THE EFFECT OF GRAPHIC CALCULATORS ON THE MATHEMATICAL ACHIEVEMENT IN QUADRATIC FUNCTIONS OF URBAN ERITREAN GRADE 10 STUDENTS

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DECLARATION

I declare that *the effect of graphic calculators on the mathematical achievement in quadratic functions of Eritrean grade 10 students* is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

Amare Teclemicael **February 2003**

Signed: ………………

Abstract

The purpose of this study was to investigate the effect of graphic calculators on the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function. The study adopted a quasi-experimental design that involved two groups of students: the graphic calculator group and paper and pencil group. A total of 41 students from two secondary schools were involved in this study. 20 students were in the graphic calculator group and 21 in the paper and pencil group. A quadratic functions test was used to determine whether there is a significant difference in the mean achievement score between the two groups at the pre-test and post-test stages. The groups were compared by using the student's t test for independent samples.

The results indicate that there was significant difference between the overall mean scores of the graphic calculator group and the paper and pencil group at the 0.05 level of significance.

Conclusions drawn from the results indicate that the graphic calculator had a positive effect on students' mathematical achievement related to the concepts of quadratic function. Based on this study it is recommend that further study in terms of greater scope and sample size should be conducted. Moreover, other factors such as the effect of graphic calculators on students' attitude towards mathematics influence on the content of the mathematics curriculum, and calculator use by students and teachers need to be considered.

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Chapter One

Introduction

1.1 Background information about Eritrea

Eritrea is a new nation, which obtained its independence in 1991 after a thirty year long war. It is Africa's newest nation. Eritrea is located in Northeast Africa facing to the Red Sea. Sudan is to the west and north and it borders Ethiopia and Djibouti to the South. It has an area of 125,000 sq. km with an estimated population of 3.5 million. Ethnically Eritrea is divided in to nine nationalities.

During the war for liberation the economy, infrastructure, social conditions and education were subject to continuous deterioration. The educational system was nearly destroyed since the human capital of Eritrea were persecuted and displaced.

Since liberation, however, there have been major achievements and adjustments in various areas in rebuilding the nation. Education has been placed among the top priorities of the government. The ministry of Education is making a continuous effort in the provision of education of which the major general objectives include:

- To produce a population equipped with the necessary skills, knowledge and culture for a self-reliant and modern economy.
- To develop self-consciousness and self-motivation in the population to fight poverty, disease and all the attendant causes of backwardness and ignorance.
- To make basic education available to all.

(Ministry of Education, 1999:1).

The pre-university school system in Eritrea has three levels. It is a 5-2-4 system consisting of five years of elementary school, two years of junior secondary school and four years of secondary school. The first part of the seven-year education, that is the elementary and junior level, is compulsory basic education. The medium of instruction is English except at the elementary level. Elementary levels follow their instruction in their mother tongue, (first language), which are nine languages.

According to the Ministry of Education (2001b), the curriculum for elementary school emphasises the basic skills of reading, writing and arithmetic along with instruction in science, civics, geography and physical education. The middle level is a transition from elementary school to secondary school. The curriculum comprises the study of basic skills along with science and social studies. The curriculum in the secondary level is divided into specific disciplines from which students can choose a particular stream, mostly natural science and social science. Very few schools provide agriculture and commerce. In all grades, mathematics and English language are taught as compulsory subjects.

Mathematics education in Eritrea has a central part in the curriculum of different areas of studies. Among the aims of teaching mathematics in Eritrean secondary schools the subject is aimed to provide students with tools which they can use in other subjects (Ministry of Education, 1999). As a result mathematics is regarded a basic subject to be taught at all levels of school. The main goals of mathematics education in Eritrean school system are:

- To develop mathematical skill among students, which will enable them to function in all practical affairs of life;
- To deepen their appreciation of the importance and role of mathematics in the society;
- To develop in pupils a positive attitude towards the subject and thus enjoy learning it;

- To enable every one to master mathematics in accordance with his/her abilities and prepare the capable ones for higher education;
- To provide pupils with mathematical tools which they can use in other subjects.

(Ministry of Education, 2001b:1).

1.2 Statement of the Problem

The mathematics curriculum of Eritrean secondary school comprises various areas of study in algebra, geometry and trigonometry. One of the main concepts in mathematics curriculum is the concept of functions. As it is indicated in the curriculum framework for secondary level mathematics in Eritrea (Ministry of education, 2001b) the concept of a function is provided in grades 9,10 and 11. However, this concept is one of the most difficult topics in the teaching and learning of mathematics.

From my experiences as a teacher in a secondary school in Eritrea there were a number of conceptual obstacles to progress in the concept of functions and the most common of these was the failure to construct the graph of functions because of the repeated algorithmic computations involved in the process of graphing. Graphical representation of functions were problematic and often students' work was inexact. Even for the teacher, the construction and interpretation of a few special functions was only possible to represent in the chalkboard. This may be, as Julie (1993a) points out, a result of paper and pencil construction of graphs is tedious and time consuming. Rich (1993:389) asserts, "when paper and pencil graphing is used, the graph often becomes the goal and the concepts get lost in finding and plotting points". Considerably, a significant amount of the class time is spent on routine algorithmic computations and rote practice of procedures. In this case students do not get sufficient time to visually explore essential mathematical ideas (Julie, 1993a).

In essence, then, some of the reasons that the concept of a function is difficult for secondary school students are:

- Construction is tedious and time-consuming (Julie, 1993a; Fey, 1989; Rich, 1993:389).

- The graphs of many interesting functions are difficult to represent on the black board.

- Little or no time is left for students to visually explore the more mathematically appropriate features of functions (Julie, 1993a: 22).

- Often the sketches of the graphs are inexact due to the repeated and enormous use of algorithms in finding and plotting points (Rich, 1993:389).

The coming of technology, however, is promising to improve the difficulty in the teaching and learning of functions. Fey (1989) asserts that computer technology " offer enormous promise for enhancing student understanding of important mathematical ideas for providing alternative visual methods of mathematics problem solving" (p.252). Julie (1993a) states, " The '*functions*' sub curriculum is one of the first curricular areas in mathematics that has benefited from the advances made in computer technology." (p.2). These technologies can enable students to construct more easily and accurately the graphs of functions and, then, help them to visually explore the properties, behaviours, and essential concepts of functions.

One of the computer technologies that show a potential to offer a great help to students in the concepts of functions is the graphic calculator. Graphic calculators are pocket sized programmable calculators that provide many interesting features including the graphing of functions to mathematics classroom. These calculators may help to remove the burden of rote practice of procedures to construct graphs and enable students to focus on the underlying concepts of functions.

Thus, this study aims at investigating whether or not graphic calculators have an effect on grade ten students' mathematical achievement related to the concepts of quadratic function. The focus of this study is to collect empirical data based on students' score on two given tests related to the concepts of quadratic function. The first test was given prior to the study to ensure the equality of the two groups. The other test (post-test) was given after the study to determine the effect of the calculators on the mathematical achievement of Eritrean grade ten students. The research question underlying the study is:

Is there any significant effect on grade ten Eritrean students' mathematical achievement related to the concepts of quadratic function if they are allowed to use graphic calculators?

1.3 Motivation of the Study

The need to make mathematics interesting and relevant to students is one of the most important goals of a mathematics teacher. Often, from my experience, students widely perceive mathematics as difficult subject. They view mathematics as a system of abstract ideas that has no connection to the daily life situations. As a secondary school teacher in Eritrea, I have observed that this belief led students to perform poorly in mathematics. Each year the failure rate in mathematics continues to be higher. Many concepts of mathematics remain 'difficult' for students during the teaching and learning process. One of these difficult concepts is that of functions.

Even though much effort has been made to improve the difficulty, there is still a problem of poor performance which may partly suggests that this is not only a factor of students' weakness. To construct a graphical representation of situations were one of the main problems encountered in dealing with the concepts of functions.

When I read studies related to graphic calculators in mathematics classroom, and work with the calculator I came to realise that they might greatly improve the difficulties in the teaching and learning of the functions concept. Nowadays there is an increasing realisation that computer technologies, particularly graphic calculators, may help secondary school students in learning mathematics and, thus, improve the ways of teaching and learning mathematics. Presently, there is a growing body of research related to graphic calculators in the mathematics classroom. Researchers worldwide have been working for better ways of teaching and learning of mathematics by integrating new strategies with technology mediated instruction.

Furthermore, technology is growing rapidly and various software packages are available to deal with complicated ideas of mathematics. As Fey (1989) asserts, using these technologies mathematical ideas and procedures can be made in dynamic ways that were impossible before. Thus, mathematics and mathematics education in our educational system should explore the potentials offered from the advancements made in technology.

1.4. Significance of the Study

It is evident that technology is growing rapidly. Computer technologies offer graphic software and symbolic manipulation systems to the school mathematics education. According to Noss (1991:82) the computer technology allows its user to explore, investigate and pose problems and offer flexible representation of situations.

Students in Eritrean secondary schools are not allowed to use (or even did not know) any kind of graphing technologies. While teaching the concepts of functions a significant amount of the class time is devoted to routine manipulations involved in the process of graphing and plotting of points to construct the graphs. That is, they may not be encouraged to visually explore the essential ideas and concepts of functions. The concept is difficult to introduce to students in such a way that they can integrate functions into their own understanding of real life situations. For instance, many students often misunderstand the concept underlying the domain and range.

Hence it is hoped that the study on the effects of graphic calculators to the context of Eritrean secondary school students may shed some insights to the teaching and learning of functions. To this end the study has the following objective:

- To investigate the effect of graphic calculators on the mathematical achievement of Eritrean grade ten students related to the concepts of quadratic function.

1.5 The Scope of the Study

The study was conducted in two secondary schools of Asmara, the capital city of Eritrea. The study is a quasi-experimental one. Two groups of students were involved. The one group was taught the concepts of quadratic function with the use of graphic calculators. The other group was taught the same content in paper and pencil format. Participants of the study were two groups of students from two secondary schools.

The participants of the study in each group were selected randomly from the population of grade ten students learning in the morning shift of the school time. The afternoon shift of the school time was used for the study. Approximately 15 hours were used for teaching the concept over one month.

1.6 Limitations of the Study

The study had the following limitations:

- The study was conducted in specific schools, and the sample is not representative of the whole Eritrean grade ten students.

- The study is limited to the effects of graphic calculators on the mathematical achievement of students. It does not involve issues such as use of calculators and effects on attitude towards mathematics.

- There was a lack of quantitative data (ESECE: Eritrean Secondary Education Certificate Examination marks) that was needed to determine the performance among schools (to calculate the correlation between schools).

- The study was limited to grade ten students and the concepts of quadratic function only. It does not include other grades and concepts of the mathematics curriculum.

1.7 Organisation of the Study

Chapter one provides background information, statement of the problem and motivation of the study.

Chapter two provides a detailed review of literature on graphic calculators in relation to mathematics education. The importance and influence of technology in mathematics education is also dealt with. Moreover students' understandings of the concepts functions and theories of learning mathematics are also discussed.

Chapter three consists of the method of research, the techniques used for the data collection and the research design used.

Chapter four continues with the presentation, discussion and analysis of data. Statistical significance tests are used to determine the effects.

Chapter five discusses the overall conclusions and recommendations of the study.

Chapter Two

Literature Review

2.1 Introduction

During the past few decades the study of mathematics education has made various developments. The field has now numerous research areas on critical issues related to the teaching and learning of mathematics. One of the issues being raised by many researchers in the field is the effect of technological tools used in the school mathematics.

This chapter provides a discussion on mathematics education and technology. The graphic calculator is given attention with regard to its use and review of studies related its use and effect on achievement. It is also worthwhile to note the theories of learning and the nature of the concepts of functions. The following section discusses theories of learning in mathematics education.

2.2 Theories of Mathematical Learning

What is mathematical learning? How do students learn? How does the learning of mathematics take place? And what is mathematical understanding? These are among the early and critical questions that studies in mathematics education looked at in the past few decades. In this regard there have been different developments in mathematics education research, from empirical and analytic research in school to more theoretical investigations (Kieran, 1994).

By taking the various aspects and dimensions of students' learning of mathematics, there is no common view on this issue. At this time it is widely recognized that mathematical learning is not simply the process of filling students' mind with knowledge as "empty vessels" (Davis and McKnight, 1979; Kieran, 1994). As Kieran (1994) points out the awareness of psychological research of Piaget and the subsequent theoretical work on understanding led to an emerging view of mathematics learning in which it rejects the metaphor of students' mind as "empty vessels". Kieran (1994) notes, "learning mathematics means with understanding and that understanding (no longer equated with mathematical rigor or correctness) is an ongoing activity, not an achievement" (p.605). Kieran goes on to say, "this evolution has been accomplished by the development of research approaches that emphasize the observation of the process of learning rather than the measurement of their products" (p.605).

Thus, the emergent view of mathematical learning which is increasingly discussed by mathematics educators and researchers in the field is the so-called 'constructivism'. Ernest (1993:169) points out that the positive side of constructivism for its acceptability by many mathematics educators is that "... it embodies a powerful vision of the active and epistemologically empowered learner." However, at the same time, Ernest (1993:169) warns for "the dangers that follow from an over enthusiastic or uncritical embracing of it or from a failure to recognize its real limitations."

Gordon (1993:177), citing Davis and Hersh, notes that the assumption underpinning constructivism is that mathematical knowledge is obtained by a finite construction which differs from the two other central beliefs of Platonism and Formalism. As Gordon (1993:177) points out Platonists believe that mathematical objects are not things which we construct but things which already exist. On the other hand, according to Gordon (1993:177), Formalism contends, "there are axioms, definitions and theorems which can be applied to physical problems even though they have no counterpart in reality." Constructivism is an epistemology that views knowledge as being 'constructed' by the learner from their prior experience.

However there is no common view for constructivism. The word 'constructivism' is controversial and used in a vague manner. Ernest (1993:168) notes that there are different forms of constructivism, which greatly vary in terms of their practical significance. Cobb, Yackel and Wood (1992) also assert that dualism emerged from the tensions between mathematical learning being viewed as enculturation or as individual construction. Ernest (1993:168) suggests that different forms of constructivism can be distinguished by their underlying metaphor and models of the mind and the world. . In the following sections I will discuss the different forms of constructivism.

2.2.1 Information Processing Constructivism

Ernest (1993:168) puts the first form of constructivism as information processing constructivism. According to Ernest information processing constructivism "recognizes that knowing involves active processing, that is it is individual and personal and it is based on previously acquired knowledge" (p.169). To this form of constructivist the metaphor of mind is largely based on the computer.

Davis and McKnight (1979) assert, "the tasks computers do nowadays are becoming increasingly to resemble intelligent human behaviour with however the special advantage that we know, more or less, what is going on inside the computer *because we wrote the program that tells the computer what to do*" (p.93, emphasis original). Hence, Davis and McKnight believe, "… 'sophisticated computer programming' can provide metaphors that are useful in analysing human mathematical thought" (p.93). They went on to say, "…mathematics is a matter of ideas that you develop in your own mind" (p.94).

Information processing constructivist, or cognitive researchers, discuss the analysis and model of student errors, hypothesize human information-processing mechanisms and draw on the historical development of the conception of science for their formulation of the theory of mathematical learning. Davis and McKnight (1979) postulate a dozen of human information process mechanisms which have been used for analysing student's mathematical thinking. They describe these mechanisms in three processes as: sequential process, Gestalt process and deeper level rules of mathematical thinking.

2.2.2 Radical Constructivism

Radical constructivism is based on Von Glasersfeld's principles, which draws from the work of Piaget (Ernest, 1993:169; Kieran, 1994). According to Glasersfeld (1995:1), "radical constructivism starts from the assumption that knowledge no matter how it is defined, is in the heads of persons... what we make of experience constitutes the only world we consciously live in ... But all kinds of experience are essentially subjective..."

Thus, radical constructivist's basic principles, according to Glasersfeld (1995:1), are:

1. a. Knowledge is not passively received either through the sensor by way of communication;
   b. Knowledge is actively built up by the cognising subject.

2. a. The function of cognition is adaptive, in the biological sense of the term, tends towards fit or viability;
   b. Cognition serves the subject's organization of the experiential world, not the discovery of an objective ontological reality.

Ernest (1993:169) notes that for radical constructivist the underlying metaphor for the mind or cognising subject is that of an organism undergoing Darwinian evolution with its central concept of the 'survival of the fit or the fitter'.

Forster and Taylor (2000), by citing Glasersfeld, note, "...on the psychological aspect of learning, it is seen to entail reflection on activity or the process of reflective absorption, which is the individual abstracting regularities and rules from experience" (p.38). However, Brown (1996) suggests that radical constructivism "down plays the social parameters built in the tasks as framed by teachers" (p.118). Cobb et al. (1992) also contends, "the suggestion that students can be left to their own devices to construct the mathematical ways of knowing compatible with those of wider society is a contradiction of terms" (p.27).

