learner never minded about the concepts of laws of indices but he went directly to use a scientific calculator on $4^6 \div 4^2$ to get $4096 \div 16$. This finding is in tandem with Dunham (1995), who argued that the use of calculators not only results in more positive feelings and better attitudes about Mathematics for both learners and teachers, but also confirms that scientific calculators improve performance in a variety of areas including problem-solving. This study has, therefore, revealed that technology was needed in the teaching and learning of certain aspects of Mathematics and as such, there is need for every learner to have access to a scientific calculator.

5.3.2 Indiscriminate Use of Scientific Calculators

This study revealed that indiscriminate use of scientific calculators among the learners was common. Learners spontaneously resorted to the use of scientific calculators when they were tasked with mathematical questions or solving mathematical problems. The indiscriminate use of scientific calculators by learners can be described as abuse. It refers to the use of scientific

calculators by learners whenever they were solving mathematical problems without regard to the nature of the questions. Learners tended to use scientific calculators even on simple arithmetic. This behaviour had led to poor performance in Mathematics when the use of scientific calculators was restricted. Therefore, there was need for teachers to monitor how learners used scientific calculators for learning and solving Mathematics. On the other hand, learners felt good practicing Mathematics with the aid of the scientific calculator because it helped them to work out the problems faster and easily, especially if the mathematical problems had large figures. These findings agree with the finding by Ochanda and Indoshi (2011) that learners are able to increase the volume of calculations in a given time because calculators make computation faster. This brings in the concept of ZPD that a scientific calculator as a mediator enables a learner to do more volume of work even when faced with large figures.

5.3.3 Use of Scientific Calculators for Paper 2 Questions

The study has established that scientific calculators were mainly used to solve questions that were asked in Paper 2 in the School Certificate Examinations. This is because most of the questions in this paper needed a lot of computations in order for one to arrive at the correct solution. Some questions in the paper, such as $cos\theta = 0.94\ for\ 0° \leq \theta \leq 360°$ [see Appendix G 4(a)], cannot easily be solved without a scientific calculator. Therefore, when learners are alone, they tended to attempt questions in both papers using scientific calculators. However, teachers insisted on allowing learners to use scientific calculators only when they were solving mathematical problems from Paper 2. This perhaps explains why learners tended to perform better in Mathematics Paper 2 where scientific calculators are allowed as compared to Mathematics Paper 1. As it has been explained in the theoretical frame work that calculators could push learners to understand and accurately find answers even to complicated mathematical problems.

5.3.4 Practical Classroom Usage of Scientific Calculators in Teaching and Learning of Mathematics

The study also revealed a picture of what went on in a Mathematics classroom in terms of availability and usage of scientific calculators by learners and teachers. It further revealed the connection between scientific calculator use and learners' achievement. The study established that teachers did give verbal instructions on how to use certain functions of a scientific calculator to find answers to specific problems during Mathematics lessons. However, it was

not the concern of the teachers to teach the learners to become conversant with all the operations of a scientific calculator. The teacher simply presented a mathematical problem and instructed the learners step by step on how to find the answer using a scientific calculator, case of teacher CB. A learner who got stuck because his scientific calculator displayed the answer in a fraction form instead of in decimal fraction form, could not get help from the teacher. This suggested that even the teachers may not have enough knowledge about the intricate operations of scientific calculators. In this vein, Baggett and Enrenfeucht (1994) observed that providing learners with calculators and simply teaching them how to use them is not enough. Sufficient pre-training enables the learners to work problems more accurately, rapidly, and efficiently (Masimura, 2016).

The need for pre-training in scientific calculator use manifested from teacher CB's lesson. During this lesson, a learner [keyed in $6\sin(30 \div 108)$] used a scientific calculator but arrived at an answer that was different from others. The learner then demanded to know why his result was different from the rest. This implied that learners needed enough orientation on the use of scientific calculator. This is in line with Masese (2016: 86) who suggested that "…. learners need to have frequent opportunity to practice using their scientific calculators, so that they become familiar with the gadgets, with all of its features and be confident in their use". Another study by Moss and Grover (2006) established that handheld scientific calculators, when used correctly, can enhance problem-solving strategies, and encourage discourse and allow learners to become familiar with multiple ways of using the tool.

5.3.5 The use of Scientific Calculator on trigonometric ratios

The results obtained from the performance test in Table 4 show that, 72.7 % and 55.5% of learners performed well in question 4 (b) and 4 (c) respectively. Learners L10 in Figure 2 part (a), learner L1 in Figure 2 part (b) and learner L11 in Figure 2 part (c) were able to demonstrate how a scientific calculator was used systematically to arrive at the solutions in these three cases. This implies that the learners L10, L1 and L11 were working in their zone of proximal development with a scientific calculator and were able to get the correct answers. The two learners L10 answered question 4 (a), 4 (c) correctly. L1 and learner 11 answered the questions 3 (b) and 3 (a) correctly in an orderly manner. For these particular learners, the scientific calculator was used in the manner that it was supposed to be used. The use of scientific calculator was necessary in these two questions for learners to arrive at the solutions. The study can therefore conclude that effective use of a scientific calculator can aid learners'

mathematical achievement. The learners in Figure 2 part (b) and part (c) showed that they knew their scientific calculators very well and as such did not waste the space doing a lot of writing. They indeed entered the figures correctly and only what they thought was necessary to write. The conclusion is that when learners are vested in the knowledge, they do not waste time in computation of mathematical problems. This also implies that some learners are able to answer questions involving trigonometry with minimal difficulties unlikely in other topics such as statistics [table 5 in question 5 (b and c)].

Learner L10 started very well working on question 4 (b) as he did to parts (a) and (c) but he lost it when it came to $tan\theta = -\frac{5}{4}$ because the type of scientific calculator used displayed negative angle [see Figure 2 (a)]. He knew that the answers lie in the second and fourth quadrants. This shows that the learner did not understand very well the functions of his scientific calculator especially on the negative inverse of the trigonometric ratios. The results showed in Table 4 indicates that 90.9% of learners could not answer question 4 (b) correctly. This implies that learners could not use their scientific calculators to find the inverse of tan $(-\frac{5}{4})$. The implication was that most of the learners had problems of using a scientific calculator in inverse of the trigonometric ratios. This finding resonates with what some learners pointed out that they were not taught in detail how to operate a scientific calculator in learning Mathematics. However, 63.6% of the learners scored, a finding that shows that the use of scientific calculators can improve learners' Mathematics achievement if it is used appropriately. It can, therefore, be theorised that if the scientific calculator was appropriately used in the teaching and learning of Mathematics in the school, it could have improved learners' Mathematics achievement. This is consistence with the argument of Pomerantz (1997) that the use of calculators, together with suitable mental, paper and pencil, and estimation skills, equips the learners with the tools to help them to carry out computations and manipulations necessary to solve a problem. Pomerantz's argument also agrees with the observation by Mbugua, Muthoni and Okere (2011) and Karpie (2013) that some computations may not necessarily require calculators and teachers prefer to instruct the learners to perform calculations mentally. Learners need to be taught to develop good mental estimation skills, internalize concepts and perform simple calculations without scientific calculator.