2.2.3 Social Constructivism

With dissatisfaction or 'limitations' of the cognitive theories a newly emergent form of constructivism is that social constructivism. Even though the cognitive sciences are the basis or point of departure for this form of constructivism, Kieran (1994) notes, the development of social constructivism is related to a limitation of the other forms of constructivism that they emphasize the cognitive oriented work. Cobb et al. (1992) state: "...dualism created between mathematics in students' heads and mathematics in their environment" (p.2). Vinner (1997) asserts that the cognitive approach is not enough. Vinner further notes, "not every event in mathematical learning can be explained in cognitive terms, and that is a fallacy to assume that the cognitive approach is adequate for almost every situation in mathematical learning" (p.97).

Drawing extensively from the work of Vygotsky, a number of mathematics educators argue the view that mathematical knowledge is certain and this knowledge is in the heads of individuals. Ernest (1993:171) contends that the individualistic emphasis makes it hard to establish a social basis for interpersonal communication. Cobb et al. (1992) state: "...the apparently common belief that constructivism as a theoretical position implies that mathematical learning should be a process of spontaneous, unguided independent invention... Constructivist theory is then interpreted to imply that students' learning should be natural and that teachers should not tell them anything as they attempt to make sense of their worlds... We do not believe that mathematical learning can ever be natural, if by natural we mean the unconstrained organic growth of mathematical knowledge independent of social and cultural circumstance." (p.27).

In the light of the above arguments, then, social constructivism permits the notion of mathematical learning as individual as well as a social constructive activity. According to Ernest (1993:170) social constructivism "regards individual subjects and the realm of the social as indissolubly interconnected". Brown (1996) also points out that the social constructive perspective offers the use of social dimension as an underlying basis in "finding a more complementary association between object and subject" (p.118).

For social constructivists the shared set of concerns and values, particularly the interaction (conversation), in the social practice has centrality for their theory of mathematics learning. The individual learner is considered as constructor of his own knowledge within the social setting. Cobb et al. (1992) assert that mathematics is both individual and collective activity in which "mathematical knowledge has a social as well as cognitive aspect in that to know is to be able to participate in a social practice" (p.27).

The underlying metaphor of mind for the social constructivist, according to Ernest (1993:70), is that of 'conversation'. The social aspect of this perspective is built around the development of communication because they believe that mathematical meanings are socially and culturally situated (Cobb et al. 1992). Mellin-Olsen (1987:33) referring to Activity Theory notes that the individual acts on the society while he/she is becoming socialised to it in which the learning setting could be the context of the classroom. Mellin-Olsen (1987:77) holds the fact that " *language* is the basic thinking tool of human being" (emphasis original). Cobb et al. (1992) agree with the above assertion that "social interaction plays an important role in students' mathematical learning." (p. 5). In line with this Sfard (2000) stresses that communication is the primary cause for the origins of mathematical objects such as number, function, set or group. Sfard (2000) writes: " mathematical objects emerge through negotiations between metaphor and rigor." (p. 324).

From the above-mentioned discussion, it can be noticed that no theory in mathematics learning is adequate in itself. As we strive to explore various dimensions of students' mathematical learning new issues will start to emerge. The society in which we live is growing rapidly. It is not static; it is, rather, undergoing complex transformations. Thus, theories in mathematics learning have to develop in the light of these transformations especially in our increasingly mathematised and highly technologically influenced society. Ernest (1993:173) states: " our theories are tools, only to be used for as long they remain useful, and technology always outgrow itself in the face of human needs and ingenuity." For me the differences in theories of mathematics learning can create confusion with respect to which theory to follow in research. The latest theories often point out 'limitations' on the foregoing theories. However it seems to appreciate the strong points of each theory it offers and use accordingly by not restricting to a single line of research (theory).

My theoretical orientation concerning the study on students' use of technological tools is: the use of non traditional approaches of learning is grounded in the tenets of social constructivism theory of learning in which students actively construct their own knowledge "in attempting to resolve problems that arise as they participate in the mathematical practices of the classroom" (Cobb et al. 1992, p.10). As Cobb et al. (1992) note, "the learning teaching process is interactive in nature and involves the implicit and explicit negotiation of mathematical meanings" (p.10) in which students as well as the teacher make inferences about each other's mathematical activity.

Mathematics is essentially a human activity (Wilder, 1981:28). The use of technology is, then, viewed as 'thinking tools' and 'communicative tools' (Mellin-Olsen, 1987:47) in which they are viewed as "integral to mathematical activity rather than an external and to internal cognitive processes and is (are) considered to profoundly influence mathematical understandings" (Forster and Taylor, 2000, p.38).

In this kind of activity, the role of the teacher is viewed to "*initiate and guide* the classroom community's development *taken-as-shared* ways of mathematical knowing that are compatible with those of the wider community" (Cobb et al., 1992, p.101 emphasis added). And students "actively construct the mathematical ways of knowing as they are initiated to the taken-as-shared mathematical practices of wide society by the teacher" (Cobb et al., 1992, p.26).

In this study the effects of technological tools -graphic calculators- on mathematical achievement of Eritrean grade ten students related to the concepts of quadratic function will be examined. Quantitative findings are the data for analysing the effect of the graphic calculators on students' mathematical achievement related to the concepts of quadratic function. The following sections discuss the concept of functions and technology and mathematics education.

2.3 The Concept of Functions

It is prudent to say that functions and their graphs are one of the central concepts of school mathematics. The concepts of a function have been the focus of numerous research studies over the past decades (Doerr and Zangor, 2000). Nowadays the studies are elevated with the advent of new computing and graphing technological tools.

Leinhardt et al. (1990) note that the concept of functions is significant in mathematics education because of:

- Increased recognition of the organizing power of the concept of functions from middle school mathematics through more advanced topics in high school and college.

- The symbolic connections that represent potential for increased understanding between graphical and algebraic worlds. (Leinhardt et al., 1990, p.1).

Functions can be represented using a variety of ways: algebraic, tabular and graphical (Brian and Hirsch, 1998; Leinhardt et al. 1990). Many students experience difficulties in the concept of a function because they often misunderstood the concept of a variable and how variables allow them to construct mathematical meanings (Graham and Thomas, 2000). The function concept is extremely difficult and involves various levels of abstractions (Leinhardt et al., 1990, Brian and Hirsch, 1998; Tall and Bakar, 1992).

The concept of a function has become problematic to students. From their review of the literature Brian and Hirsch (1998) note that research studies in traditional functions curriculum indicates that:

- ♦ Students developed very limited conceptions about functions.

- Students' conceptual knowledge lagged far behind their procedural knowledge.

- Students could not apply their knowledge to problem solving situations.

- Students have difficulty translating among the different representations of functions.

- Students do not appreciate overall structure of the function concept.

Brian and Hirsch (1998) point out that the modern set theoretic definition of function often used by teachers and textbooks is too formal and abstract to students. Tall and Bakar (1992) also note that the set theory form of domain, range and rule relating each element in the first with a unique element in the second proved difficult for most students. They assert, " somehow the general concept seems to be *too general* to make much sense. [Although] we may teach pupils about the general concepts such as the *domain* on which the function is defined and the *range* of possible values, these terms do not seem to stick in their memories. Instead, they gain their impression of what a function is from its *use* in the curriculum, implanting deep seated ideas which may be at variance with the formal definition" (p.39).

Sfard, cited in Brian and Hirsch (1998), suggest that functions should appear as models of relationships because that is how they first came into being historically. Leinhardt et al. (1990) also note that graphs are taught earlier separately from the topic of functions. They contend, "neither functions nor graphs can be treated as isolated concepts" (p.3). They refer that both are communicative systems, on the other hand, and a construction and organisation of mathematical ideas on the other. In line with this Tall (1992:497) refers the historical development of functions that complex network connections such as graphs, algebraic expressions, the relationship between dependent and independent variables has evolved from the concept of functions. Thus, as Brian and Hirsch (1998) point out, the historic definition of functions, as a relationship between variables, is more relevant and meaningful to students as it capitalises on their prior intuitive notions of the function concept. This is because students possess prior knowledge of functions as relationships. Leinhardt et al. (1990) point out the existence of an implicit understanding of function, in the early age of a student. They note, by citing Piaget, that it exists as early as the age of three and half.

One of the difficulties that students face during the learning of functions is the concept of algebraic variables. Eventhough variables are fundamental to functional relationships and graphical representations (Leinhardt et al., 1990) students find it very difficult to understand graphs as abstractions and to develop a link between algebraic and graphical forms (Ernest, 1989:38). The notion of a variable is not straightforward as it is described as having a wide variety of using it (Graham and Thomas, 2000). Graham and Thomas note that defining a variable is extremely difficult. Leinhardt et al. (1990) give two interpretations of a variable. They note that the first interpretation of a variable is "a relatively static one, which emphasises a variable as a tool for generalisation or for describing patterns" while the other is a more dynamic "which in essence captures the variability and simultaneous changes in one variable in comparison to other" (p.22).

Graham and Thomas (2000) suggest that the difficulties in understanding variables stem mainly from their sophisticated and multi-faceted nature of role of symbols. They believe that mathematical entities present themselves in two distinct but complimentary faces: dynamic process or as static objects. They build their ideas on the term 'procept', which comprises the combination of mathematical symbols as a process and as a concept. They suggest, "the term procept is a useful one as it draws attention to the duality present in symbols in which mathematical idea in question is both a process and a concept" (p. 267) Hence, they assert, "the ability of students to use variables effectively will depend crucially on their versatility in accessing these alternative mental modes, being able to think both holistically about the object, and sequence capsulated"(p.267). Moreover the set of values that are assigned to the variable are central to students' understanding (Leinhardt et al., 1990). Hence the concept of a variable becomes difficult to students due to the meaning of the context of the variable. Gray and Tall (1994) note that, for example, f (x) in traditional mathematics represents both the process of calculating a specific value of x and the concept of the function for general x.

Another difficulty in student understanding of the concept of a function is the idea of graphs. Dunham (1991:148) suggests that understanding of graphs is critical to success in mathematics, however recent studies show that most secondary students have difficulty interpreting and using graphical display. Hennessy et al. (2001) point out that students find it very difficult to understand graphs as abstractions and develop a link between algebraic and graphical/ visual forms.

Janvier, cited in Leinhardt et al. (1990), suggests that most graphing instruction was overly focused on quantitative, abstract, localised skills. Janvier argues that students first should be introduced to qualitative graphs of concrete situations and asked to view them globally instead of point wise. That is traditional instruction begins with tasks of graphs that require students to read and plot individual points on scaled Cartesian Coordinate systems. Leinhardt et al. (1990) put it: "students should be encourage to attend to the entire graph as a expression of the relationship between two simultaneously changing variables and to express that relationship in *words* rather than numbers" (p.28, emphasis added).

Browning (1991:129) suggests that students understanding of graphs occur in levels. Browning characterises four levels in studying levels of graphical understanding.

The following is a sample of characteristics for each level.
Level 1: recognition of the graphs of a parabola; placed in different positions, simple interpretations of information from a graph, and development of initial vocabulary.

Level 2: translation from verbal information into a simple sketch of a graph, use of initial vocabulary learned in level 1 and simple interpretation from a graph.

Level 3: usage of properties of graphs of functions to determine functions from non functions, recognition of connection between a graph and its algebraic representation, and usage of properties of functions to construct graphs.

Level 4: usage of a given information to construct a graph, usage of information from a graph to deduce more information, and recognition of what is required to find from given information.

Given the above levels of graphical understanding of graphs and students understanding of the function concept, it is often noted that students encounter difficulties in comprehending the function concept. Besides, the notion of variable and graph in the function concept, there are also many notions such as domain and range. Leinhardt et al. (1990) discussed student misconceptions and difficulties by noting: a) what is and is not a function; b) correspondence; c) linearity; d) continuous versus discrete graphs;
e) representations of functions; F) relative reading and interpretation; g) concept variable and h)notation.

Thus it becomes obvious thing to say that the concept of functions is problematic to students. However, numerous research studies note that technologies offer much promise to facilitate the learning of functions (for example Leinhardt et al., 1990; Julie 1993a).

Ernest (1989:38) suggests that LOGO provide a meaningful context for the introduction of a variable concept. Beckmann (1999) notes that graphic calculators allow investigation to function through tables, graphs and equations in ways that were not possible before their proliferation. Leinhardt et al. (1990) recommends for empirical studies of computers both as facilitators and as problems for learners.

2.4 Technology and Mathematics Education

This time is a remarkable time for the community of mathematics education in the light of technological developments in which numerous issues related to its use and impact may influence greatly the teaching and learning of mathematics. Advancements in computer technology have made it possible to carry out sophisticated mathematical procedures in a user-friendly manner in a more accurate and relatively small amount of time. To date numerous software packages are available to work with mathematical concepts.

The use of technology in mathematics instruction has become a focus of various research projects, seminars, workshops and conferences (See for example, Fey 1989, Dunham and Dick, 1994; Lum, 1993; Demana et al., 1991). It is often noted that these technological tools provide a more powerful mathematical problem solving and graphing opportunities and offer new possibilities in the learning and teaching of mathematics (see Fey, 1989; Julie, 1993a and Hennessy et al., 2000). Thus, these technological tools can revolutionalise the existing traditional mathematics instruction. Dunham and Dick (1994) note that mathematics education is considering technology as a 'catalysts for change'. In light of the technological opportunities, it has often been suggested that these tools greatly influence mathematics education (for instance, Fey, 1989; Heid, 1997; Julie, 1993a). Technological tools can facilitate the need for radical evaluation of the content of school mathematics (Heid, 1997). Fey (1989) notes that these technological tools challenge mathematical education in terms of *'what we should teach'*, *'how we should teach'* and *'what students can learn'* (emphasis original). Anderson et al. (1990) also point out that technology affect not only the way mathematics is taught but also what mathematics is taught and how it is assessed.

2.4.1 The Role of Technology in Mathematics Instruction

Technology can play a prominent role in today's mathematics instruction. The great potential of computer technologies in mathematics instruction is increasingly believed to bring a transformation in mathematics education and has brought new possibilities to the teaching and learning of mathematics.

In the beginning, technological tools were greatly advocated for their role in removing the routine and time consuming computational burdens associated with paper and pencil performance of algorithms. Later on, however, their development began to include the manipulations of symbolic and graphic expressions in algebra and calculus, which has been "quite a surprise" (Fey, 1989) to the mathematics education community.

In an environment where technologies are available there is a shift in the emphasis of mathematics instructions since the algorithmic computations involved in traditional mathematics instruction are often lengthy and time-consuming. Most of the class time is devoted to rote practice of these procedures. But in a technologically rich classroom environment the instruction can change to concept development and problem solving by concentrating on the underlying concepts since these tools remove the burden of lengthy and time-consuming routine work (Lomen et al., 1992:237; Wheatley and Shumway, 1992:7; Branca et al., 1992:7; Fey 1989; Judson, 1993:65). Fey (1989) states that computer technologies "play a role in helping move students from concrete thinking about an idea or a procedure to the ultimately more powerful abstract symbolic form…(It) plays a role as a kind of intermediate abstraction" (p.255-256). For instance, the process of graphing in calculus can be replaced with graph interpretation (Judson, 1993:65) and students can examine more graphs more quickly with a high degree of accuracy, with minimal input and effort (Hennessy et al., 2000). Thus, as Wheatley and Shumway point out (1992:1), these technologies can transform school mathematics from a procedurally dominated subject to an exciting body of patterns and relationships.

The fast growing technology and its implications in mathematics education have also brought the greater acceptance of constructivism theory of learning mathematics. Technology can enable students to explore relevant mathematical ideas through constructivist methods (Pugalee, 2001). It serves students as an information resource, a learning tool or a storage device that can support students to construct their own mathematical knowledge (Nicaise and Barnes, 1996) and allows students to actively participate and be responsible for their own learning. Demana et al. (1991:8) point out the role of technology in this kind of learning by noting that "if students construct something on the computer, they correspondingly construct something in their head." Schoaff (1993) also points out that in the environment when technologies are available students might be involved in running experiments, testing conjectures, solving and posing problems, and exchanging ideas. Thus, the wide spread availability of technologies in school mathematics may allow students to explore mathematics on their own.

The other role of computer technologies in mathematics instruction is that they offer students varieties of linked approaches to the same problem situation (Brown, 1991:13; Von Embese and Yoder, 1998:1; Julie, 1993c:343; Judson, 1993:65; Hennessy et al., 2001). Julie (1993c:343) states that computer technologies, the graphic calculator, offer students the opportunity "to experience mathematical ideas and notions in multi-representational-symbolic, numeric and visual-modes." He believes that these technologies have a prominent role in the mathematical practice in such a way that they "stress a cyclical movement between graphic and symbolic representations." He depicted diagrammatically as:

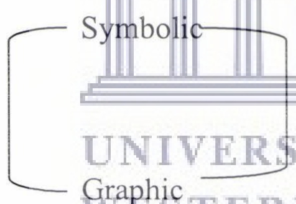


Fig 2.1 Cyclical model of multiple representations in using graphic calculators

Julie asserts, "…this cyclical model is that multi-representational exploration offers learners opportunity to make sense of mathematical ideas and notions visually and to develop visually-based strategies to solve problems." (p.344). Likewise, Fiske (1991:164) notes that the linkage of symbolic manipulation system with graphic utility permits a more presentation of the equation solving process. He goes on to say, "students are able to see the effects of their algebraic actions symbolically and graphically." (p.164)

Furthermore, Fiske (1991:164) notes the following with regard to linking symbol manipulation with graphic representations in the equation solving process.