It is noted from Table 4 that only 9 out of 24 learners got Question 1 (a) correct while 15 out of 24 failed to use scientific calculators to solve the problem. This further implies that most of the learners did not know how to use a scientific calculator to solve mathematical problems

involving fractions. It was shocking to note the 15 Grade 12 learners could not get to the correct answer on question 1(a). This agrees with the study done by Pomerantz (1997) who found that calculators can only do low-level tasks for calculations, and that they do not instruct learners what to do, but rather that the learners instruct the calculator what to do. It was interesting to note that learners lacked computational skills and cognitive abilities which they needed to compute certain mathematical problems. This was also observed by Pomerantz (1997) who pointed out that, apart from its benefits, the calculator will never substitute the human mind (cognitive ability) in terms of reading and understanding a problem situation, writing a suitable equation, deciding on a suitable problem-solving approach, interpreting the answer, and deciding whether or not an answer is suitable. Therefore, it is imperative for teachers to train learners not only in the computational skills but also in these cognitive abilities. Teaching the two will help to allay the fears expressed by Rey and Arbaugh (2001) that scientific calculators inhibit the logical reasoning of the learners.

It is observed from Table 4 that the majority of learners got Question 3 correct with the aid scientific calculators. This is because the question came from trigonometry, the component of Mathematics in which the learners were well guided on how to use the scientific calculator. This shows that learners were working in the zone of proximal development.

It is also noted from Table 4 that 18 learners failed to get correct answers in Questions 5 (b and c). The failure to answer these questions correctly did not mean that the questions were difficult or needed the aid of the scientific calculator but was because the questions were more involving in terms of mathematical computation. In the process of computing the answers, the learners made a lot of errors leading to wrong answers. Again, this implies that most of the learners may not have been very conversant with using the scientific calculator or lacked the mental dexterity to manage the calculations, hence needed for more experience and practice to get a better understanding.

5.3.6 The use of scientific calculator on fractions and indices

Question 1 (a), (b) and (c) involved fractions and indices. 63.6% of learners could not perform well in question 1 part (a) which involved mixed fractions. 72.7% of learners could not answer question 1 (b) correctly but 55.5% of learners managed to score on question 1 (c) [see Table 4]

The fact that the learner in Figure 3 part (a) was able to answer Question 1 (a) correctly without the aid of a scientific calculator shows that learners could do basic Mathematics without the

aid of a calculator. Yet, another learner in Figure 3 part (b) could not find the correct solution to the same question even with a scientific calculator at his disposal. Clearly, the problem here was that the learner did not follow the correct procedure when he attempted to have 'a direct computation'. This implies that this learner did not have the knowledge of using the device on fractions. In Figure 3 part (c), another learner solved the problem correctly and demonstrated that he used a scientific calculator because part (b) of Question 1 had big figures. The same learner used a scientific calculator in part (c) of Question 1 because the question demanded learners to do so. In social constructivism, a scientific calculator in the zone of proximal development was needed by the learner to do the necessary computations.

Figure 4 parts (a) and (b) which shows worked examples by two learners who failed to use a scientific calculator to answer Questions 1(b) correctly. The learner in figure 4 part (a) thought of cancelling the base 4 and then divide the indices. The conclusion is that when learners have little knowledge on the use of scientific calculators (for example, that calculators can only be used when answering questions involving trigonometry), they are unlikely to do well in certain questions in Mathematics. The results agree with what learners stated in the focus group discussion that they were not adequately taught on how to use scientific calculators. It is, therefore, the responsibility of teachers to see to it that learners get relevant mathematical knowledge and skills that will enable them to solve mathematical problems in a wide spectrum.

5.4 Challenges Learners and Teachers Face as they Use Scientific Calculators in the Teaching and Learning of Mathematics

Oliva (2016) explains that many challenges faced by learners in schools can be mitigated or eliminated when barriers to learning and participation are identified and minimized. Therefore, this section identifies and discusses the challenges faced by learners and teachers during instructions in Mathematics.

5.4.1 Inadequate Numbers of Scientific Calculators

One of the challenges found by this study was that there were inadequate number of scientific calculators among the learners and teachers. This challenge can be linked to lack of financial resources among the learners as individuals and the school as a whole. Oliva (2016) asserts that lack of financial resources may prevent the use of technological advances since technology can only be procured using finances. Therefore, without financial resources, many learners cannot afford the cost of buying a scientific calculator. This study found that 21% of learners did not

have scientific calculators during Mathematics lessons even when the teachers emphasised the need for learning with its aid (as shown in Table 5). The main explanation for this was that some parents could not afford to purchase the much-needed scientific calculators. In a situation where many learners do not have access to a scientific calculator and yet the calculator is a typical requirement in some mathematical computations, the learners are left with no option but to borrow from others in the classroom (Ochanda and Indoshi, 2011). This option might not be the best as it inconveniences other learners who come to class with scientific calculators. It might be of utmost necessity, therefore, that schools mobilise sufficient financial resources to procure scientific calculators for use by learners.

In some cases, learners did not tell their parents that a scientific calculator was one of the learning resources that they needed to have. This could imply that some learners did not take learning Mathematics seriously, hence the poor attitude they displayed towards the subject. Manoah, Indoshi, and Othuon (2013) note that learners' attitude towards Mathematics is one of the factors that contribute to poor performance in the subject. Therefore, talking to such learners about their self-worthy and the importance of Mathematics (for example, that it is required for admission to scientific and technological professions) may help them to change their negative attitudes towards the subject.

In all the three lessons observed, it was noticed that although some learners did not have scientific calculators, the teachers neither took notice nor cared about these learners. This finding could be yet another attribute contributing to poor performance in Mathematics. It implies that some teachers went to class to teach what was supposed to be taught but never cared about the learners' participation or involvement in the lesson. These teachers did not make any deliberate effort to go round the classroom to find out whether or not learners were following the instructions that they had given. This was the same point in the case where a learner was spotted out (by the researcher) using a non-scientific calculator (Figure 7) during a trigonometry lesson (which involved calculating angles in a triangle using the sine rule) but the teacher took no notice. Laxity and indolence on the part of teachers can lead to poor academic performance of the learners both in class tests and the School Certificate Examinations and, therefore, needs to be checked.