- Symbols and graphic representations can be used to explore other algebraic transformations.
- The process of solving equations gains a new meaning within the framework of symbolic and graphic representation system.

The availability of computer technologies in mathematics instruction also plays a role in facilitating interactions and cooperative group work among students and teachers (Heid, 1997; Nicaise and Barnes, 1996). Pugalee (2001) points out that, through question and discourse, technological tools help students explore important algebraic concepts and make connections that are vital in the development of algebraic understanding. In relation to this Adams (1997) report that the quality of mathematics instruction improved after introducing a class a graphic calculator. Adams (1997) points out that the teacher no longer simply asked questions, but also initiated communication that consisted of non-question exchanges between the teacher and the student. Furthermore, Adams notes, student-to-student discourse increased when students used the graphic calculators.

Moreover, it is worth to note that technology can enable the entry of mathematical modelling to the school mathematics education (Heid, 1997). It has been argued that mathematical modelling can become the core of mathematical learning. Various researchers (for instance de Lange, 1993:3; Schoenfeld, 1992:339; Swetz, 1991) hold the view that problem solving and applications are the heart of mathematics instruction.

Swetz (1991) describes mathematical modelling as " ...a multistage process that evolves from the identification and articulation of a problem through its eventual solution in the original problem situation." (p.358). He goes on to say that the word model signifies "something that can be manipulated and that lends itself to experimentation" (p.358). Since modelling problems often arise from real life situations the availability of technological tools greatly facilitate its feasibility in school mathematics instruction.

Often problems involving modelling are not 'ready made'. For instance, as Branca et al. (1992:12) note, numbers in real life are messy which can be very large or very small. But the burden of lengthy and time-consuming procedures associated with problem solving can be removed by the use of technological tools. Branca et al. (1992:12) point out that technological tools create the possibility to " pull timely and relevant problems about economy and populations from the front pages of the news paper."

Thus, the use of technological tools can facilitate real life problems which lend themselves to modelling problems. Swetz (1991) put it: " mathematical modelling is the heart of mathematics education reform, and technology is playing a starring role in placing it there because the facility with technology can generate and manipulate mathematical models." (p.358).

Hence, computer technologies can play prominent role in today's mathematics instruction. The availability of such tools to school mathematics education might make possible the teaching and learning of mathematics through constructivist methods. It can facilitate group work, interaction, the use of various linked approaches to the same problem situation and the use of the real world problems, which are relevant to student experiences. In a nutshell, as Hennessy et al. (2001) put it, "more complex mathematics is potentially becoming more accessible to the majority of learners" (p.25).

2.4.2 The Impact of Technology in Mathematics Education

According to Harvey and Osborne (1991:74), one of the major influences of computer technologies is that "the creation and maintenance of attention to the quality and character of mathematics taught". Harvey and Osborne note, "a clear and present danger or disadvantage of implementing technologies may be that the nature of technologies used will cause you to change the mathematical emphasis and the goals of your mathematics or to change the sequence in which the topics are covered."(p.74). Fey (1989) asserts that technology influences mathematics education in such a way that it has an impact on the selection of the content and process goals, organisation of teaching and learning environments and assessment of achievement. Moreover, due to its influence, teachers and students began to cope with changing of content, intended goals and modes of assessment in which they undergo a shift in their roles in the teaching-learning process (Heid, 1997; Fey, 1989; Norman and Prichard, 1992:260). In the subsequent sections we will discus technologies impact on content to be taught, assessment, teacher and student roles, and the classroom environment in general.

2.4.2.1 Content

According to Norman and Prichard (1991:260), "technology influences mathematical content by providing students and teachers with great mathematical power for the embodiment of multiple representations of concepts and performing numerical, graphical and symbolic computations." They assert that the actual mathematical content is changing in context with mathematical power available by computer technologies. They illustrated that topics, for example, probability in statistics, combinatories and discrete structures are becoming more prevalent in school mathematics education. In line with this Fetta (1992:30) argues that topics like probability and statistics were more emotional than intellectual. Fetta further argues, "…this emotional reaction results in a student being in attentive and poorly prepared, avoiding the problem by not attending the class, not doing assigned homework and consequently *not learning the material*" (p.30, emphasis added). Heid (1997) supports this assertion that technologies are an 'amplifier' extending the existing curriculum. Heid notes: "it can be a reorganiser, changing the fundamental nature and arrangement of the curriculum." (p.2). Heid (1997) also points out that the influence of technology lies in their degree of transparency and the extent to which they foster the externalisation of mathematical representations.

The traditional way of teaching and learning of mathematics in schools is often restructured to use certain mathematical concepts in schools and colleges. The feasibility of technology for the execution of a wide range of concepts influence the mathematics curriculum to fundamentally transform school mathematics from a procedurally dominated subject to study of patterns and relationships (Wheatley and Shumway, 1992:1).

La Torre (1993:12) notes that technology allows students to move quickly and easily beyond the usual computational burden and to experience some of the true richness of the subject. Schlais (1991:280) also points out that the use of technology in mathematics instruction transform the content from a dead collection of topics to a real 'application' course. Arney et al. (1991:99) note that technology allows for a reorganisation of mathematical concepts within a topic in which more concepts are covered and less emphasis is placed on memorisation and manipulative skills.

Computer technologies allow students and teachers to engage in more realistic problems so that they can solve problems of real life situations (Burill, 1992:15; Fey, 1989; Judson, 1993:65). It has been argued for a long time that mathematics instruction should engage students in problem solving of real life situations. Judson (1993, 65) points out that computer technologies enlarged the class of problems that might be assigned. Judson notes that it is no longer necessary "to use only artificial problems which demand the tools to be integral" and "to restrict examples to unrealistic problems"(p.65). Students in pre-calculus instruction, for example, are often involved in the practice of specific concepts such as studying functions of lower degree polynomial and special functions that suit for computational purposes. Higher order polynomials and other types of functions are rarely to be discussed and simply only given by the teacher. Moreover the sequence of topics covered in the traditional mathematics instruction can be examined in the light of using these technological tools in terms of what students learn and how they learn to have the advantage of technologies in mathematics instruction. In sum, the use of these technological tools can allow students to learn concepts at quite an intuitive level, more complete and useable process (Schlais, 1991:280), in which it influences to revisit the content traditionally taught. As Schoen (1991) states, "we must factor the technology variable into our curriculum planning"(p.10).

2.4.2.2 Educational Goal or Objective

The other impact of technology in mathematics education is that it makes us revise or examine the goals and objectives of our instructions. In traditional mathematics courses the goal of mathematics instruction has been dominated by mastery of skills and procedures. Schoen (1991:8), for instance, points out that the goal of instruction in traditional calculus course is symbolic and graphic manipulations. Fiske (1991:164) also notes that the goal of instruction in traditional method for solving equations in algebra emphasises symbolic manipulations. Traditional mathematical practice that emphasises the above activities create a dissatisfaction in mathematics instruction in terms of students' achievement and understanding which led to the so called 'mathematics reform movements' of the past decades in which efforts have been made to revisit the goals and objectives of mathematics teaching and learning in the light of mathematical contents. Nowadays around the world efforts are underway to improve the quality of mathematics education. In parallel to these efforts, the readily availability of technologies to school mathematics has also forced to facilitate the reconsideration of curricular objectives in every topic that the potential of computer technologies can be explored (Fey, 1989). Fey notes, "...computer graphic tools can be used to revise the balance between conceptual and procedural knowledge in mathematics or to create entirely new graphic orientations of traditional mathematics topics" (p.250).

2.4.2.3 Assessment

Another influence of technologies in mathematics education is in the kind of assessment and examination given in mathematics where the potential of technology is powerful in the enhancement of teaching and problem solving by using it. Beckmann et al. (1999) note that the assessment items previously used are no longer appropriate in technologically rich classroom environments. The traditional assessment rarely involve testing students' understandings based on multiple representations because it has been dominated by the assessments of testing skills by manipulating symbolic expressions (Dick, 1992:145). Branca et al. (1992:12) assert that technological tools allow teachers to assess students' activities by focusing on relevant educational objectives. For instance, most assessment items in traditional advanced algebra and pre-calculus, according to Beckman et al. (1999), can often be obtained by the use of computer technologies. They assert that concepts such as determining the domain and range, evaluating a function, determining x when f(x) = g(x) and analysing periodic functions can be completely understood by the use of technological tools.

When computer technologies are used teachers can focus more easily on assessing their students' growth in conceptual understanding and problem solving activity rather than merely on procedures. Harvey and Osborne (1991:84) point out that due to the contribution of the use of technologies to a better conceptual learning, a more extensive knowledge of applications, development of higher order skills and improved problem solving performance becomes more accessible for assessment by de-emphasising testing of lower level skills. For instance, Branca et al. (1992:12) assert that "…if the goal of a unit is for students to develop skill in (story problems) percents, the use of calculators in assessment can reduce computational errors with decimal operations that are peripheral to the unit objectives." Anderson et al. (1999) state that the proficient use of technologies makes many standard questions unnecessary to test the mathematical skills traditionally regarded as fundamental. That is, according to Anderson et al. (1999), an examination or test with access to computer technologies enable students to be assessed more readily on real-world situations, which may involve mathematical concepts outside his or her current experiences. Furthermore, Andersen et al. (1999) point out, "with the emphasis on routine drill and practice examples, the future of mathematics syllabi can be expected to have a greater emphasis on examples requiring to interpret information or to give evidence of reasoning used in obtaining an answer …and these skills require a change in the tasks set to assess student achievement" (p.846).

2.4.2.4 The Mathematics Classroom Environment

Dick (1992:145) asserts that computer technologies can "fundamentally redefine the teacher and student environment." In the presence of technology the lecture format of the class can become a more formal exploration of concepts by both the teacher and students (Fetta, 1992:30). The traditional classroom environment, as Fey (1989) characterises it is "a contest between a teacher and a student in which the challenge to figure out secrets that the teachers keep hidden." (p.250). The teacher usually stands in front and is rarely interested to interact with students on individual basis. However, the use of technological tools can permit teachers to work with students more likely in an individual way with the nature of their intended audience switching from students and classmates to the student zone (Heid, 1997). Similarly Harvey and Osborne (1991:75) put teachers' activity as "…a guide on the side instead of a sage on a stage, that is to work with students more closely and on an individual basis instead of lecturing to them, at best, engaging in problem solving with the whole class." Heid (1997) reports that when using technological tools "…there was less teacher control of the classroom activities and that teachers were less likely to function as authoritative experts and more likely to serve as collaborators." (p.24). Thus, the use of technologies can change the classroom environment to be more likely interactive in which students get freedom and opportunity to interact with complex mathematical objects and facilitates students' ability to self regulate (Nicaise and Barnes, 1996). Nicaise and Barnes (1996) suggest that technology supports the concept that learning can be individually guided and can be a reflective activity rather than a mass-produced and teacher-centred activity. Schoenfled, cited by Heid (1997), reported that: "By the time the bell to start the class rings three-fourths of the students in class today have problems on the screen and are working on them. The others (have all logged in and appear to be waiting for their problems to appear…I'm struck by the fact that the students have started their work without word from the substitute teacher who is in charge of the class today." (p.24-25). Moreover the use of these technological tools may facilitate interaction among students themselves. Nicaise and Barnes (1996) note that technologies allow students " to observe and interact with individuals, many of whom have divergent views and opinions. This interaction [should] provide students with opportunities to react to differing views, challenge others beliefs, and reflect their own ideas" (p.208).

Thus, the availability of technological tools can fundamentally shift the classroom environment in which the role of students and the teacher changes as compared to that of traditional instruction. This is discussed below.

2.4.2.4.1 Role of the Student

In technologically rich classroom environments students exhibit a wider variety of roles (Dunham, 1993:89). Ruthven (1992:100) points out that during the use of technologies in the mathematics instruction "responsibility is devolved to students that play a more active part in developing and evaluating mathematical ideas." Ruthven (1992:100) asserts that students not only grasp ideas but also develop their "capacity to tackle novel situations". That is, students learn mathematical concepts by their active participation in mathematical practice.

Students are encouraged to do exploration and experimentation of mathematical ideas since a more detailed explanation of concepts can be offered due to the relative ease of simulation and drill and practice exercises can be effectively supplemented with realistic problems (Fetta, 1992:30). Fetta (1992:30) notes that the use of technologies in mathematics instruction make students not to depend on a teacher by allowing them to conjecture, build, test and discover mathematical concepts by their own and able to evaluate their ideas for themselves. The acceptability of a piece of mathematics is seen to depend not on the authority of the teacher but on it being consistent with some accepted wider body of mathematics (Ruthven, 1992:00). In this kind of learning students' roles in mathematics instruction can undergo a shift from passive listeners of information to becoming less didactic, less passive, and do more group work, problem solving, investigating, symbolising and consulting with technology (Dunham, 1993:89). La Torre (1993:163) puts it: "students are considered as having responsibility for their own learning of the material and to have a greater stake in the outcomes of that learning."

2.4.2.4.2 Role of the Teacher

The use of technological tools make teachers to be able to provide activities that encourage students exploring, conjecturing, testing, discussing and building. (Norman, 1992:260). As compared to traditional paper-pencil way of teaching and learning of mathematics teachers can have more time to introduce much more problem-solving and investigative work and to develop their own teaching styles (Shuard, 1992:33) which best suit their students in particular settings of the classroom environment. Shuard (1992:33) holds the fact that "teachers become more responsible to children's ideas work rather than an instructors who told children how to do mathematics." Nicaise and Barnes (1996) hold the same view of changes in roles of students and teachers. They note that the task of the teacher changes from information providers to problem or task presenters or scafolders. Similarly Norman (1991:260) and Dunham (1993:90) point out that teachers continue as managers but less often task setters and explainers and become expert at guiding, questioning, discussing, clarifying and posing mathematical concepts.

In the study of Shuard (1992:35) it is reported that the use of technology allowed teachers to develop "a style of talking with students about mathematics that was different from the usual questions-answers evaluation style." Shuard noted that the teacher no longer pointed students towards the expected 'correct answers' to the teacher's questions but instead asked the students to explain their own thinking and become expert in responding to students' questions in such a way that the students are valued and supported but required to do mathematical thinking for themselves. Ruthven (1992:100) gives similar idea to the above by suggesting that the role of the teacher is mainly "to create mathematical situation from which important concepts and relations are likely to emerge and through sensitive intervention to support students in exploring this situation and clarify their ideas."

As is discussed in the previous sections computer technologies can have great potential in transforming school mathematics education by providing conducive environments and new possibilities. However, the presence of such technologies is not readily accessible to schools mathematics education. Computers are expensive, they need electricity, and special rooms needed for their placement (Julie, 1993a; Rich, 1993:389). In addition, Graham and Thomas (2000) note that two reasons often mentioned by teachers for the possible under-utilisation or hindrance of computers are: "...their role of confidence in using technology in teaching, and the lack of resources, both in terms of computers and relevant, tried and tested software."(p.268). Ruthven (1992:92) notes that, even if every class is equipped with a single micro-computer, it is often used predominantly for demonstration by the teacher and even where direct use by students is encouraged, access is usually limited under teachers' role. As a result, Ruthven (1992:92) states, "few students are able to make spontaneous use of computing facilities."

The advent of graphic calculators, however, created a new option of using computer technologies. Hennessy et al. (2001) notes that these powerful little tools offer the same opportunities from those of computers in which they are highly personal, portable and more controllable by students. Using the graphic calculator students can explore all the mathematical representations in ways that emphasise the connections between various forms (Von Embese, 1992:92; Laridon, 1993:353).

2.4.3 Graphic Calculators and Mathematics Education

The graphic calculator is not just simply a calculator for algorithmic computations. As it is described by Von Embese (1991:67), the graphic calculator, for instance the Casio, is like a computer with a large text screen (See figure 2.2) which can display eight lines of text, with 96 by 64 pixels, and is easily programmed to perform a variety of mathematical procedures. Von Embese (1991:67) also points out that the graphical calculator, unlike computers, has built-in graphing and statistical routines, which are user friendly.

The most important factors for attempting to integrate these technologies to school mathematics curriculum are:

- Their portability (Julie 1993a; Hennessy et al., 2001).

- Offer access at relatively affordable price (Hennessy et al., 2001; Julie, 1993c: 342; Ruthven, 1992:92; Graham and Thomas, 2001).

- Do not require facilities or highly specialised rooms (La Torre, 1993:162).

- Can be accessed any time anywhere in all types of environments (Hennessy et al., 2001; Julie, 1993c:342). Julie (1993c:342) notes that these calculators are not dependent on electricity and their use is important for disadvantaged students in non-electrified regions.

Furthermore, graphic calculators, unlike computers, can de-emphasise the dominant use of technology by males in school mathematics (Smart, 1993:372) and create equality in society by doing mathematics (Julie, 1993c:348). Julie (1993c:343) lists some of the distinct functions of graphic calculators in such a way that it allows users to:

- Enter the defining equation for graphs such as circles in section formats
- Freely select a domain and range of their choice
- Choose scaling factors of their choice
- Zoom in or out of particular regions of interest
- Overlay (superimpose) graphs
- Access any point on a graph and display the coordinates of such a point and
- Shade regions indicating inequalities

The above-mentioned functions of the calculator attracted the attention of mathematics educators and researchers to study the effect of their potential in school mathematics education. The incorporation of graphic calculators in school mathematics education has become the focus of numerous research studies due to the high expectations of their functions in enhancing the teaching and learning of concepts, particularly the 'functions' concept.