5.4.2 Over-dependence on the Scientific Calculator

The finding that learners depended heavily on scientific calculator each time they were doing Mathematics resonates with the finding of Miles (2008) that learners relied on scientific calculators to do the simplest of Mathematics computations. Furthermore, the same learners did not know if the calculator derived answers were correct. As such many teachers were apprehensive at the mere thought of allowing learners to use the scientific calculator indiscriminately. Both Zheng (1992) and Usiskin (1978) argue that using calculators in Mathematics classroom can have negative consequences if they are used inappropriately. The most common mistake is allowing learners to use scientific calculators on arithmetic problems that could be done by paper and pencil; learners will then be unable to do arithmetic when the calculator is absent. Teachers should therefore disallow calculator usage for arithmetic calculations. Rather, teachers could still allow learners to use calculators, quite appropriately, for higher-order processes, such as graphing two functions to see where they intersect, and to see if the answer found that way comports with the answer attained by solving the systems simultaneously by hand. In as much as learners need to develop new skills, they need guidance from the teacher so that a scientific calculator is not necessarily used.

One valid concern that teachers had was failing to develop learners' paper and pencil (mental computation) ability. Thus, teachers feared that the use of scientific calculators may prevent learners from learning the basic Mathematics that they needed later in life. This fear was confirmed by six learners who stated that they found it difficult to solve Mathematics without a calculator. This finding appears to support the findings by Ochanda and Indoshi (2011:56) that calculators make "learners lazy in computation in the absence of the calculators." (However, a question can be asked as to whether this is sheer laziness or lack of ability. For example, there were learners who failed to use scientific calculators when others found calculators helpful). One learner said a scientific calculator was faster and easier to use and lessened the tedious mental computations. This study concluded that learners who depended mostly on scientific calculators even for basic calculations did not perform well when they did not have access to the device.

Depending too much on scientific calculators made learners lose out on relevant mathematical skills in the topic area called Number Sense. If learners do not acquire basic understanding and skill development of the core concepts in Mathematics, they will not be successful in higher level courses, where Mathematics thinking is concerned (Ochanda & Indoshi, 2011), such as

geometry, algebra and trigonometry, because Mathematics is a subject that builds on itself throughout schooling. Learners lacking those basic Mathematics facts will fall behind quickly, and once behind in Mathematics, it is very hard to catch back up (Ochanda & Indoshi, 2011). This implies that too much exposure to the scientific calculator, the learner will not understand the actual meaning of an exponent in an equation or expression. Too little exposure, the learner will not learn how to use a tool that will make them more efficient. There is, obviously, a mid-way point that is the ideal amount of exposure to the calculator. For example, Ballheim (1999: 6) explains that most educators believe "calculators should be used only after students [have] learned how to do the relevant Mathematics without them." On the contrary, Immerzeel (1986) feels that allowing his learners to first explore with calculators would create increased learner interest and ownership of their learning. He also admits that the calculator made teaching easier for him. Considering that these are two polar positions, it can be stated that teachers have a pivotal role of providing enough guidance to learners on the appropriate use of scientific calculators and early enough.

5.4.3 Missing Out on Important Mathematical Concepts

The results of a performance test showed that there were gaps in learners' content knowledge about the functions of scientific calculators. Learners seemed not to know the rule of "BODMAS" (Brackets first, then Orders, Division and Multiplication before Addition and Subtraction) and were unable to convert mixed fractions into improper fractions. It is therefore the responsibility of the teacher to guide and encourage the learners. In this case, the zone of proximal development allows for learners to be pulled forward in their mathematical abilities with the aid of a teacher or a more knowledgeable other. Learner L1 in Figure 8 completely failed to work out simple fractions and lacked common content knowledge on fractions yet the same learner was able to use a scientific calculator in trigonometry question [see figure 2 part (b)]. Learners in figure 5 lacked common content on laws of indices as well. These findings concur with the conclusion made by Rey and Arbaugh (2001) that calculators inhibit logical reasoning of the learners if concepts and skills are not emphasized. The findings of the current study differ from those by Hembree and Dessart (1986) that suggested that calculator usage does not lead to deterioration in basic paper and pencil skills. Hembree and Dessart's study suggested that, in fact, calculator usage enhances these skills for students of average ability. For some topics, teachers did not allow learners to use scientific calculators but instead wanted them to use the traditional method whenever they faced mathematical problems. This view is

consistence with Pomerantz (1997) that the calculator does not replace mental ability to solve problems but, instead, it provides multiple solution techniques. Pomerantz also states that calculators do not think for students and sometimes it is faster to compute mentally. The concern expressed by Ochanda and Indoshi (2011) was that, for problems such as ($\frac{2}{3}+\frac{3}{5}$), a calculator can enable a learner to get the correct answer to the question without the learner necessarily gaining the conceptual understanding of the question. If the teacher does not guard against this, it will defeat the whole purpose of learning and, later-on, education. This takes us back to the theory of social constructivism that the teacher's role in guiding and assisting learners in their zone of proximal development.

5.4.4 Teachers do not teach the Use of Scientific Calculators

In teacher CA's class, it was observed that some learners did not know how to change their scientific calculators into degree mode. All what they knew was to enter numbers and copy what the scientific calculators displayed. This report agrees with the findings of the study by Ochanda and Indoshi (2011) that learners lacked hands-on training opportunities when it came to use of calculators in Mathematics. This was because teachers did not teach learners how to use scientific calculators in detail and well in advance, before concepts from a particular topic were taught (Ochanda and Indoshi, 2011). Mostly, learners struggled to use scientific calculators in the event that they were faced with mathematical problems. This shows that teachers did not take time to teach learners the major functions of a scientific calculator before application. The interview with teachers confirmed that teachers only talked about the basic functions of a scientific calculator at the time trigonometry was introduced. This creates an opportunity for learners to share ideas and allowing them to interact with challenges in a collaborative manner. For learning to take place, Vygotsky believed that social interaction between a more knowledgeable other and the learner was critical. While the expert may be an adult, here Vygotsky also emphasized the power of peer learning (Vygotsky, 1978). Some of the learners who were both interviewed and subjected to writing a performance test stated that teachers did not teach them how to use scientific calculators in details. These learners found it difficult to use the tool when it came to the exponential function (as seen in Figure 5) and other operations. This challenge is also seen in Figure 6 where a learner failed to differentiate a coma from a decimal point. This means that learners were not much oriented on the use of scientific calculators.