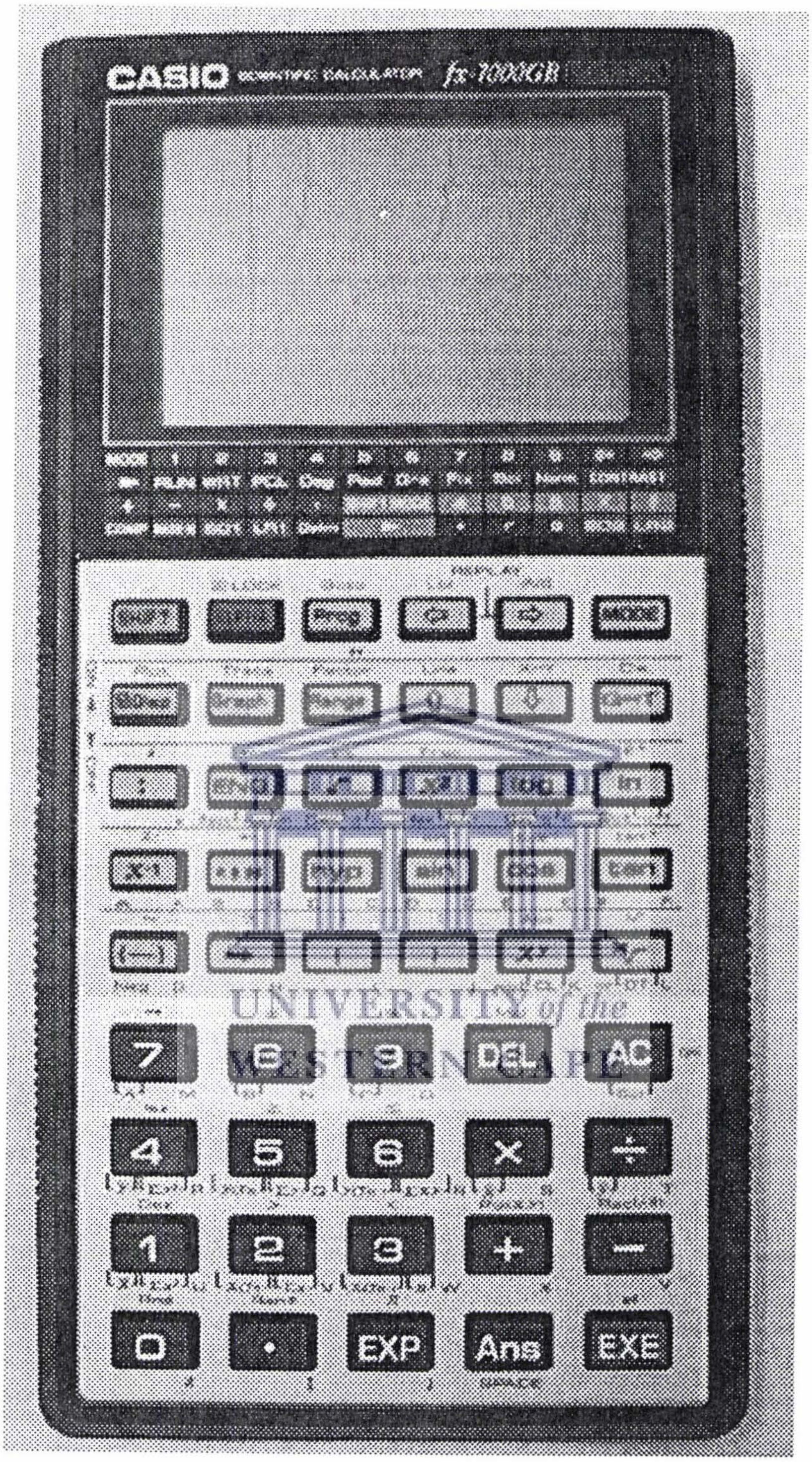


Fig 2.2 The Casio fx-7000GB Graphic Calculator

2.4.3.1 Studies Related to Graphic Calculators Use

Numerous researchers (for instance, Boers and Jones, 1994; Durmus, 2000; Quesada and Maxwel, 1994; Rich, 1993; Ruthven, 1992) explored new curricular and instructional approaches to exploit the capability of graphic calculators in various areas. Most studies compared the use of graphic calculators with the use of traditional paper-and-pencil by dealing the same content of a given mathematics topic or concept.

Quesada and Maxwel (1994) studied the effects of using graphic calculators to enhance college students' performance in mathematics (pre-calculus). They report that a group of students who used the graphic calculator had significantly higher scores than those students who did not use the calculator. However, according to Quesada and Maxwel, the following factors may have influenced the positive results.

- Students in the experimental groups were aware of their participation in the experiment

- The final exam may have been biased towards the students in the experimental sections, since it was prepared by one of the teachers.

Quesada and Maxwel (1994) also note that students seem to become overconfident and/or bored and did not work consistently since college students taking pre-calculus have previously been exposed to basic ideas from an algebraic point of view. However, they point out that some students in the experimental group use graphic approach of solving problems (which is new to them) not only to confirm the answers obtained algebraically but also for solving problems before trying to solve it algebraically.

Similar reports have been reported by Alexander (1993), Chandler (1993) and Durmus (2000) that students using the graphic calculator had significant gains on the overall achievement scores as compared to those who did not use it.

In another study, Rich (1993:38) examined the effects of the use of graphic calculators on the learning of function concepts in pre-calculus. In this study Rich found no evidence for the overall achievement effect of using graphic calculators in pre-calculus. However, according to Rich (1993: 391-392):

- There were positive effects on graphing concepts and somewhat negative effects on paper-and-pencil procedures for finding slope and verifying trigonometric identities

- Students who are taught pre-calculus using graphing calculators learn that algebra problems can be solved graphically as well as through algebraic manipulation, and they often choose graphic approaches

- Students who are taught pre-calculus using a graphing calculator better understand the connection between an algebraic equation and its graph

- Students who are taught pre-calculus using a graphing calculator view graphs more globally, in that they better understand the importance of a function's domain, intervals where it increases and decreases, its asymptotic behaviour and its local behaviour.

- Pre-calculus classes, that are taught using a graphing calculator tend to include more studied exploration and conjecturing

- Teachers, who teach pre-calculus using a graphic calculator, ask more higher order (application, analysis, evaluation) questions.

In the same line to that of Rich (1993), Pankow (1994) and Hall (1993) found that there was no significant difference between the mean scores of the students who used the graphic calculator and those who did not. Hall, however, notes that the study was not generalisable to other populations due to sample size, unit brevity, lack of randomisation, non equivalent classes, teacher concerns, student attitudes, lack of control group uniformity, lack of supervision and possible out-of-class use of calculators.

My review of the literature failed to find studies, except to that of Giamati (1991), that reports the use of graphic calculators affected students' performance negatively. Giamati found that students that used the traditional paper and pencil method were superior in various aspects of the concept being taught. He notes that students in the traditional paper and pencil group were superior at sketching functions, understanding translations and stretches and shrinks, and describing parameter variations.

Besides the achievement studies discussed above, other researchers investigated graphic calculator use in various dimensions. Boers and Jones (1994) examined students' use of graphic calculators under examination conditions. They found that students did not utilise the calculators under examination conditions. Boers and Jones point out that the main reasons for the under-utilisation is the lack of mathematical understanding or mathematical judgement necessary to enable them to more backwards and forwards between algebraic and graphical representations of problem situation with confidence.

In another study, Dugdale (1993:102) examined visualisation of polynomial functions by conducting a 'monomial sums approach' in which students were asked to use the graphs of the monomial functions to predict the graph of their sum. Dugdale (1993:107), then, concluded that by using technology students:

- Increased their proficiency in relating functions to their graphical representations.
- Increased their relevance on mathematical reasoning.
- Decreased dependence on memorised rules.

Dugdale (1993:107) further illustrated, "the most troublesome idea involved in the monomial sums approach was the fact that for x^n larger exponents produce smaller values when 0</x/<1. Students frequently encountered situations that challenged their persistent notion that, for example, x^4 is always greater than x^2. Repeated encounters seemed necessary for students to accept that x^4 is indeed less than x^2 for certain values of x."

In the same manner, Browning (1991:129) studied the understanding of functions and their graphs. Browning (1991:129) devises levels of graphical understanding in which, Browning believes, understanding of functions and their graphs occur in levels. On the comparisons conducted to high school and college pre-calculus students it was found that students who have no access to graphing technology have a lower understanding of functions and their graphs. Browning (1991:131) also notes that the use of technology "allows for experimentation and examination, not previously possible in a non-technology based pre-calculus curriculum." Moreover Browning (1991: 131) note, "the interaction between students and the computers/graphic calculators provide for an environment to make the mathematical connections between a function and its graph, connections which are necessary to appreciate the uses and values of graphs in the mathematics curriculum."

In another study, Doerr and Zangor (2000) studied how students create mathematical meaning and how they used the graphic calculator to construct mathematical meaning out of particular tasks. They identified five categories of patterns and modes of calculators use by the students. They listed the use of calculators by students as: computational tool, transformational tool, data collection and analysis tool, visualising tool and checking tool. They also note that the graphic calculator can in certain situations take on more than one role simultaneously. Thus, Doerr and Zangor concluded that "the graphic calculator is a rich, multidimensional tool and that the continued study of its use in classroom practice will need to carefully delineate the patterns and modes of use that occur in any given context as conclusions are drawn related to student learning." (p.161).

2.5 Concerns (Constraints or Issues) Related to Technology Use

Having noted the promising features of technologies in mathematics education, there are concerns of its use in the teaching and learning of mathematics (Doerr and Zangor, 2000; Heid, 1997).

Doerr and Zangor (2000) note that the graphic calculator emerged as a constraint and limitation in two ways.

- Students' attempted uses of the device as a 'black box' without attending to meaningful interpretations of the problem situation.

- The personal (or private) use of the tool.

Doerr and Zangor (2000) point out that the use of the calculator as a 'black box' represent the class of situations in which students didn't have a meaningful strategy for the use of the calculator. The second constraint of the graphic calculator as a private tool signifies the limited visibility of calculator's screen to share among a group of students. Doerr and Zangor also point out that students frequently used their calculators when the teacher or other students were talking in lecture. Thus, according to Doerr and Zangor, this personal use of technology served to break down group communications.

Heid (1997) asserts that computer technologies would simply replace one set of routine and recipe-like behaviours. Schoen (1991:11), for instance, notes that students may rotely manipulate graphs and their scale in the same way of manipulating symbols on paper. Hennessy et al. (2001) hold similar view that it should be determined that what paper and pencil skills retain their importance with the advent of new technology. Hennessy et al. (2001) contend that the use of computer technologies " can push students on to the undesirable side of the threshold between scaffolding and dependence." (p.285).

Smith and Shotsberger (1997) remind us that the use of graphic calculators is not necessarily beneficial for learning some algebra topics. They suggest "an extensive research on the patterns of calculator use both by students and instructors, including long term benefits or disadvantages of technology for mathematics learning" (p.12).

Along with the pedagogical concerns, the incorporation of technology in mathematics education may generate a list of concerns. Heid (1997) points out that finance, access and equity, the nature of teacher preparation and public perception are issues of technology use in mathematics education. Heid notes, " a feared consequence of the incorporation of technology is that wealthier schools can acquire more technology than poorer and that educational gap between the economically advantaged and disadvantaged would increase" (p.30).

Another concern raised by Heid (1997) is that the adequacy of teacher preparation. Heid notes the importance for addressing issues of "teachers' knowledge of mathematics, their knowledge of technology, their understanding of learning and the nature of mathematical knowing, and the ways in which they implement technology-intensive curricula" (p.31). The other issue is a political one. Heid (1997) states: "how should be changes brought on by technology be communicated to public, to mathematicians who are uncommitted to their use, to parents, to school board members, and to legislators" (p.31).

2.6 Summary

From the foregoing, it has been stressed that computer technologies can have a prominent role in mathematics education. The function concept is one of the concepts in mathematics that computer technologies can offer a better way of learning than the traditional approach. Technologies can also change the classroom environment into a more interactive environment through constructivist methods. Numerous research studies have been undertaken on this issue.

Concerning the effect of graphic calculators in the mathematical achievement of students in learning certain concepts of mathematics, various researchers found that the use of graphic calculators didn't affect students' achievement negatively. The results of these studies reported that a group of students who used the graphic calculator had significantly higher scores than those students who did not use (see for instance Alexander, 1993; Chandler1993 and Durmus, 2000). Rich (1993:138), Pankow (1994) and Hall (1993), however, reported that there was no significant difference between the mean scores of the students who used the graphic calculator and those who did not. However they noted that there were some positive effects on other dimensions of students' mathematical learning.

In another study Giamati (1991) found that students using the traditional paper and pencil method were superior at sketching functions, understanding translations and stretches and shrinks, and describing parameter variations.

Most studies cited above might indicate that the graphic calculator can have a positive effect on students' mathematical understanding of certain concepts. In their extensive reviews of the literature, Dunham and Dick (1994) reported that in most cases the graphic calculator didn't affect student achievement negatively.

But in Eritrea it is far too early to draw conclusion about their effects. The aim of this study is to investigate the effects of graphic calculators on the mathematical achievement of Eritrean grade ten students related to the concepts of quadratic function. The next chapter deals with the methodology employed in this study.

Chapter Three

Research Methodology

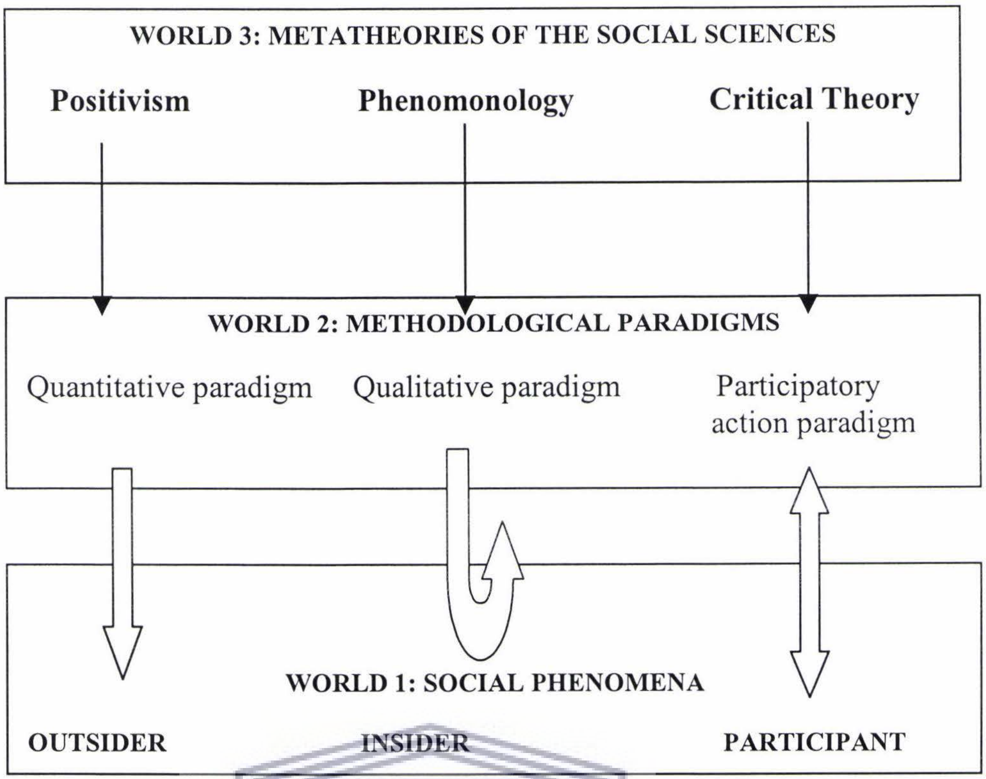
3.1 Introduction

This chapter discusses the research methodology and methods adopted in the present study. It describes the research design, the scope and area of the study, the samples and subjects, and the procedures of the research process. It also points out the background of the research and the choice of the research approach.

3.2 Paradigms in Research Methods

The ultimate end of any research of study is to describe or explain what is happening in the real situation. To this end researchers employ different means of studying reality. The research approaches are the function of our understandings of the objects under study and the nature of our data. Cohen and Manion (1994) point out that people comprehend the world around them in different ways by means of deductive reasoning, inductive reasoning, and the combined inductive-deductive approach.

The basic difference for these research methods stems from their roots for the theory of knowledge (Epistemology). Babbie and Mouton (2001:49) note that quantitative research method (deductive reasoning) has been linked to positivism; the qualitative research method (inductive reasoning) to phenomenology or interpretivism and participatory action research (combined inductive-deductive) to critical paradigm in metatheory. They illustrated this diagrammatically as follows:



(Babbie and mouton, 2001:49).