5.4.5 Types of Scientific Calculators Used

The other important aspect that this study revealed is the different models of scientific calculators that different learners use during Mathematics instructions. It was discovered that some teachers did not know how other types of scientific calculators function. This was the case for teacher CA who could not help the learner to adjust the scientific calculator from fraction mode to decimals. It was evident that both learners and teachers were not very familiar with scientific calculators under use. Lack of knowledge on scientific calculators by the teachers was pointed out by one of the learners who took part in focus group discussion that even teachers have problems of knowing some of the functions of the tool. This report agrees with the findings made by Indoshi (1999), who concluded that any profession including teaching requires the practitioner to continue his education throughout his entire professional life. This includes attendance of courses frequently. This is also supported by Wild (1996), who claimed that teachers need to know how to use the tools of technology without first knowing why they need the tools, and what they are going to do in the classroom with the tools. The findings of this study is consistent with that of Doerr and Zangor (2000), who said there is need for methods courses to address the pedagogy issues of using scientific calculators by providing pre-service teachers a forum to examine their pedagogical perspectives of using graphing calculators in teaching, explore when and how to use calculators in classroom, and provide them with opportunities to practice teaching with calculators (Doerr & Zangor, 2000). This means that, some teachers did not know how to use scientific calculators during the teaching and learning process. In this case the teacher can also allow learners with more knowledge other (MKO) to assist the other learners who need more guidance. Especially in the context of collaborative learning, group members who have higher levels of understanding can help the less advanced members learn within their zone of proximal development. This implies that teachers are not well vest in the operation of scientific calculators on certain computations. There is need in including training teachers on handling scientific calculators in forums such as subject association and during continuous professional development meetings.

It was suggested that the school should be specifying on acceptance letter the model of a scientific calculators that teachers want their learners to have. It is important for school management to monitor Grade 10 learners as they report to ensure that desired scientific calculator is bought too.

5.5. The Teachers' and Learners' Perceptions regarding the Effective ways of using Scientific Calculators in the Teaching and Learning of Mathematics

It is asserted that the pros and cons of scientific calculators are based entirely on how they are used (Banks, 2011). If utilized properly under proper supervision, then scientific calculators can provide learners with a wealth of learning possibilities. This section, therefore, presents the effective ways for using scientific calculators in the teaching and learning of Mathematics.

5.5.1 Leaners should use Calculators to aid Fluency, Speed and Accuracy

The first effective way is that, since Mathematics is a practical subject, learners need to do a lot of mathematical problems as they consolidate what they learn and research. As such, learners need to use the scientific calculator as an aid so that they spend less time on doing calculation/computations and more time on research and thinking. The use of calculators can also assist learners to increase their understanding of and fluency with arithmetic operations, algorithms, and numerical relationships and enhancing student motivation. In this situation, the teacher's role is that of a focal point in controlling and guiding the learners in areas where scientific calculators are needed.

5.5.2 Leaners should use Calculators for Topics that require their use

The second effective way, since not all topics in the Mathematics syllabus require the use of a scientific calculator, learners should get used to using scientific calculators only when they were working on topics that required their use. For now, learners tend to use the tool indiscriminately even on questions that can be worked out mentally in a short period of time. Learners need to be taught basics of Mathematics and to develop good mental estimation skills to internalize concepts and perform simple calculations without the aid of a scientific calculator. In this vein, teachers have a bigger role to play in monitoring the use of scientific calculators during Mathematics lessons among learners. The result agrees with the findings of Noraini (2002) and Ellington (2003) that the calculator should not be a substitute for learning to do mental operations but as a tool to let learners explore and afterwards the teacher should explain things and justify the Mathematics rule. Although literature viewed that National Council of Teachers of Mathematics' (NCTM) supports the use of technology in the teaching and learning of mathematics, the teacher has a bigger role to play too by controlling and guiding its usage.

5.5.3 Schools should adopt a Particular type (model) of Scientific Calculator

The third effective way of using scientific calculators is for the school to adopt a particular type of scientific calculator for use in teaching and learning process. At the time of the current study, learners at the school which was studied, some scientific calculators had functions learners did not even fully understand. This points out to social constructivism that learners through social interaction can create their knowledge in a collaborative learning. This challenge was not only evident among learners but also among teachers too. The failure by a teacher to help a learner who was having problems with operating his scientific calculator during a lesson observed is consistent with the study by Ochanda and Indoshi (2011) that a majority of teachers do not know how to use scientific calculators during the teaching and learning process. By adopting one type of calculator and practicing on it, both teacher and learner will become conversant with the functions of the calculator, and by the time of the School Certificate Examinations, the learners would have gained proficiency in the use of the device.

5.5.4 Inclusion of a Topic on Calculator use in the Examination Syllabus

The observation that teachers do not teach learners how to use a scientific calculator necessitates the recommendation that it might be appropriate to include a topic on calculator use in the Senior Secondary School Syllabus for Mathematics that is examinable. In Ghana, for example, the Minister of Education suggested that teachers should start every lesson with a practical problem to help learners acquire the habit of analytical thinking and the ability to apply knowledge in solving practical problems and also make use of the calculator and the computer for problems solving and investigations of real life situations (MOESS 2007). However, Kwesi, Asiedu-Owuba and Boinde-Sigme (2016) are of the view that this orientation to teaching and learning requires more than recommendations contained in syllabi. The inclusion of questions in the final examination that involve the application of functions on scientific calculator will help learners to be serious and able to buy their own scientific calculators than borrowing from their friends. This was pointed out by some of the teachers who took part in the research. Teachers too will be compelled to teach learners the most important functions of a scientific calculator.

5.6 Summary

This study has established that learners in the school studied were able to use scientific calculators quite well when given trigonometry questions. The study also revealed that learners were usually not taught many operational functions of a scientific calculator. As a result, most of them failed to solve questions that involved indices. Further, the study revealed that some teachers could not help learners when they got stuck because some teachers themselves were not familiar with certain models of scientific calculators. It was found out that even teachers needed training in the handling of scientific calculators. Learners too needed more time for orientation on the use of scientific calculators. The study established that the recommended appropriate way of using the device is to discourage learners from using it anyhow and telling learners the areas where it was most needed during Mathematics instructions.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

The main objective of the study was to investigate the use of the scientific calculator in teaching and learning of secondary school Mathematics in Zambia. This chapter gives the conclusions and recommendations of the study.

6.2 Conclusions

The study concluded that learners in the selected secondary school often used scientific calculators each time they were solving mathematical problems. Teachers encouraged learners to use calculators where necessary, especially on topics that were usually examined in Mathematics Paper 2 in the School Certificate Examination. The teachers knew that not all problems required the use of the scientific calculator. However, the teachers realized that some learners depended heavily on scientific calculators whenever they were solving problems in Mathematics. As a result, such teachers had to put control to the usage of the calculator.