Fig 3.1 Research methods in social science

The fundamental distinction between the research methods often referred is that between the qualitative and quantitative research methods. These two research methods differ in a variety of ways but compliment in many ways (Neuman, 2000:121). He points out that quantitative researchers emphasise "precisely measuring variables and testing hypotheses that are linked to general casual explanations" (p.121). By contrast qualitative researchers emphasise "detailed examinations of cases that arise in the natural flow of social science" (Neuman, 2000:122).

Epstein (1988:187) notes that these two different research methods differ in terms of their "ultimate purpose, the logic and research designs they employ, their point of view, type of language and their theoretical bases." Neuman (2000: 123) presents the differences between quantitative and qualitative research as follows:

Quantitative	Qualitative
Test hypothesis the researcher begins with	Capture and discover meaning once the researcher becomes immersed in the data
Concepts are in the form of distinct variables	Concepts are in the form of themes, motifs, generalisations, taxonomies
Measures are systematically created before data collection and are standardised	Data are in the form of words from documents, observations, transcripts
Theory is largely casual and deductive	Theory can be casual or non casual and is often inductive
Procedures are standard, and replication is assumed	Research procedures are particular, and replication is very rare
Analysis proceeds by using statistics, table, or charts and discussing how they show relates to hypothesis	Analysis proceeds by extracting themes or generalisations from evidence and organising data to present a coherent, consistent picture

(Neuman, 2000:123)

Table 3.1 Differences in quantitative and qualitative research methods

Although the differences in the orientations of these two research methods are noted, both research methods are planful, systematic and empirical (Epstein 1988:190). Epstein (1988:190) notes, "both methods are equally valid approaches."

3.3 Choice of the Research Approach

As has been mentioned earlier, the present study investigates the effects of using graphic calculators in the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function. As far as my present study is concerned the study falls within quantitative research area. This is because the study involves investigating whether there is significant effect of a treatment on students' mathematical achievement by testing the mean differences in the achievement scores. That is a hypothesis was designed to answer the research question and the nature of the observations (data) rely on quantitative measures. In addition dealing with students' achievement scores on tests is quantifiable data. Thus, quantitative research method is selected as it aptly suited to investigate the effects of graphic calculators on students' mathematical achievement.

3.4 Research Design

In this study a quasi-experiment is used to determine the effects of using graphic calculators on the mathematical achievement of Eritrean grade 10 students. According to Davis (1995:52) "an experiment is a test of cause-effect relationships by collecting evidence to demonstrate the effect of one variable on another".

It is often considered that experiments are well suited to physical sciences that are conducted in science laboratories. However, social scientists employ experiments to study the cause-effect relationship of two or more variables in social settings. Babbie and Mouton (2001:208) note that experiments are used by social scientists which take place in a regular course of social events.

In conducting experiments the most commonly used technique is to test two or more groups of subjects, which differ in one respect in the treatment given, and the observed difference in their performance can then attributed to the different treatment (Davis, 1995:54). Babbie and Mouton (2001:208) also note that the foremost method of offsetting the effects of the experiment itself is the use of control group, which help researchers to detect any effects of the experiment itself.

As it is mentioned in the first chapter the research question of this study is:

Is there any significant effect of using graphic calculators on the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function?

Hence, a hypothesis is designed to answer the research question. The null hypothesis is:

> Ho: There is no significant difference between the overall mean achievement score of students in the two groups.

The preference of conducting an experiment in this study is then mainly that experiments are especially appropriate for hypothesis testing (Babbie and Mouton, 2001:208; Davis, 1995:52). Grinnell and Stothers (1988:199) suggest that a research design involve an experiment in situations when we want "to discover with a reasonable degree of certainty whether one variable causes another, or less dogmatically, whether one variable is associated with another."

In the present study the variables are students' exposure to the graphic calculators and achievement scores on tests in which the former is independent variable and the latter are dependent variables. Thus, this experiment attempts to discover the cause-effect relationship between the use of graphic calculators and students' mathematical achievement related to the concepts of quadratic function.

There are many kinds of experimental designs. Researchers adopt experimental designs that best suit to the practices of their study. The most common method of investigating the effects of a treatment (independent variable) is the use of control groups in an experiment (Babbie and Mouton, 2001:210). The experimental and control group design involves the use of two or more groups, which can be constituted by randomisation or non-randomisation. Cohen and Manion (1994:213) refer a 'true' experimental design for a design that involve experimental and control groups which have been constituted by randomisation. The aim of random assignment of subjects to the groups is to ensure the greatest equivalence of groups (Cohen and Manion 1994:213).

Grinnell and Stothers (1988:221) suggest that a true experiment is one which approaches certainty more closely. They identify four factors involving true experiments:

- Manipulation of independent variables

- Control over intervening variable
- Random sampling
- Random assignment or randomisation

(Grinnell and Stothers, 1988:221).

However, most educational studies do not lend themselves to undertake true experiments (Cohen and Marion, 1994:214). In educational studies the most commonly used experimental designs are the 'quasi-experimental' designs or the non-equivalent control group designs in which the experimental and control groups are not equated by randomisation. This is because the sampling process involves intact classes rather than individual subjects.

The present study involves a quasi-experimental design, which involve two groups of students, experimental and control groups, which have not been constituted by randomisation. This is because, as mentioned, the random selection of samples involves sections or classes of students rather than individual students. Thus, the design adopted can be represented as:

Experimental group:	O1	x	O2
Control group :	O1		O2

Where the letter 'x' refers to the independent variable or the treatment given to the experimental group, and 'O' refers to the observations of the dependent variable in which 'O1' is first set of observations of the dependent variable, and 'O2' is the second set of observations of the dependent variable.

The two groups may not be equivalent since the members were not randomly assigned to the two groups. However the pre-test will allow us to know in what respects they differ

(Grinnell and Stothers, 1988:230). If they are comparable, we proceed with the experiment to conclude that the change in the post-test is attributed to the treatment effect. The two groups may not be comparable. In this case analysis of covariance might allow us to compensate for these differences.

The chief advantage of the above quasi-experimental design lies in the isolation of the experimental variable (Babbie and Mouton, 2001: 225). Another advantage of this design is that it allow us to involve two groups of subjects if we are not in a position to randomly assign subjects to either control group or to an experimental group (Grinnell and Stothers, 1988: 229). This is useful in cases if the two groups are already in existence or if there are some ethical issues involved.

However, this experimental design suffers from potential sample selection biases (Fife-Schaw, 1995:91). The lack of random assignment may affect the validity of the research study. The two groups may not be comparable at the very start. Another disadvantage may be the testing effect of the pre-test. Grinnell and Stothers (1988:214) suggest that the pre-test might have effect on the post-test. For instance, some people might have higher score on the post-test because they recall the items on the pre-test, or they might have a lower score because their experience with the pre-test have made them anxious.

It has been discussed that in the above section the design chosen for the research study was a quasi-experimental design. In the next section we describe the scope of the study and procedures for selecting samples that are representative of the population from which they are drawn.

3.5 Scope and Site of the Study

In Eritrea there are six administrative regions (Zobas). The study was conducted in one of the six Zobas in Zoba Maekel (Central Zone), which includes the city of Asmara the capital city and the largest urban area in the country. This region has a total population of 538,749 of which 74% of the total population live in the city of Asmara (UN Report, 2001).

In Zoba Maekel there are 14 public and private secondary schools out of the total 33 schools in the country. Of these 14 secondary schools 11 are located in the city of Asmara, which are large in size and student population as compared to other secondary schools in other Zobas. In the 2000 ESECE (Eritrean Secondary Education Certificate Examination) there were 4642 students from Zoba Maekel out of the total 6924 students participated in the examination (Ministry of Education, 2001a). That is, 67% of the total matriculates were from Zoba Maekel.

Having all these I have selected secondary schools in Zoba Maekel as site of the study. The reason for the selection of this Zoba (region) is that, there are many large secondary schools and I live in this area that I can get access to school continuously and with minimised cost.

3.6 Samples and Subjects

The main purpose of sampling is to select a set of subjects out of the total population under study. Often the study population is large in size and is impossible to conduct researches that involve all subjects in the population. Thus, samples of the population are examined that are considered as a representative of the wider population under study. Seasberg (1988:240) notes that the idea of sampling is that "all appropriate subjects or individuals of the total set will not participate in the study".

In sampling two major methods are frequently used (Cohen and Manion, 1994:99; Babbie and Mouton, 2001:166). These are probability (random) sampling and non-probability sampling. As Cohen and Manion (1994:99) point out in probability sampling every member of the population have equal chance to be selected for a sample. Likewise, in non-probability sampling every member of the population doesn't have equal chance for selection because this kind of sampling definitely includes some members of the population (Cohen and Manion 1994:99).

In the present study probability sampling (random sampling) is used. The study population that Eritrean grade 10 students who have registered to learn in the secondary schools of Zoba Maekel in the 2001/2002 academic year. Of the 14 secondary schools in Zoba Maekel two schools, Semaetat Secondary School (SSS) and Barka Secondary School (BSS) were randomly selected. The main reason for involving two secondary schools was to minimise the possible interaction effect while conducting the experiment.

Semaetat secondary school was taken as a control group because the teacher (Mr. Bereket) who was assigned to teach the control group teaches in this school. I was responsible to teach students from the experimental group. The advantage of teaching the two groups by different teachers is that it minimises the possible bias that might be encountered by the teacher in the favour of a particular group.

For purposes of the study three groups (classes from grade 10) of students were randomly selected from each school. Thus, from the three groups in each school, one group had to be selected for the study.

Mr. Bereket and I outlined a general multiple choice mathematics test that was administered to the six chosen groups. After it was marked by both of us, the Spearman's rank difference formula was used to find the two most correlated scores of the groups out of the six groups. The correlation coefficient of group C of BSS and group A of SSC was the best, which was 0.83. Thus, these two groups were used as a sample for the purpose of the data collection.

The chosen group of students from BSS was taken as graphic calculator group (experimental group) and the group of students from SSS was taken as paper and pencil group (control group). That is the former group used graphic calculators while learning the concepts of a quadratic function and the latter were not provided with the graphic calculators.

Both the graphic calculator group and paper and pencil group were exposed to the same content on the concepts of quadratic function and achievement test in quadratic functions at the pre-test and post-test stages. As is mentioned the aim of the study is to determine the effects of using graphic calculators on the mathematical achievement of students related to the concepts of quadratic function. Thus if the scores of the post-test scores of the two groups are significantly different, it is reasonable to conclude that the effect can be largely caused by the treatment, that is using the graphic calculators.

BSS				SSS			
Age	Sex		Repeaters in grade 10		Sex		Repeaters in grade 10
	M	F			M	F	
14	1	-			-	-	-
15	2	1			3	2	-
16	3	1	1		4	3	3
17	3	4	1		1	4	1
18	1	2	1		1	1	1
19	1	1	1		1	1	-
Total	11	9	4		10	11	5

Table 3.2 profiles of the subjects in the samples.

3.7 The Measure

The data gathering materials for the study were the scores of students on the pre-test and post-test on the quadratic functions achievement tests.

The pre-test was administered prior to the experiment to investigate the equivalence of the groups. And the post-test was given at the end of the experiment. It was hoped that the two achievement tests would shed some light to the effects of using graphic calculators in the mathematical achievement.

The pre-test and post-test materials consist of nine questions. These were developed from related instruments on experiments using graphic calculators (Von Embese and Olmstead, 1993 and Gillian, 1991). Many of these questions were followed by sub questions (see appendix).

Before administering the pre-test and post-test I showed the test materials to my supervisor, Professor Cyril Julie. He gave me the necessary comments and modifications. Furthermore, a panel of experts: two mathematics educators and four-experienced secondary school mathematics teachers examined it after which several improvements made.

Students from each group were given 50 minutes to complete the pre-test and the post-test. Each item in the questions were scored one mark for the most correct answer, a fraction for an attempted answer according to the joint judgement of the teachers and zero for any thing else. A third person was in charge to correct the papers for cases where differences between mark of the papers of the two groups.

3.8 Process of Data Collection

In order to present the experiment, I was considering the idea of involving students in the study. I discussed it with Mr. Bereket and vice-principals of the schools on how the lessons be presented. One idea was to force students by school authorities to participate in the study. This was because it is often said that students did not normally attend extra classes that did not count to their regular classes. But thinking that forcing students to participate in the study did not give a reliable information, it was decided to find some way to motivate students instead. To this end students were told by their respective mathematics teachers that there would be a mathematics class, which will be helpful for them, prepare for the coming year ESECE (matric) exam. A book consisting of solutions to selected problems was also given to students as a motivation.

As has been mentioned the intervention in this study was an exposure of students to using graphic calculators while learning the concepts of quadratic function. Each student in the graphic calculator group was provided with Casio *fx7000-GB* graphic calculators.

Each student in the graphic calculator group received an orientation on how to use the functions of the graphic calculator. Often I let students to discover the dynamics of the graphic calculator by themselves. I observed that students were using their own examples to see the capability of the calculator in drawing the graphs of functions.

At the beginning of the experiment students in the graphic calculator group were using the graphic calculators during class time only. However, later on many students were observed using the graphic calculator for a long time after the ending of the class time. As a consequence many students strongly insisted me to give the calculator for home use. There were even some who asked me to get them to buy a new one. Unfortunately there was no such calculator on sale. By making them sign on their school records I gave them it to keep till the end of the experiment.

As far as my awareness is concerned students from the paper and pencil group did not know that other group of students were involved in the same study with an exposure to graphic calculators. The paper and pencil group learned the concepts of quadratic function through the traditional method. That is they were not provided with any computing and graphing technology.

Before starting teaching the two groups the concept of quadratic function, Mr. Bereket and I decided to first outline the learning material on functions based on students' prior knowledge of functions. Thus, we discussed about the development of the lessons, lesson plan and the overall content. In the first lesson we decided to ask students about their overall understanding of functions. Then we met frequently to exchange ideas on the presentation of the topics.

Both the graphic calculator group and the paper and pencil group experienced a three-week time with the quadratic functions concept during their afternoon shift. During the three-week project, Mr. Bereket and I conferred frequently so that the activities and contents should be closely the same, at least in the form of examples and exercises. To preserve his natural style of teaching, I did not provide Mr. Bereket with specific guidelines for teaching the concepts of quadratic function to the paper and pencil group.

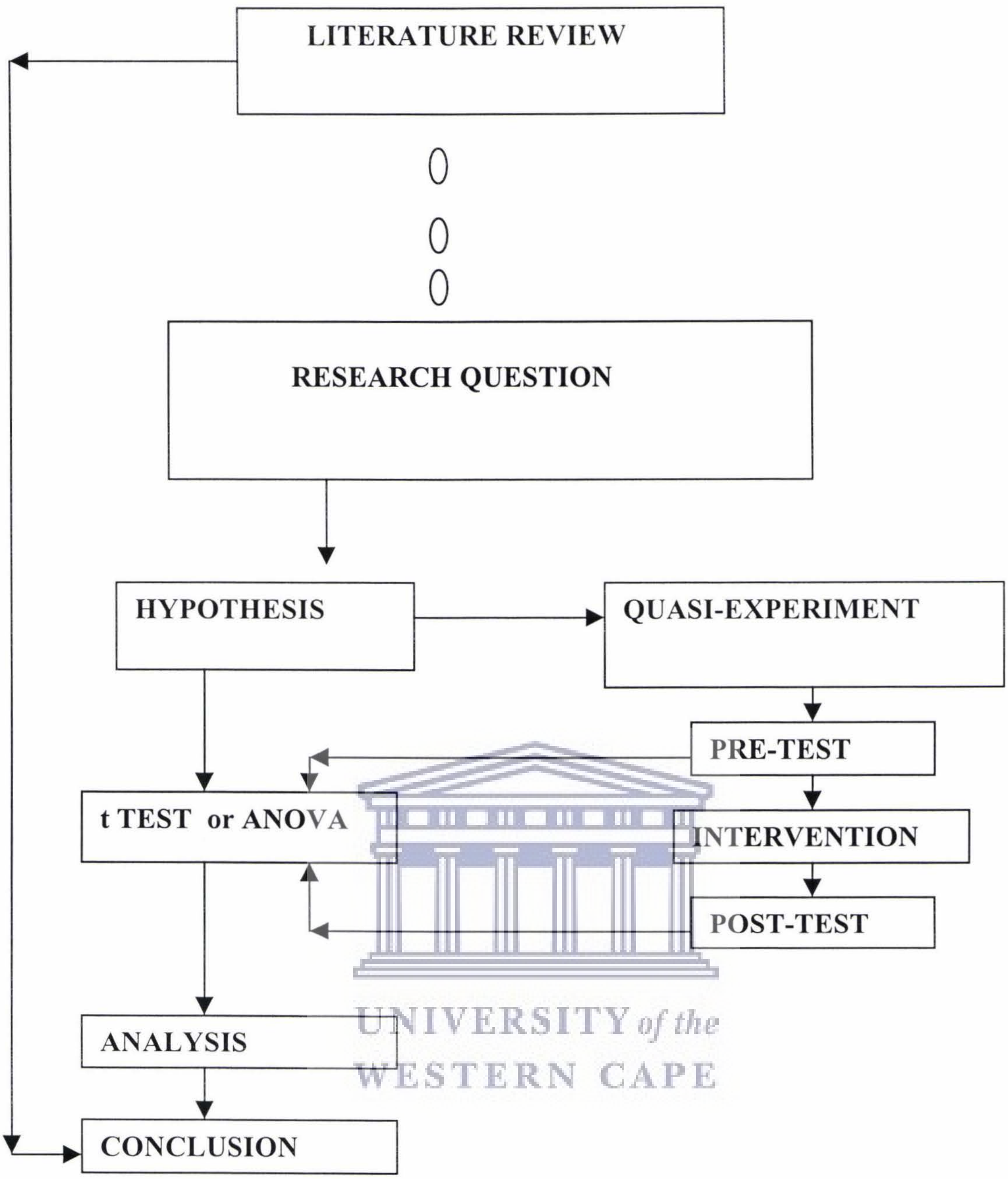


Figure 3.1 Flow chart of the research process

3.9 Research Familiarisation Session

One week before the start of the experiment I considered the idea of doing a study on students' use of graphic calculators, how students familiarise themselves with the functions of the graphic calculator, the way of dealing the concept of functions and the process of sampling.

I selected two groups of students (one from morning shift and the other from the afternoon shift) from Adi-Ugri Secondary School whom I taught the concept of functions. This school is located at the town of Mendefera, Zoba Debub (Southern Region). At the beginning I guided students on how to use the functions of the graphic calculator. The lessons continued for three days. I kept a record of students' involvement in the study, the environment created and the ways students use the graphic calculator.

During this exercise, I learned a lot on how to present the functions concept, the way of involving students with the calculators, way of dealing with the two groups, and the process of sampling, all of which gave me a solid experience which played a valuable role in the main study which followed. As is mentioned, the two groups of students involved in this session were from Zoba Debub which is different from the study area.

3.10 Method of Data Presentation and Analysis

3.10.1 Data Presentation

Before conducting the experiment the pre-test was administered to the students in the two groups. Mr. Bereket and I corrected it. First I corrected the papers of the first group and I gave it to Mr. Bereket. The papers of the second group were also first corrected by Mr.Bereket and then by me. For different way of corrections it was decided to involve an external examiner. Fortunately there was no significant disagreement on the corrections made by both of us.

After conducting the experiment the post-test was also administered. There was the same procedure to correct the post-test.

Thus the data are presented in the form of raw scores of students' achievement on the concepts of quadratic function at the pre-test and post-test stages.

3.10.2 Method of Data Analysis

To analyse the collected data based on students' achievement scores I used the Student's t test for independent groups to determine whether there is significant difference between the overall mean score of the graphic calculator group and the paper and pencil group. The difference between the mean score in gender between the two groups was also tested.

In the foregoing the research approach and methodology of the present study have been discussed. The next chapter examines the data presentation and analysis of the data.

Chapter Four

Data Presentation, Analysis and Discussion

4.1 Introduction

This chapter provides the data presentation, analysis and discussion of the present study. As has been mentioned in chapter three the study adopted a quasi-experimental design as a research approach. A pre-experimental test and a post-experimental test were administered to two groups of students before and after the experiment respectively. The achievement scores of the two tests were the measurement for this study. Thus, the collected data using the two tests served as a basis from which I could explore my research question. A Student's t test was used to investigate whether there was significant difference between the overall mean scores of the two groups of students.

4.2 Overview of the Study

The present study sought to investigate the effect of using graphic calculators in the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function. Mathematical content on quadratic functions was developed to involve students in the study. A pre-test and a post-test versions consisting of nine questions were conducted to two groups: graphic calculator group and paper and pencil group. The graphic calculator group was taught the concepts of quadratic function with the use of graphic calculators. The paper and pencil group of students were taught the same content in paper and pencil format.

Participants of the study were 41 grade 10 Eritrean secondary school students randomly selected from two urban secondary schools. There were 20 students in the graphic calculator group and 21 in the paper and pencil group. The main hypothesis tested was that there is no significant difference in the overall mean scores of students in the graphic calculator group and paper and pencil group. The significance in the achievement of the two groups was tested statistically.

Initially at the start of the experiment I asked students from the graphic calculator group if they have used a graphic calculator before. They responded that they had never used such a calculator. They went on to say that it was their first time to see a calculator with graphing capabilities. Thus the use of graphic calculator was a new experience to this group of students. I also assumed that the paper and pencil group of students had the same response since the two secondary schools are in the same city and have the same status in relation to the background of the students. As far as my awareness is concerned there were no graphic calculators available for sale in the stores.

Many students in the graphic calculator group seemed to enjoy working with the graphic calculators. They were giving their full attention to graphs they constructed with the calculator and paper and pencil. I observed that initially students were busy checking the graphs obtained by the graphic calculator and the graphs obtained in paper and pencil format. They were active in discussions about the graphs produced using the graphic calculator, which was mostly in group of three. However, very soon they seemed to be gaining confidence in producing graphs with the calculators. When asked to draw the graph of a function many students were observed to copy the graph obtained in the graphic calculators directly to their exercise book.

Throughout the classroom discussions the use of home language was also encouraged. This was because often the English language becomes a barrier to express their view clearly.

The teaching approach was more of facilitating students' learning by using the graphic calculators. This was because I have observed students concentrating on the calculators and discussions with their peers rather than the usual teacher centred concentration.

In the paper and pencil group the same content and method of teaching was followed. To follow more or less the same method of teaching the teacher of the paper and pencil group of students and I conferred frequently to follow the same style in teaching and informed each other what was happening in the two groups concerning the teaching method and activities given. The following sections provide the data presentation of the present study.

4.3 Data Presentation

4.3.1 Pre-test

The following table presents the achievement scores of students in the graphic calculator group and paper and pencil group for pre-test.

Student number	Graphic calculator group	Paper and pencil group
1	3	1
2	2.5	5
3	0	5
4	3	6.5
5	2	3
6	3	4
7	4.5	5.5
8	1	2
9	4	5
10	4.5	2
11	5	2
12	1	3.5
13	3	1
14	2	1
15	4	4
16	4	1
17	2	0
18	7	6.5
19	4	4
20	3	1
21		1

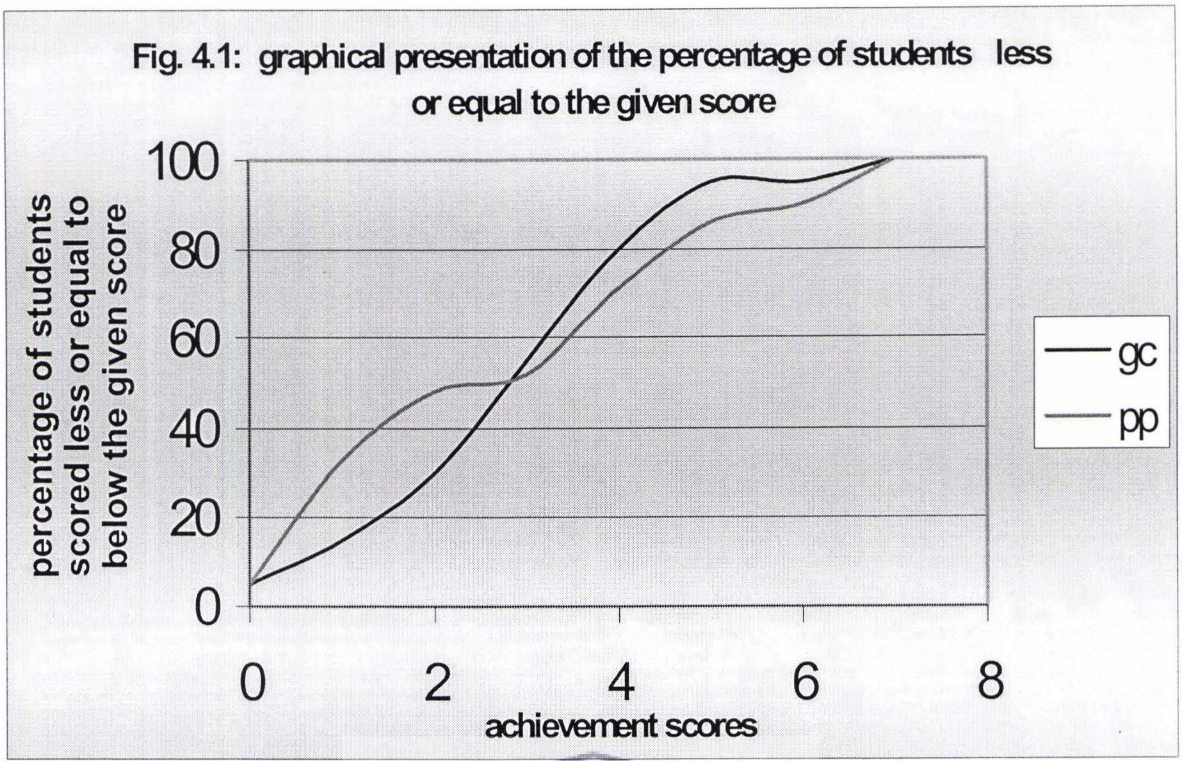
Table 4.1 Pre-test achievement scores of graphic calculator and paper and pencil group of students

As can be seen from table 4.1 for the graphic calculator group the achievement scores ranged from 0 to7 in which the mean was 3.13 and the standard deviation was 1.60. For the paper and pencil group the scores ranged from 0 to 6.5. Their mean achievement score was 3.05 and their standard deviation was 2.02. The mean and standard deviation of the two groups in relation to gender appears in the table below:

	Population	Mean	Standard deviation
Graphic calculator	Total	3.125	1.60
	Female	3.06	1.38
	Male	3.18	1.82
Paper and pencil	Total	3.05	2.02
	Female	3	2.24
	Male	3.1	1.87

Table 4.2 Mean and standard deviation of the pre-test of the graphic calculator group and paper and pencil group

It can be seen from the table that the overall mean achievement scores of the pre-test for the paper and pencil and graphic calculator groups seems close while the mean score of females in the paper and pencil group is low as compared to the females in the graphic calculator group. The overall data on the achievement score of the two groups can be put graphically as follows. The graph provides the percentage of students who scored less than or equal a given score.



In the above figure the achievement scores of the two groups indicate that the percentage of students who scored less than the mean (3.125) in the graphic calculator group is 55% and in the paper and pencil group 52% of the students scored less than their mean. The two graphs seem to go closely in the same pattern as the percentage of students who scored less than a given score increases. However the comparability of the two groups is tested statistically in the later section of this chapter.

4.3.2 Post-test

As indicated earlier, for the purposes of the study a post-test study was administered for the basis of comparing the performances of the two groups in the achievement test. Table 4.3 reports the achievement scores of the two groups at the post experimental stage on the given quadratic functions achievement test.

Student number	Graphic calculator	Paper and pencil
1	13	3.5
2	12.5	15
3	7.5	13
4	15	13.5
5	6.5	7
6	13.5	13.5
7	15.5	8.5
8	11	6.5
9	14	8.5
10	5.5	11
11	3.5	7
12	5	6.5
13	14.5	5.5
14	15	5.5
15	9	10
16	16	6.5
17	15	6.5
18	15.5	18
19	14.5	8
20	16	5.5
21		13

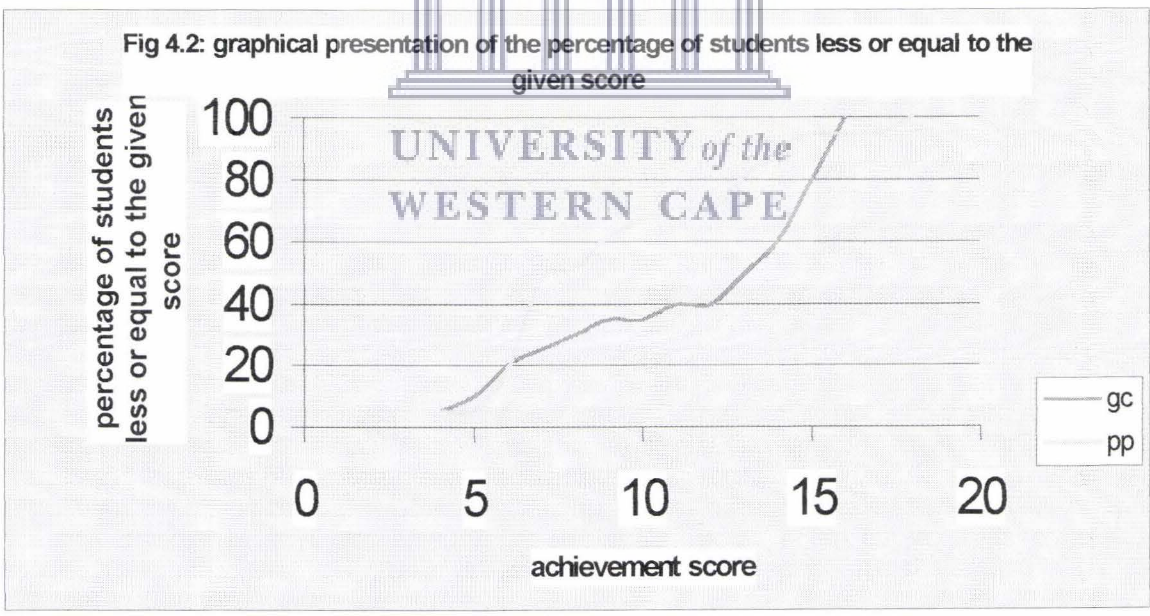
Table 4.3 Achievement scores of the graphic calculator group and paper and pencil group.

In the post experimental test the achievement score for the graphic calculator group ranged from 3.5 to 16 in which the mean was 11.9 and the standard deviation was 4.15. For the paper and pencil group the achievement score ranged from 3.5 to 18. Their overall mean was 9.14 and standard deviation 3.84. At the post-test stage females had better mean scores than males in both groups. The following table presents the overall mean and standard deviation of the post-test scores of the two groups with respect to gender:

Group	Population	Mean	Standard deviation
Graphic calculator	Total	11.9	4.15
	Female	12.19	4.1
	Male	11.71	4.34
Paper and pencil	Total	9.14	3.84
	Female	9.41	3.92
	Male	8.85	3.95

Table 4.4 Mean and standard deviation of post-test scores of the graphic calculator group and paper and pencil group

At this post experimental stage the overall mean of the two groups seemed to differ. The mean of the graphic calculator group was 11.9 as compared to that of 9.14 of the paper and pencil group. The significance in their difference will be tested statistically. Since the post-test was conducted after dealing with the concepts of quadratic function it was expected that students of both groups score more on this test. To present more on the difference on the achievement scores of the two groups a graphical representation of the percentage of students in each group who scored below their score appears below:



As can be seen from the graph 90% of the students in the paper and pencil group scored less than or equal to 14 while in the graphic calculator group 60% of the students scored less than or equal to 14. The percentage of students in the graphic calculator groups who scored less than or equal to their mean was approximately 62% and in the graphic calculator group the percentage of students who scored less or equal to their mean was 40%.

4.4 Analysis and Discussion

The main objective of this study was to test the null hypothesis that the mathematical achievement between students using the graphic calculator and those using only paper and pencil is not significantly different. Thus, a t test was employed to test whether the overall mean scores between the graphic calculator group and paper and pencil group were not statistically different. The level of significance which was accepted as sufficient to reject the null hypothesis was 0.05, which is commonly used in two-tailed tests. The formula for calculating the t value for independent samples is:

$$t = \frac{X_{GC} - X_{PP}}{\sqrt{\frac{[(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2]}{N_1 + N_2 - 2}[\frac{1}{N_1} + \frac{1}{N_2}]}}$$

Where: X_{GC} stands for mean of the graphic calculator group of students and X_{PP} for the mean of paper and pencil group of students; N_1 and N_2 stand for sample size of the two groups and S_1^2 and S_2^2 for their variances respectively.

4.4.1 Pre-test

The calculated t value of the pre-test (t=0.131) is less than the tabulated value of t (t=2.02) with 39 degrees of freedom at 0.05 level of significance. Thus, there was no significant difference between the overall mean scores of the graphic calculator group and the paper and pencil group of students as measured by the given pre-test on the the concepts of quadratic function. Hence, we conclude that the two groups of students were comparable at the pre-test stage. Table 4.5 summarises the result of the t- test using the formula presented.

Group	Mean	Standard deviation	Calculated t	Tabulated t at 0.05 and 39 degrees of freedom
Graphic calculator	3.05	1.60	0.131	2.02
Paper and pencil	3.125	2.02		

Table 4.5 Calculated and tabulated values of t, standard deviation, and mean for the pre-test.

4.4.2 Post-test

At the post-test stage the calculated value of the t (t=2.21) is greater than the tabulated value of t (t=2.02, with 39 degrees of freedom) at 0.05 level of significance. Thus, there was a significant difference between the overall mean score of the graphic calculator group and the paper and pencil group of students for the given concepts of quadratic function as measured by the post-test when the two groups were compared. Since the two groups were statistically comparable at the start of the experiment, the difference between the two groups is attributed by the treatment using the graphic calculators in the graphic calculator group. It is assumed that the effects of other variables and environmental effects are additive in nature. Table 4.6 summarises the mean, standard deviation and the t values of the post-test.