On the other hand, learners revealed that Mathematics was interesting and enjoyable when it was approached with scientific calculators. Learners further indicated that they performed better in Mathematics and worked out more problems when they had scientific calculators. The study also established that learners finished their work faster and did their work more fluently when they used the scientific calculator. In this way, many learners thought using scientific calculators made Mathematics easier. Using scientific calculators had positively motivated learners in doing more mathematical problems as compared to using the paper-and-pencil traditional method. Nevertheless, many learners complained that teachers did not give them enough guidance on the functional operation of the scientific calculator. This was the biggest challenge that learners revealed to this study. Another challenge was that, although the scientific calculator was allowed, it was not easily accessed by learners. It was observed that that 21% of learners did not have scientific calculators in a lesson of trigonometry. Lack of access to the calculator denied the learners an opportunity to use this device which made doing Mathematics more unbearable for the some of the learners.

In general, it can be said that use of the scientific calculator could benefit the learner and the teacher in a wide range of situations in Mathematics education. This was observed when the learners were actively involved in the learning process with minimum teacher supervision and direction. The benefits included making Mathematics concepts well understood, increasing the mastery of computing skills, displaying accurate answers on the screen and using the calculator to confirm answers, motivate learners to want to work more, and were convenient for confidential working for those who knew how to use the scientific calculator. These benefits should be exploited to increase the number of learners who are proficient in the use of the scientific calculator to make teaching and learning more effective and learner-centred. This will go towards improving performance in the subject.

6.3 Recommendations

Based on the findings of the current study, the following recommendations are proposed for consideration on the use of scientific calculators in the teaching and learning of secondary school Mathematics in Zambia:

- Learners, parents, and other stakeholders of research should be made aware of the benefits of using the scientific calculator as a tool for teaching and learning Mathematics in secondary schools in Zambia.
- Mathematics teachers at all levels should promote the appropriate use of scientific calculators to enhance instruction.
- The appropriate use of the scientific calculator would encourage learners to actively get involved in their own learning.
- The government should subsidize the price of the scientific calculator to ensure that they are cheap and affordable to many learners. Alternatively, government could supply scientific calculators to schools because teachers and learners need access to them before any useful application can be done.
- Learners need to have frequent opportunity to practice using the scientific calculator, so that they become familiar with the gadget if the learners are to make effective use of them during Mathematics examinations.
- Learners should be given appropriate instructions when it is best to use the scientific calculator and when is it best to use paper-and-pencil methods so that the scientific calculator does not pose any threat to learners' Mathematical computation ability and skills.

- Teachers should continue learning about how to use the scientific calculator during their Continuous Professional Development (CPD) and other refresher courses.
- Higher learning institutions should introduce a topic on the use of calculators to equip teachers with knowledge and skills on how to use the scientific calculator.
- The Examinations Council of Zambia should make a topic on the use of scientific calculators examinable.
- Schools should specify on their acceptance letters a particular model of scientific calculators required in order to promote standardization.
- More research should be done to look into the long-term effects of scientific calculator use on secondary school learners in Zambia.

6.4 Future Research

Several ideas could be implemented to improve this study. As always, the sample size could be increased. Working with learners from different schools, located in different areas (urban, peri-urban, and rural) could generate different data. An exploration of the use of scientific calculators at junior secondary schools could potentially change the data. The comparison of junior and senior secondary school learners could lead to an interesting analysis.

REFERENCES

Adom, D., Hussein, E.K. & Adu-Agyem, J. (2018). Theoretical and conceptual framework: mandatory ingredients of a quality research, *International Journal of Scientific Research* 7(1), 438-441.

Arends, R. I. (1998). *Resource handbook. Learning to teach* (4th ed.). Boston, MA: McGraw-Hill.

Baggett, P. & Ehrenfeucht, A. (1994). Encoding and retaining information in the visuals and verbals of an educational movie. *Educational Communication and Technology Journal, 31*(1), 23-32.

Ballheim, C. (1999). How our readers feel about calculators. In Z. Usiskin (Ed.), *Mathematics Education Dialogues*. Reston, VA: National Council of Teachers.

Banks, S. (2011). *A historical analysis of attitudes toward the use of calculators in junior high and high school math classrooms in the United States since 1975.* A Masters of Education thesis submitted to Cedarville University.

Beaton, A.E., Martin, M.O., Mullis, I.V.S., Gonzalez, E.J., Smith, T.A., & Kelly, D. (1996). *Mathematics achievement in the middle school years: IEA's Third International Mathematics and Science Study*: Chestnut Hill, MA: Centre for the Study of Testing. Evaluation, and Education Policy, Boston College.

Becker, H. (2000). *Secondary teachers of mixed academic subjects, out of field problem or construvist innovators.* Irvine, CA: University of California.

Boyer, C. B. (1991). *A history of Mathematics*. John Wiley & Sons. ISNB 978-0-471-543978.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology,* 31, 77-1-1.

Briggs, L. (1997*). Instructional design: Principles and applications*. New York, NY: Englewood Cliffs.

Burke, G. (2001). *Computers and calculators in schools: A status report, Electronic Data Resourse service.* Montreal, Canada: McGill University.

Chileshe, B. (2018). *Enhancing health campaigns through Environmental Education: A case of the 'Keep Zambia Clean and Healthy' programme*. Unpublished PhD Thesis submitted to the University of Zambia, Lusaka.

Churcher, K.A., Boinde, B.S.& Asiedu, O.L. (2016). *Teachers' perceptions of the usage of calculators in the teaching and learning of Mathematics at the Junior High School Level in Ghana*. European Centre for Research Training and Development UK: St. John Bosco College of Education. Navrongo.

Close, S., Oldham, E., Hackett, D. Dooley, T., Shiel, G. & O'Leary, M. (2003b). *A study of the effects of calculator use in schools and in certificate examinations: Final report on Phase I.* Dublin: St Patrick's College.

Close, S., Oldham, E., Surgenor, P., Shiel, G., Dooley T., & O'Leary, M. (2003a). *A Study of the effects of calculator use in schools and in cAertificate examinations: Final report on Phase II.* Dublin: St Patrick's College.

Conrad, Peter (1987). The experience of illness: recent and new directions. *Research in the Sociology of Health Care, 6, 1-31.*

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions.* Thousand Oaks, CA: SAGE Publications.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and, evaluating quantitative and qualitative research* (4th ed.). Boston, MA: Person.

Creswell, J. W. (2014). *Research design: Quantitative and mixed methods approaches* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Creswell, J.W. (2010*). Qualitative inquiry and research design*: Choosing among five traditions. Thousand Oaks: Sage.

Croninge, R. G. & Rabhum, A. (2003). *Teacher qualification and first grade, and experience on first-grade achievement.* College Park, MD: Centre for Education Policy and Leadership.