Group	Mean	Standard deviation	Calculated t	Tabulated t at 0.05 and 39 degrees of freedom
Graphic calculator	11.9	4.15	2.21	2.02
Paper and pencil	9.14	3.84		

Table 4.6 Calculated and tabulated values of t, standard deviation, and mean for the post-test.

A significant difference in achievement was found from the pre-test to the post-test in all groups. However, this result was anticipated since both the graphic calculator group and paper and pencil group of students didn't have much knowledge in the concepts of function and were not expected to score well on the pre-test.

The graphic calculator group and the paper and pencil group were significantly different in their mathematical achievement related to the concepts of quadratic function. The difference among gender of the two groups was also checked as the next step. Therefore, t tests were conducted in relation to gender. Another set of hypotheses was presented in a null form to allow comparisons between students of the two groups with regard to gender. Table 4.7 summarises the hypotheses to be tested in relation to gender.

Hypotheses	*Groups Compared*
Hypothesis 1	Comparison between females in graphic calculator group and paper and pencil group
Hypothesis 2	Comparison between males in graphic calculator group and paper and pencil group
Hypothesis 3	Comparison between females and males in graphic calculator group

Table 4.7 Gender-related hypotheses

A Student's t test, at 0.05 level of significance, was employed to test the difference in the in the achievement of the mean scores groups compared. The following analysis was made specifically to the three gender-related hypotheses given above at the pre-test and post-test stages.

1. There was no significant difference in mean scores of the achievement between females of the graphic calculator group and paper and pencil group as measured by the quadratic functions test at the pre-test and post-test stages.
2. There was no significant difference in mean scores of the achievement between males of the graphic calculator group and paper and pencil group of students as measured by the quadratic functions test at the pre-test and post-test stages.

3. There was no significant difference in achievement among females and males of the graphic calculator group as measured by the quadratic functions test at the pre-test and post-test stages.

The results of the test statistic and the tabulated value of are presented in the following table.

	Hypothesis 1		Hypothesis 2		Hypothesis 3	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
t calculated	0.031	1.136	0.099	1.8798	0.033	0.435
t tabulated	1.734	1.734	1.729	1.729	1.734	1.734

Table 4.8 Calculated and tabulated values of t for the gender related hypotheses

4.5 Limitations

In this study no attempt is made to analyse the effects of graphic calculators on students mathematical achievement with regard to their economic, social, cultural and historical backgrounds.

The duration of the study was short and scope of the study was limited to the concepts of quadratic function. Perhaps if the study has been extended over much longer period and greater coverage on the content much more accurate pictures of information would have been obtained.

The small sample size (20 in graphic calculator group and 21 in paper and pencil group of students) in this study is a limitation. Obtaining a statistical significance with a small sample size is difficult. Due to small sample size (classroom size) and modest test of reliability the statistical power of this comparison was not great.

There are also other limitations such as lack of randomisation, non-equivalent classes, lack of supervision, lack of teaching approach uniformity.

There were some problems associated to the study that have been encountered during the course of the experiment. There was also a shortage of classroom which were booked by other subject teachers for the paper and pencil group of students. Consequently, some times the teacher of the paper and pencil group of students was forced to give more than one lesson on Saturdays. This was because his timetable of his regular schoolwork sometimes clashed with the free time of the tutorial room, where the teaching was conducted.

Some problems were also highlighted during this study:

- Some students, especially in the paper and pencil group were absent.

- Some of the students in the graphic calculator group sometimes forgot to bring the calculator.

4.6 Additional Observations

Although it was not of interest of the present study, the influence of graphic calculators in the mathematics classroom on motivation and attitude of students must not be overlooked. I made some observations, which I thought to be important about the attitudes and motivation of the graphic calculator group of students during the course of the experiment. They are not part of the formal study, but reflect my impressions that were obtained by observing students' behaviour.

The participants of the graphic calculator group were not volunteers, nor they were selected because of their interest in using graphic calculators. They represented a population of students usually registered for the 2001/2002 academic year in an urban secondary school in Eritrea. Consequently, I informally interviewed 5 students from the graphic calculator group at the end of the experiment.

Many students in the graphic calculator group seemed to enjoy learning with the graphic calculator and were often engaged in discussions among themselves. Observations of the class time and video recording (one hour) revealed that the way students use the graphic calculator was interactive in nature. At the start of each lesson students spend some time individually with the graphic calculator when they are presented with classroom activities. However, later on, they would gradually start to discuss with their peers, during which the classroom became a place for discussions and explorations.

Most of the time the discussions were carried out in groups of three. There were frequent occasions that two students help each other in exploring the concepts from the problems given. The seating position of the students was in groups where three students shared one desk. What impressed me was the students themselves took the initiative for discussions of mathematical problems and the use of the functions of the calculator. By interfering in the discussions I came to learn that the graphic calculator was a key tool in facilitating discussions for the exploration of mathematical concepts. I have observed that a great proportion of the students seemed engaged in active work with the calculator. What was frequently happening was that students went back and forth to the calculator and group discussions. They were eager and ready to share new concepts or skills on the calculator to their groups.

When the students were asked about their overall experience of learning mathematics using graphic calculators they responded that, when using graphic calculator they were more motivated to learn. They mentioned that their attitude and motivation towards the learning of mathematics was great. One of the respondents, Rufael, said, "The use of the calculator impressed me ... the way I do mathematics with the calculator made me to learn with full motivation. For instance when I used the calculator I sometimes do my *own equations* [examples] on the calculator. Then unknowingly [gradually] I came to engage in mathematics." Another student, Liya, stated: "Graphs were very hard [problematic] to me. For me it was difficult and boring. But using the graphic calculators we (students in the classroom) were engaged in searching answers to the problems given by the teacher with full concentration. If we do not succeed in producing correct graphs we often retry it immediately." She went on to say, " Previously (using paper and pencil) if we graph it on the wrong way we were forced to graph it on separate sheet of paper, which is tiresome. But now we can automatically retry it on the calculator. This way we were encouraged to learn motivately. Consequently my desire [attitude] to learn mathematics was great." Regarding her experience of using the graphic calculator Lidya stated: " In this [using the graphic calculators] it is hard to make yourself out of the classroom discussion. This is because everybody was busy doing something with the calculators. Everybody was engaged in discussions and his own activities." She went on to say that, " This makes us follow the instruction attentively." Another student, Biruck, also stated: "Previously we were learning just to complete a set of tasks [mathematical contents or problems], but here the learning went on according to our understanding"

The students, whom I had asked, noted that they were engaged in active mathematics with the calculator individually and in groups. From my observation and the video recording, none of the students seemed idle in the classroom. Whenever the students finished their activities given by the teacher they were observed repeating their work even if it was confirmed by the teacher as correct and some of them tried more examples of their own.

An interesting issue from my observations and students' responses was that most of the students enjoyed working in groups. All of the students, whom I had informally asked, noted that they loved working in groups. All of them felt impressed and liked to learn that way. My diary and video recording revealed that after spending some time individually with the calculator, most of the students were observed to interact with each other. Sometimes those students who were fast in producing answers and had relatively good competence with the calculator often asked their peers if they too also produced similar answers. They often asked students around their seats and were ready to offer help or comment while their peers were working on the calculator.

Those students who got stuck preferred to ask their peers rather than the teacher. I noticed that the students were often asking the teacher when moving near their seats. They were often observed to asking questions that were beyond their groups' ability. By the end of the experiment I came to identify some students who often facilitate group discussions and were competent in using the graphic calculators.

Comments from the students indicated that the graphic calculators promoted the habit of working in groups. Lidya stated, " Our attitude to learn mathematics was positive specially when we work co-operatively. Our motivation and desire to learn was uplifted. For instance, when we argue or give each other's comment about the problems we became more attracted to learn. And Rufael said the following: "When discussing in groups we often comment to each other. We say, *'this is the better way', 'yeah, that sounds good', ' I have got his, and yours?' and 'what about this one?'* Thus we enjoyed [working in groups] and learned a lot from this. For instance when we talk about graphs we discuss whether it looks upward or downward, its co-ordinates on the x-axis and y-axis on the graphic calculator." Another student, Liya, also noted that the graphic calculators promoted to work co-operatively after confronting the problems individually. She said that, "When we work using the calculators we work attentively. We ask each other *'have you got the answer?' 'No. Look, it is like this.' 'Let me show you mine"* All of the students whom I asked had similar comment.

An interesting thing that follows from the experiment was that the students developed new friendships. Frehiwot said, " we developed strong friendships and get acquainted each other more than before". The friendships and the sense of working in groups became well-organised clusters of groups that were efficient in peer learning/teaching.

The students also commented on how mathematics should be taught. They hold the view that mathematics should be taught by discussions and explorations. The graphic calculator had centrality in many aspects of the students' involvement in discussions and explorations.

When the students were asked how the teaching approach was they stressed relationship they had with the teacher. They noted that their relationship with the teacher was different from what they had experienced before. They mentioned that the way they learn with the graphic calculators was centred in explorations and discussions, and getting individual assistance from the teacher when confronting with problems. Biruck stated, "we rarely [previous experience] ask our teacher, but now when we used the graphic calculators we don't feel shy to ask what we feel." Another student, Rufael, said, "Previously we don't interact much with our teacher. We had a gap with the teacher. But here [during the experiment] the situation was friendly [co-operative]. We individually could ask help and get assistance. The teacher was, most of the time, available for individual assistance." Rufael further noted, " We normally don't ask our teacher any questions that we feel. But now since we worked on our own with the calculator we were encouraged to struggle with questions in our mind. In this process we feel at ease to ask the teacher." Lidya and Frehiwot also had similar comment that when they got stuck while working with the problems they could ask the teacher individually.

One of the respondents mentioned that the graphic calculator was helpful outside of the experimental class use. She used the calculator for other mathematical concepts taught in her regular class time. However she mentioned her concern on calculator use during examinations. She noted that any kind of computing tools are not allowed in examinations.

4.7 Summary of the Findings

The mean scores on achievement of the pre-test and post-test of the graphic calculator group and paper and pencil group were analysed statistically. The difference in mean scores on the achievement tests of the graphic calculator group and paper and pencil group on the pre-test and post-test were tested for significance by a two tailed t-test. The findings are summarised below.

1. On the pre-test, no statistically significant difference, at 0.05 level of significance, was found between the graphic calculator group and paper and pencil group. These findings indicate that the two groups were comparable at the start of the experiment. Thus any difference between the two groups at the post experimental stage is thought to be attributed to the exposure of students to the graphic calculators.

2. At the post-test stage, there was a significant difference between the overall mean achievement of the graphic calculator and the paper and pencil group of students. Thus the findings revealed that after the experiment the graphic calculator group of students obtained higher mean scores than the paper and pencil group of students.

3. Furthermore, there was no significant effect for gender. There was no significant difference between males and females between and within the two groups.

In sum the findings of this study suggest that the use of graphic calculators had positive impact on the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function. Based up on the data and its analysis discussed in this chapter the research question *'Is there any significant effect of using graphic calculators on the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function?'* was answered. The results show that students in the graphic calculator group scored significantly better than the students in the paper and pencil group as measured by the tests given in the concepts of quadratic function. However it should be noted that the students in the two groups scored low marks in the achievement tests.

Chapter Five

Conclusions and Recommendations

5.1 Overview

One of the main goals of research mathematics education is to improve the teaching and learning of mathematics. There have been enormous efforts and initiatives worldwide that aim at finding better ways of teaching and learning mathematics. The field has become a scientific discipline that has now numerous research areas on issues related to the teaching and learning of mathematics. At this stage where, for instance, our society is growing rapidly and undergoing complex transformations, the community of mathematics education is actively engaging in studies on various dimensions of mathematics learning.

One of the issues is the arrival of computers and calculators in schools. The central concern of this study was to investigate the effect of the graphic calculators on the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function.

In pursuance of this concern the study tested the significant differences on the mean scores of two groups of students, one taught using the graphic calculator and the other through paper and pencil, in quadratic functions test.

5.2. Conclusion

There have been extensive studies on the impact of technological tools on students' mathematical learning (see for example Dunham and Dick, 1994; Ruthven, 1992; Rich, 1993). Most of the studies revealed that technological tools, such as computers and advanced calculators, have positive effect on students' mathematical understanding of certain concepts.

Advancements in computer technologies have made it possible to carry out sophisticated mathematical manipulations in a user-friendly manner in a much more accurate and relatively small amount of time. It is often noted that these technological tools provide for more powerful mathematical problem solving and graphing opportunities and offer new possibilities in the learning and teaching of mathematics (see Fey, 1989; Julie 1993a; Heid, 1997)

Reviewing literatures that are related to the present study, i.e. the use of graphic calculators, most findings reveal that the graphic calculator does not affect students' mathematical achievement negatively.

Quesada and Maxwell (1994) note that the use of graphic calculators enhanced college students' performance in pre-calculus. They report that a group of students who used the graphic calculator had significantly higher scores than those students who did not use graphic calculators Other studies by Alexander (1993) Chandler (1993) and Durmus (2000) have also documented that students who used the graphic calculator had significant gains on the overall achievement as compared to those who did not use them.

In another study Rich (1993:38), however, found no evidence for the overall achievement effect of using graphic calculators in pre-calculus. Similarly Pankow (1994) and Hall (1993) also found that there was no significant difference between the mean scores of the students who used the graphic calculator and those who did not. However, these studies note that there were some positive effects on other dimensions of mathematical learning. For instance Rich (1993:38) notes that there was a positive effect in terms of graphic concepts, use of multiple representations for solving algebra problems, understanding of graphs more globally, and exploration and conjecturing.

Giamati (1991) studied the effect of graphic Calculator use on students' understanding of variations on a family of equations and the transformations of their graphs. Giamati's findings show that students using the traditional; paper and pencil method were superior at sketching functions, understanding translations and stretches and shrinks, and describing parameter variations. Giamati notes that students with poorly and partially formed conceptual links between graphs and equations were cognitively distracted by also having to learn how to use the graphing utility. However, Giamati points out that the unfamiliarity with certain characteristics of the calculator might have affected its effectiveness as an instructional tool and, initially, students' achievement.

The present study investigated the effect of using graphic calculators in the mathematical achievement of Eritrean grade 10 students related to the concepts of quadratic function as measured by the pre-test and post-test in the quadratic functions test. The finding of this study reports similar findings to those Quesada and Maxwell (1994), Alexander (1994), and Chandler (1993). These studies that found the graphic calculator had positive effect on student mathematical achievement in learning certain concepts of mathematics. The findings of this study show that students who used the graphic calculator significantly gained better scores than those who did not use it in learning the functions concept. Thus, it is concluded that the use of graphic calculators has positive effect on the mathematical achievement of urban Eritrean secondary school students related to quadratic functions.

When comparing groups of students related to gender, the present study show that there was no significant difference among females and males of the two groups. Moreover there was no significant difference among the same gender in both groups. Hence it is concluded that there was no evidence for the effect of using graphic calculators in the mathematical achievement of Eritrean grade 10 students with respect to gender.

As has been mentioned in the previous chapter, though it was not the main aim of the study, the involvement of students in the mathematics instruction when using the graphic calculators must not be overlooked. The class time observations revealed that students exhibited a wide range of roles.

With regard to examining students' use of the graphic calculator certain mathematical concepts many studies reveal that the graphic calculator was a useful tool in concept understanding in terms of various dimensions of students' mathematical learning.

Dugdale (1993:102) reported that students increased their proficiency in relating functions to their graphical representations, increased their relevance on mathematical reasoning and decreased dependence on memorized rules. Browning (1991:131) points out that graphic calculators allow students for experimentation and examination of concepts that are not possible in traditional curricula and the interaction between students and the graphic calculator provide an environment to make the mathematical connections between the function and its graph.

In another study Ruthven (1992:100) points out that during the use of graphic calculators in mathematics instruction "responsibility is devolved to students that they play a more active part in developing and evaluating mathematical ideas. He asserts that students not only grasp ideas but also develop "their capacity to tackle novel situations`" (P.100).

This study confirms the above review that students change their roles when using graphic calculators. Dunham (1993: 89) points out that during the use of graphic calculators students' roles in mathematics instruction can undergo a shift from passive listeners to becoming less didactive, less passive and do make group work, problem solving, investigating, symbolizing and consulting with technology. Comments from the students indicated that the graphic calculator promoted this habit of working in groups. I observed that students were engaging in interactions among themselves and the calculator. Most of the time, I observed that after spending some time individually with the calculator, most of the students were observed to interact with each other. Those students who were fast in producing answers and had relatively good competence on the calculator were observed to ask their peers if they also obtain similar answers. They often asked students around their seats and were ready to offer help or comment while their peers were still working with the calculator. This confirms an assertion made by Nicaise and Barnes (1996) that technological tools allow students " to observe and interact with individuals many of whom have divergent views and opinions." According to Nicaise and Barnes students' interaction " provide students with opportunities to react to differing views, challenge other beliefs, and reflect their own ideas." (p.208).