Demana, F. & Waits. B.K. (1990). Implementing the standards: The influence of technology in teaching Mathematics. *Mathematics Teacher*, 83, 27-31.

Denzin, N. K., & Lincoln, Y. S. (2011). The discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (4th Ed.), pp. 1–19). Thousand Oaks, CA: SAGE Publications

DES/NCCA (Department of Education and Science/National Council for Curriculum and Assessment). (1999a). *Primary school Mathematics curriculum. Content*. Dublin: Stationery Office.

DES/NCCA (Department of Education and Science/National Council for Curriculum and Assessment). (1999b). *Primary school Mathematics curriculum. Teacher guidelines*. Dublin: Stationery Office.

Doerr, H.M. & Zangor, R. (2000). Creating meaning for and with the graphing calculator. *Educational Studies in Mathematics*, 41: 143-163.

Dunham PH (1995). Calculator use and gender issues. *Association for Women in Mathematics Newsletter*, 25(2), 16-18.

Dunham, P. 1-1. & Dick, T.P. (19942). Connecting research to teaching: Research on graphing calculators. *Mathematics Teacher Journal*, 87(6), 440-445.

Ellington, A. J. (2003). A meta-analysis of the effects of calculators on students' achievement and attitude levels in precollege Mathematics classes. *Journal for Research in Mathematics Education*, *34*, 433–463.

Ernest, P. (1991*). The philosophy of Mathematics Education*, London, UK, The Falmer Press.

Examination Council of Zambia (2003). *School Certificate Ordinary Level Chief Examiner's Reports*. Lusaka: Examinations Council of Zambia.

Examination Council of Zambia (2015). *School Certificate Ordinary Level Chief Examiner's Reports*. Lusaka: Examinations Council of Zambia.

Frank, J. S & Victor, J. K. (2011). *"Mathematics treasures from the Smith and Plimpton collections- Introduction"*, Convergence: Columbia University.

Gillham, B. (2000*). Case study research methods*. London: Continuum.

Gillings, R.J. (1972). *Mathematics in the time of the Pharaohs*. Cambridge, MA: MIT Press.

Glaserfeld, E. (eds.) (1995). A constructivist approach to teaching. In Steffe L.P. & Gale J. (Eds.), *Constructivism in Education* (pp. 3-15). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gunstein, L.S., Lipsey, S.J. (Eds.). (2001). *Encyclopedia of Mathematics Education*. New York, NY: Routledge Falmer.

Hancock, B. (1988). *Trent focus for research and development in Primary Health Care: An introduction to qualitative research*. Trent Focus Group.

Hembree, R. & Oessart. O.J. (1986). Effects of hand-held calculators in precollege Mathematics Education, A meta-analysis. *Journal for Research in Mathematics Education,* 17(2), 83-99.

Hunter, P.E. (1994). Mathematics as Author. Strategies for developing successful classroom. In Carey D., Carey, R, Anna, D. & Willis, J. (Eds). *Technology and Teacher Education Annual*. Washington: AACE.

Immerzeel, G. (1986). It is 1986 and every student has a calculator. *Instructor*. 85, 24-51, 148.

Indoshi, FC (1999). *An assessment of in-service education and training needs of primary school agriculture teachers in Kenya. A case study of Vihiga*. Unpublished PhD Thesis, Maseno University.

Jayeeta, B. (2015). Constructivist approach to learning–An effective approach of teaching learning. *International Research Journal of Interdisciplinary & Multidisciplinary Studies*, 1 (6), 65-74.

Karpie, M. B. (2013) Calculator dependency and operations with exponents in an introductory college Mathematics class. *Suny Digital Repository*. Masters thesis. Available from: https://dspace.sunyconnect.suny.edu/handle/1951/62655 [Retrieved 7th October, 2020].

Kissane, B. (1999). The algebraic calculator and Mathematics education. In W-C Yang, D. Wang, S-C. Chu, & G. Fitz-Gerald (Eds). *Proceedings of 4th Asian Technology Conference on Mathematics,* (pp 123-132) Guangzhou, China, Asian Technology Conference in Mathematics.

Kratochwill, T.R., Cook, J.L., Travers, J.F, & Elliott, S.N. (2000). *Educational psychology: Effective teaching, effective learning* (3rd ed.). Boston, MA: McGraw-Hill College.

Kwesi-Amanyi, C., Boinde- Sigme, B. & Asiedu-Owuba, L. (2016). Teachers' perceptions of the usage of calculators in the teaching and learning of Mathematics at the Junior High School level in Ghana. *European Journal of Educational and Development Psychology*, 4(2), 33-52.

Lagrange, J.B., Artigue, M., Laborde, C. & Trouche, L. (2003). Technology and Mathematics Education: a Multidimensional study of the evolution of research and innovation. In A.J. Bishop, M.A. Clements, C. Keitel, J. Kilpatrick & F.K.S. Leung (Eds.). *Second International Handbook of Mathematics Education*, 1, 239-271). Dordrecht: Kluwer Academic Publishers.

Leedy, P. D., & Ormrod, J. E. (2005). *Practical research: Planning and design* (8th ed.). Upper Saddle River, NJ: Prentice Hall.

Manoah, S.A., Indoshi, F.C., & Othuon, L.O.A. (2013). Influence of attitude on performance of students in Mathematics curriculum. *Educational Research*, 2(3), 965-981

Masese, F.O. (2016). *Influence of using scientific calculators on secondary school students' development of computational skills in Mathematics in Murang'a County, Kenya.* Masters thesis.

Masimura, T. (2016). *An investigation into the impact of calculator usage on the mathematical skills of secondary school learners*. A Masters dissertation presented to the University of Pretoria.

Maxwell, P. (2004). *Calculators in Mathematics instruction and assessment.* A position Statement for Mathematics K-12 in the province of Newfoundland and

Labrador. Labrador. Government of Newfoundland and Labrador Department of Education.

Mbugua, Z. K., Muthoni, M. V., & Okere, M. O. (2011). Attitude of secondary students on use of scientific calculators in learning Mathematics in Embu District in Kenya. *International Journal of Humanities and Social Science*, 1(13), 131-136.

McCopy, L.P. (1996). Computer-based Mathematics learning. *Journal of Educational Computing Research*, 28(4), 438-455.

McMillan, J.H., and Schumacher, S. (2010). *Research in education. (Evidence based inquiry) 7th* Ed.. United States of America: Library of Congress Cataloguing in Publication Data.

McNamara, D. (1995) Effects of prior knowledge on the generation advantage: Calculators versus calculation to learn simple multiplication. *Journal of Educational Psychology*, 87(2), 307-318.

Miles, C. (2008). The use or non-use of calculator's effects on student's ability to perform basic Mathematics problems. *OTS Master's Level Projects & Papers. Paper 89*.

Ministry of Education (2002). *Meeting the challenges of education in the twenty first Century. Report of the president's committee on view of education reforms in Ghana. Accra*, Ministry of Education, Ghana.

Morgan, D. L. (1988). *Focus group as qualitative research*. Thousand Oaks, CA: SAGE Publications.

Moss, L.J. & Grover, B.W. (2006). Not just for computation: Basic calculator can advance the process standards. *Mathematics Teaching in the Middle School*, 12(5), 266 - 273.

Myers, M. D. (2009). Qualitative research in business and management. London: SAGE Publications.

NCTM, N. N. (2000). *Principles and standards for school Mathematics*. New York, NY: V.A. Reston.

Nor'ain, M. T. (2011). The use of graphic calculator in teaching and learning of Mathematics: Effects on performance and metacognitive awareness. *American International Journal of Contemporary Research,* 1(1), Institute for Mathematical Research, University Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia.

Noraini, I. (2002*). Developing self-confidence among Malay students: Usage of graphing calculators.* Proceedings of Second East Asia Regional Conference on Mathematics Education in Singapore.

Ochanda, J. P., & Indoshi, F.C. (2011*).* Challenges and benefits of using scientific calculators in teaching and learning of Mathematics in secondary education. *Journal of Media and Communication studies. Kenya,* 3 (3), 102-11.

Oliva, D.V. (2016). Barriers and resources to learning and participation of inclusive students. *Psicologia da Universidade de São Paulo*, 27(3). https://doi.org/10.1590/0103- 656420140099

Orodho J. A. (2003). *Essentials of educational and social science research methods*, Nairobi: Masola Publishers.

Orton, A. (1992). *Learning Mathematics: Issues, theory and classroom practice* (2nd ed.). London: Cassel Education Series.

Patton, M.Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: SAGE Publications.

Pendelton, D. (1975). Calculators in the classroom. *Science News*, 107, 175-181.

Pomerantz, H. (1997). *The Role of Calculators in Math Education*. A research prepared for the Urban Systematic Initiative/Comprehensive Partnership for Mathematics and Science Achievement (USI/CPMSA). Dallas, Texas.

Rebecca, G. (2013) Research summary – A brief review of calculator usage in mathematics. *Research Division Assessment Research and Development Cambridge Assessment 1*. Regent Street, Cambridge, CB2 1GG.

Redding, S. & Walberg, H. J. (2012). *Promoting learning in rural schools.* Lincoln, IL: Center on Innovation and Improvement.

Reys, B. J. & Arbaugh, F. (2001). Cleaning up the confusion over calculator use in Grades k-5. *Teaching Children Mathematics*, 8(2), 90-94.

Rice, J.K. (2010). *The impact of teacher experience examining the evidence and policy implications*, BRIEF 11, National Center for Analysis of Longitudinal Data in Education Research.

Risser, H.S. (2011). What are we afraid of? Arguments against teaching Mathematics with technology in the professional publications of organisations for US mathematicians. *International Journal for Technology in Mathematics Education*, 18(2), 97-101.

Sarah, B. (2011) *A historical analysis of attitudes toward the use of calculators in junior high and high school math classrooms in the United States since 1975*. Cedarville University.

Saunders, A. (1997). *Financial institutions management: A modern perspective* (2nd ed.).Homewood, IL: Irwin.

Seán, C. et al (2008). The *effects of calculator use on Mathematics in schools and in the certificate examinations*: School of Education. Dublin: Trinity College.

Smith, H.W. (1991) *Strategies of social research* (3rd ed.). Orlando, FL: Holt, Rinehart & Winston.

Suydam, M.N. (1976). Computation: Yesterday, today, and tomorrow. In S. Hill (Ed.), *Education in the 80's: Mathematics*. (pp.36-45). Washington DC: National Education Association.

Tajuddin, N.M., Tarmizi, R.A., Konting, M.M., & Wan Ali, W.Z. (2009). Instructional efficiency of graphing calculators in teaching and learning Mathematics. *International Journal of Instruction*, 2(2), 11-30.

Usiskin, Z. (1978). Are calculators a crutch? *The Mathematics Teacher*, 71(5), 412-413.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wenglinsky, H. (2002). Technology and achievement: The bottom line. *Educational Leadership*, 63(4), 29-32.

Wild M (1996). Technology refusal: Rationalizing the failure of student and beginning teachers to use computers. *British Journal of Educational Technology*, 27(2), 134-143.

Wild, F., Scott, P., Valentine, C., Gillet, D., Sutherland, R., Herder, E., Duval, E., Méndez, G., Heinze, N., Cress, U., & Oxoa, X. (2009*). Report on the state of the art in TEL*. Milton Keynes, UK: Open University.

Wimmer, H. & Goswami, U. (1994). The influence of orthographic consistency on reading development: Word recognition in English and German children. *Cognition,* 51, 91-103. DOI: 10.1016/0010-0277(94)90010-8

Yin, R.K. (1994). *Case study research: Design and methods* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

Zheng, T. (1992). *Impact of calculators in learning Mathematics*. New York, NY: State University of New York. Fredonia.

APPENDICIES

APPENDIX A: LETTER TO THE DISTRICT EDUCATION BOARD SECRETARY

The University of Zambia
School of Education
P.O Box 32379
Lusaka.

……. January, 2019.

The District Education Board Secretary
Lusaka District
Lusaka,

Dear Sir/Madam,

Ref: Request for Permission to Conduct Research in Some of The Schools in Lusaka District

I ……., a Master of Mathematics Education at the University of Zambia hereby request to conduct a research as indicated above that will be meet the requirements of the sampling technique that will be used in the study.

The title of my research study is: *Use of scientific calculators in the teaching and learning of Mathematics in secondary schools in Lusaka district.*

The ethics policy of the University of Zambia requires that I get permission from your office.

The Ministry of Education will benefit from this study by getting information about ways to support our learners on the best ways of using technology.

Mashekwa Mashekwa

Mobile: 0977847759

Email: mashekwam122@gmail.com

APPENDIX B: LETTER TO THE SCHOOL HEAD

The Headteacher
…… Secondary School
Lusaka
Zambia.

Dear Sir/Madam,

Ref: Request for Permission to Conduct Research at Your School

I ……., a master of Mathematics education with the university of Zambia hereby request to conduct a research as indicated above that will be meet the requirements of the sampling technique that will be used in the study.

The title of my research study is: *Use of scientific calculators in the teaching and learning of Mathematics in secondary schools in Lusaka district*.

The ethics policy of the University of Zambia requires that I get permission from your office.

The Ministry of Education will benefit from this study by getting information about ways to support our learners on the best ways of using technology.

Mashekwa Mashekwa

(0977847759)

Email: mashekwam122@gmail.com

APPENDIX C: CONSENT FORM FOR LEARNERS

Dear Learner,

You are invited to take part in a focus discussion group whose aim is to get information from the learners concerning the use of scientific calculators in the learning of Mathematics.

As a learner who is studying Mathematics, the information you will provide will be very useful in finding ways of improving the teaching of this subject while incorporating the use of scientific calculators. This information will strictly be kept confidential and you are free to discontinue participating in the focus group discussion if you feel so.

Mashekwa Mashekwa

(0977847759)

Email: mashekwam122@gmail.com

APPENDIX D: GUIDE FOR FOCUS GROUP DISCUSSION

The learners' analysis on availability, accessibility and challenges experienced while using calculators in Mathematics classrooms.

1. Does the school provide scientific calculators during Mathematics lessons?
    - What happens in the event that you don't have calculator during Mathematics lessons?
    - Does your teacher allow you to share with your friend in the event that they don't have a calculator?
    - Do you think sharing a calculator with a classmate is a good thing while the lesson is going on?
2. What topics in the senior secondary Mathematics syllabus rely heavily on the use of calculators?
    - What difficulties do you experience in solving mathematical problems involving these topics without a calculator?
    - Do you think the use of scientific calculators has improved your attitude towards Mathematics?
    - Which other methods do you use to solve Mathematics in the absence of a calculator?
3. Do you face any challenges in using a scientific calculator in learning Mathematics?
4. Do you enjoy solving mathematical problems even without using a scientific calculator? (over-dependence)
5. Do you think computations would be easier if calculators were not allowed to be used to solve Mathematical problems?
6. Does calculator use in Mathematics make you develop critical thinking in solving problems? If yes, how?

7. Does your Mathematics teacher encourage you to use calculators every time you are doing a Mathematics problem?

8. Do Mathematics teachers adequately guide you in the use of calculators? If so, how?

9. Do Mathematics teachers always use calculators while teaching?

THANK YOU FOR YOUR PARTICIPATION

APPENDIX E: CONSENT FORM FOR TEACHERS

My name is …….. I am a Master of Mathematics Education student at the University of Zambia. I am conducting a study titled *Use of scientific calculators in the teaching and learning of Mathematics in secondary schools in Lusaka district*. You have been selected to take part in the study. The study is purely for academic purposes only and the results of this discussion will be kept confidential. I, therefore, request you to be very free to contribute to this discussion.

Mashekwa Mashekwa

(0977847759)

Email: mashekwam122@gmail.com

APPENDIX F: UNSTRUCTURED INTERVIEW SCHEDULE FOR TEACHERS

1. What is your professional qualification?
2. How many years have you been teaching Mathematics at senior level in the Ministry of General Education?
3. Is there a way you are expected to teach Mathematics with the use of scientific calculators as a tool? Explain.
4. Is there a way you are supposed to assess learners with regards to the use of scientific calculators? Explain.
5. Do you always allow learners to use a calculator while learning Mathematics?
6. After incorporating calculators, does the amount of effort you put into your work make a difference in Mathematics performance?
7. Is there any difference between learners who use calculators and the ones who do not? If so, what difference is there?
8. How have you been influenced in your teaching of Mathematics after calculators were introduced?
9. In your opinion, do you think the introduction of scientific calculators is enough to equip you with more innovative Mathematics teaching methodology?
10. For which topics in Mathematics do you think learners need the knowledge of using scientific calculators when learning? Why is that so?
11. Do you spend time during Mathematics instruction teaching the learners how to use the calculator?

THANK YOU FOR YOUR PARTICIPATION

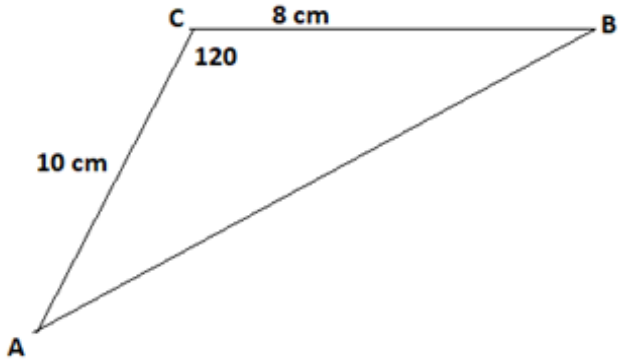
APPENDIX G: PERFORMANCE TEST

Performance Test with the Aid of Scientific Calculator

1. (a) Evaluate $(a)\ 2\frac{1}{4} + 4\frac{1}{2} \div \frac{2}{9}$ (b) $4^6 \div 4^2$ (c) $25^{2/3}$ [2] [2] [1]

2. A sequence is given as: 128, 64, 32, 16, …..,
   (a) find the 10^{th} term of the sequences [2]
   (b) the sum of the first 10 terms of the sequence. [2]

3. In the diagram below, ABC is a triangle for which BC = 8 cm, AC = 10 cm and angle ACB = 120^0



   (a) Find the area of the triangle ABC [2]

   (b) Calculate the length of AB [4]

4. Solve the following equations

   (a) $cos\theta = 0.94\ for\ 0° \leq \theta \leq 360°$ [2]

   (b) $tan\theta = -\frac{5}{4}\ \ for\ 0° \leq \theta \leq 270°$ [1]

   (c) $sin36°\ \ correct\ to\ 3\ significant\ figures$ [2]

5. The table below shows marks obtained by pupils in a Mathematics test.

Mark	1 −3	4 − 6	7 − 9	10 − 12	13 − 15
No. of Pupils	3	1	4	3	2

(a) Calculate the mean mark [3]

(b) Calculate the variance [2]

(c) Standard deviation [1]

APPENDIX H: SCHEDULE FOR LESSON OBSERVATION

The researcher introduces himself to the teacher to be observed prior and explains relevance of the research being undertaken.

School code……. **Teacher's code…….**

Time…… **Number of learners: ……**

Date…….

Item #	Elements to check/observe	Observation(s)	Comment(s)
1	If the teacher has the knowledge of using a scientific calculator.		
2	If the teacher is able to guide the learners as they use calculators in learning Mathematics.		
3	If the teacher is able to control learners who might use the tool anyhow.		
4	If the teacher is helping the learners to use calculators appropriately.		
5	How the teacher is treating those who don't have calculators		
6	The areas that need the aid of calculators in the teaching and learning of Mathematics.		
7	If the teacher is giving work that needs the help of a calculator		
8	If all learners have calculators during Mathematics lesson.		
9	If the teacher has problems in using a scientific calculator in the teaching of Mathematics		
10	If the learners have difficulties in using scientific calculators in the learning on Mathematics		

THANK THE TEACHER AND CLASS