The relationship between the teacher and the student was changed. The students, whom I interviewed, noted that their relationship with the teacher was different from what they have experienced before. They responded that they feel at ease to interact or ask questions during the course of the experiment. They indicated they were getting individual assistance from the teacher and were involved freely in classroom discussions and explorations with their peers. This may be due to the change of the roles of the student and teacher when using technological tools (see Norman, 1992:260; Shuard, 1992:33; Dunham, 1993:90; Ruthven, 1992:100; Heid, 1997)). Heid (1997) reported that when using technological tools "there was less teacher control of the classroom activities and that teachers were less likely to function as authoritative experts and more likely serve as collaborators". Thus, the use of graphic calculators change the classroom environment to be more likely interactive in which students get freedom and opportunity to interact with complex mathematical objects and facilitates students' ability to self regulate (Nicaise and Barnes, 1996). Thus, it can be concluded that the use of graphic calculators can have promising potential to the learning and teaching of mathematics.

Finally, with regard to this study the conclusion may be drawn that the use of graphic calculators has positive effect on students' mathematical achievement related to the concepts of quadratic function. Moreover, the use of graphic calculator offered enormous potential in the learning and teaching of mathematics in terms of students' motivation, developing the habit of group work, facilitating student interactions and explorations of mathematical ideas, and changing their roles from passive listeners of the lecture.

However, the findings of this study might have been influenced due to the limitations that occurred during the course of the experiment. There was small sample size, lack of supervision, lack of teaching approach uniformity, and modest test of reliability. Further research should be conducted with greater sample sizes so that stronger statistical tests can be carried out.

5.3 Further Research and Recommendations

It is evident that the results presented in the previous chapter are by no means clear-cut. However they do provide some interesting pointers for further research on the use of graphic calculators in the learning and teaching of mathematics.

Several interesting issues related to this research project were uncovered during this study. The effect of using graphic calculators on the mathematical achievement by considering their social, cultural and economic back ground of students was not studied. More over the attitude of students towards mathematics when using the calculator was not investigated. Other factors such as the effect of the use of calculators on students' attitude towards mathematics, the ways students utilise (use) the calculator and the effect of the graphic calculator where it includes rural settings need to be studied.

In Eritrea, as far as my awareness is concerned, there is no study on the use and effects of graphic calculators on students' mathematics learning. Therefore studies that pertain the Eritrean context should be conducted.

Some of the topics suggested for possible further research are listed below:

- The influence of graphic calculators on the curriculum

- Teachers' use of the graphic calculator in mathematics teaching

- Calculator usage under examination conditions

- Impact of the calculator on the contents that are taught

Furthermore, there should be an awareness through seminars or workshops that the community of mathematics educators, teachers, students, parents, policy makers and the general public on how technologies, such as the graphic calculator, influence mathematics instruction and their usefulness on students' mathematical learning. There is an argument that graphic calculators are not affordable by the majority of students.

Rather, I would argue that it is not a sufficient condition for not incorporating the calculators in to school mathematics education. As Julie (1993b) pointed out we can not also prevent the use of the calculators by those students who can afford it. Moreover technology outgrows itself and is increasingly becoming more accessible from time to time. We have to speculate what will happen after these students graduate from high school. My belief concerning the availability of computer technologies is that it is increasingly becoming more affordable to the wider society. Therefore the incorporation of computer technologies, such as graphic calculators, to the school mathematics education curriculum should be taken as an important aspect that influences students' mathematical learning. Further research need to be conducted in this area in order to explore new curricular and instructional approaches where the graphic calculator is more beneficial to the majority of our students.

Bibliography

Alexander, M. P. (1993). The Effective Use of Computers and Graphing in College Algebra. *Dissertation Abstracts International*, 54(6): 2080A.

Arney, D. C., Dewald, L. S. and Schumacher, R. (1991). Computer Technology and its Impact on Undergraduate Mathematics Education. In F. Demana, J. Harvey, L. C. Taylor and B. K. Waits (eds.). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing Company.

Babbie, E. and Mouton, J. (2001). *The Practice of Social Research*. Cape Town: Oxford University Press.

Beckmann, C. E., Senk, S. L. and Thompson, D. R. (1999). Assessing Students' Understanding of Functions in a Graphic Calculator Environment. *School Science and Mathematics*, 99(8): 451-456.

Boers, M. A. and Jones, P. L. (1994). Students' Use of Graphic Calculators Under Examination Conditions. *International Journal of Mathematical Education in Science and Technology*, 25(4): 491-516.

Branca, N. A., Breedlove, B. A. and King, B. (1992). Calculators in the Middle Grades: Access to Rich Mathematics. In J. T. Fey (ed.). *Calculators in Mathematics Education*. Reston: The National Council of Teachers of Mathematics.

Brant, S. and Zeideman, E. (1993). Guided Experiments for Pre-Calculus using the TI-81 Graphic Calculator. In L. Lum (ed.). *Proceedings of the Fourth International Conference on Technology in Collegiate Mathematics*. Massachussettes: Addison-Wesley Publishing Company.

Brian, A. K. and Hirsch, C. R. (1998). Student Preference for Representations of Functions. *International Journal of Mathematical Education in Science and Technology,* 29(1): 1-17.

Brown, T. (1996). The Phenomenology of the Mathematics Classroom. *Educational Studies in Mathematics*, 31: 115-150.

Browning, C. A. (1991). Levels of Graphical Understanding: Comparisons Between High School and College Pre-Calculus Students. In F. Demana, J. Harvey, L. C. Taylor and B. K. Waits (eds.). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing Company.

Burrill, G. (1992). The Graphing Calculator: A Tool for Change. In J. T. Fey (ed.). *Calculators in Mathematics Education*. Reston: The National Council of Teachers of Mathematics.

Chandler, P. A. (1993). The Effect of the Graphing Calculator on High School Students' Mathematical Achievement. *Dissertation Abstracts International*, 53 (11): 3832A.

Cobb, P., Yackel, E and Wood, T. (1992). A Constructivist Alternative to the Representational View of Mind in Mathematics Education. *Journal for Research in Mathematics Education*, 23(1): 2-33.

Cohen, L. and Manion, L. (1994). *Research Methods in Education*. London: Routledge.

Davis, A. (1995). The Experimental Method in Psychology. In G. M. Breakwell, S. Hammond and C. Fife-Schaw (eds.). *Research Methods in Psychology*. London: SAGE Publications Ltd.

Davis, R. B. and McKnight, C. (1979). Modelling the Process of Mathematical Thinking. *The Journal of Children's Mathematical Behaviour*, 2(2): 91-113.

De Lange, J. (1993). Innovation in Mathematics Education Using Applications: Progress and Problems. In J. de Lange, C. Keitel, I. Huntley and M. Niss (eds.). *Innovation in Maths Education by Modelling and Applications.* London: Ellis Horwood.

Demana, F., Harvey, J., Taylor, L. J. and Waits, B. K. (1991). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing.

Dick, T. (1992). Super Calculators: Implications for Calculus Curriculum, Instruction, and Assessment. In J. T. Fey (ed.). *Calculators in Mathematics Education.* Reston: The National Council of Teachers of Mathematics.

Doerr, H. and Zangor, R. (2000). Creating Meaning for and with the Graphing Calculator. *Educational Studies in Mathematics*, 41: 143-163.

Dugdale, S. (1993). Visualizing Polynomial Functions. In L. Lum (ed.). *Proceedings of the Fourth International Conference on Technology in Collegiate Mathematics.* Massachusetts: Addison-Wesley Publishing Company.

Dunham, P. H. (1991). An Investigation of Students' Understanding of Scale in Technology Oriented Classrooms. In F. Demana, J. Harvey, L. C. Taylor and B. K. Waits (eds.). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing Company.

Dunham, P. H. (1993). Teaching with Graphing Calculators: A Survey of Research on Graphing Technology. In L. Lum (ed.). *Proceedings of the Fourth International Conference on Technology in Collegiate Mathematics*. Massachusetts: Addison-Wesley Publishing Company.

Dunham, P.H. and Dick, T. P. (1994). Research on Graphing Calculators. *The Mathematics Teacher*, 87(6): 440-445.

Durmus, S. (2000). The Effects of the Use of Technology on College Algebra Students' Achievement and Attitudes Towards Mathematics: a Constructivist Approach. *Dissertation of Abstracts International*, 60(10): 3622A.

Epstein, I. (1988). Quantitative and Qualitative Methods. In Grinnell, R. M (ed.). *Social Work Research and Evaluation.* ITASCA, Illinois: F. E. Peacock Publishers Inc.

Ernest, P. (1989). What's the Use of LOGO? In P. Ernest (ed.). *Mathematics Teaching: The State of Art.* New York: The Falmer Press.

Ernest, P. (1993). Constructivism and the Problem of the Social. In C. Julie, D. Angelis and Z. Davis (eds.). *Political Dimensions of Mathematics Education 2: Curriculum Reconstruction for Society in Transition.* Cape town: Maskew Miller Longman.

Fetta. I. B. (1992). Graphing Calculator Enhanced Introductory Probability and Statistics. In J. G. Harvey, F. D. Demana and B. K. Waits (eds.). *Proceedings of the Third International Conference on Technology in Collegiate Mathematics.* Massachusetts: Addison-Wesley Publishing Company.

Fey, J. T. (1989). Technology and Mathematics Education: a Survey of Recent Developments and Important Problems. *Educational Studies in Mathematics,* 20: 237- 272.

Fife-Schaw, C. (1995). Quasi-Experimental Designs. In G. M. Breakwell, S. Hammond and C. Fife-Schaw (eds.). *Research Methods in Psychology*. London: SAGE Publications Ltd.

Fiske, M. B. (1991). Algebraic Manipulation of Equations: Symbolic and Graphic Representations on the HP-28S. In F. Demana, J. Harvey, L. C. Taylor and B. K. Waits (eds.). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing Company.

Forster, P.A and Taylor, P. C. (2000). A Multiple Perspective Analysis of Learning in the Presence of Technology. *Educational Studies in Mathematics*, 42: 35-59.

Giamati, C. M. (1991). The Effect of Graphing Calculator Use on Students' Understanding of Variations on a Family of Equations and the Transformations of their Graphs. *Dissertation Abstracts International*, 52(1): 103A.

Gilligan, L. G. (1991). *Pre-Calculus Experiments with the Casio Graphics Calculator.* Lexington: D. C. Heath.

Glasersfeld, E. V. (1995). *Radical Constructivism: A Way of Knowing and Learning.* London: Falmer.

Gordon, A. (1993). Constructivism and the Politics of Pedagogy: The 'Social' in Constructivist Mathematics Programmes. In C. Julie, D. Angelis and Z. Davis (eds.). *Political Dimensions of Mathematics Education 2: Curriculum Reconstruction for Society in Transition.* Cape town: Maskew Miller Longman.

Graham, T. M. and Thomas, O. J. (2000). Building a Versatile Understanding of Algebraic Variables with a Graphic calculator. *Educational Studies in Mathematics*, 41: 265-282.

Gray, E. M. and Tall, D. O. (1994). Duality, Ambiguity, and Flexibility: A "Perceptual" View of Simple Arithmetic. *Journal for Research in Mathematics Education*, 25(20): 116-140.

Grinnell, R. M. and Stothers, M. (1988). Utilising Research Designs. In R. M. Grinnell (ed.). *Social Work Research and Evaluation.* ITASCA, Illinois: F. E. Peacock Publishers Inc.

Hall, M. K. (1993). Impact on the Graphing Calculator on the Instruction of Trigonometric Functions in Pre-Calculus Classes. *Dissertations Abstracts International*, 54(2): 451A.

Harvey, J. G. and Osborne, A. (1991). Calculator and Computer Technologies in the Mathematics Classroom: a User's Guide. In F. Demana, J. Harvey, L. C. Taylor and B. K. Waits (eds.). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing Company.

Heid, M. K. (1997). The Technological Revolution and the Reform of School Mathematics. *American Journal of Education*, 106(1): 5-61. [Online]. Available http://www.ebsco.com/html.

Hennessy, S., Fung, P. and Scanion, E. (2001). The Role of Graphic Calculator in Mediating Graphing Activity. *International Journal of Mathematical Education in Science and Technology*, 32(2): 267-290.

Judson, P. T. (1993). Using a CAS to Increase Student Understanding in Calculus. In L. Lum (ed.). *Proceedings of the Fourth International Conference on Technology in Collegiate Mathematics*. Massachusetts: Addison-Wesley Publishing Company.

Julie, C. (1993a). The Functions Sub-Curriculum and Graphic Calculators: Where are We Heading with the School Mathematics Curriculum? *Pythagoras*, 32: 21-27.

Julie, C. (1993b). People's Mathematics, Graphic Calculators and the Development of Mathematical Culture. In A. Oliver (ed.). *Fourteenth National Convection on Mathematics and Natural Science Education.* Cape Town: Mathematical Association of Southern Africa.

Julie, C. (1993c). Graphic Calculators: Beyond Pedagogical and Socio-Political issues. In C. Julie, D. Angelis and Z. Davis (eds.), *Political Dimensions of Mathematics Education 2: Curriculum Reconstruction for Society in Transition.* Cape Town: Maskew Miller Longman.

Kieran, C. (1994). Doing and Seeing Things Differently: A 25-Year Retrospective of Mathematics Education. *Journal for Research in Mathematics Education*, 25(6): 583-607.

La Torre, D. (1993). The Impact of Super Calculators on the Teaching and Learning of Linear Algebra. In L. Lum (ed.). *Proceedings of the Fourth International Conference on Technology in Collegiate Mathematics*. Massachusetts: Addison-Wesley Publishing Company.

Laridon, P. (1993). Technology Appropriate to the Learning of Mathematics in South Africa. In C. Julie, D. Angelis & Z. Davis (eds.), *Political Dimensions of Mathematics Education 2: Curriculum Reconstruction for Society in Transition*. Cape Town: Maskew Miller Longman.

Leinhardt, G., Zaslavsky, O. and Stein, M. K. (1990). Functions, Graphs and Graphing: Tasks, Learning, and Teaching. *Review of Educational Research*, 60(1): 1-64.

Lum, L. (1993). *Proceedings of the Fourth International Conference on Technology in Collegiate Mathematics*. Massachusetts: Addison-Wesley Publishing Company.

Mellin-Olsen, S. (1987). *The Politics of Mathematics Education*. Dordrecht: D. Reidel Publishing Company.

Ministry of Education (1999). *Education Brief*. Asmara: Adulis Printing Press.

Ministry of Education (2001a). *Basic Education Statistics*. Asmara: Adulis Printing Press.

Ministry of Education (2001b). *Curriculum Framework for Secondary School Mathematics*. Asmara: Unpublished Document.

Neuman, W. L. (2000). *Social Research Methods: Qualitative and Quantitative Approaches*. Boston: Allyn and Bacon.

Nicaise, M. and Barnes, D. (1996). The Union of Technology, Constructivism, and Teacher Education. *Journal of Teacher Education*, 470(3): 205-212.

Norman, F. A. and Prichard, M. K. (1992). Technology in Pre-Service Teacher Education Programs for Elementary and Secondary Mathematics Teachers. In J. G. Harvey, F. D. Demana and B. K. Waits (eds.). *Proceedings of the Third International Conference on Technology in Collegiate Mathematics*. Massachusetts: Addison-Wesley Publishing Company.

Noss, R. (1991). The Computer as a Cultural Influence in Mathematics Teaching. In M. Harris (ed.), *School, Mathematics and Work*. UK: The Falmer Press.

Pankow, C. K. (1995). The Effects of College Student Use of Graphic Calculators on the Learning of Algebraic Concepts. *Dissertation Abstracts International*, 55(12): 27774A.

Pugalee, D. K. (2001). Algebra for All: The Role of Technology and Constructivism in an Algebra Course for At-Risk Students. *Preventing School Failure*, 45(4): 171-177.

Quesada, A. R. and Maxwel, M. E. (1994). The Effects of Using Graphing Calculators to Enhance College students' Performance in Pre-Calculus. *Educational Studies in Mathematics*, 27: 205-215.

Rich, B. S. (1993). The Effect of the Use of Graphing Calculators on Learning the Function Concepts in Pre-Calculus Mathematics. In L. Lum (ed.). *Proceedings of the Fourth International Conference on Technology in Collegiate Mathematics*. Massachusetts: Addison-Wesley Publishing Company.

Ruthven, K. (1992). Personal Technology and Classroom Change: A British Perspective. In J. T. Fey (ed.). *Calculators in Mathematics Education.* Reston: The National Council of Teachers of Mathematics.

Schlais, H. (1991). The Slope Function, Graphics and Functional Analysis in Pre-Calculus. In F. Demana, J. Harvey, L. C. Taylor and B. K. Waits (eds.). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing Company.

Schoen, H. L. (1991). A or B. Programming in Calculus: Some More Important Issues. In F. Demana, J. Harvey, L. C. Taylor and B. K. Waits (eds.). *Proceedings of the Conference on Technology in Collegiate Mathematics: Second Annual Conference.* Massachusetts: Addison-Wesley Publishing.

Schoenfeld, A. H. (1993). Learning to Think Mathematically: Problem Solving Metacognition, and Sense Making Mathematics. In D. A. Grouws (ed.). *Handbook of Research on Mathematics Teaching and Learning*. New York: MacMillan Publishing Company.

Seasberg, J. R. (1988). Utilising Sampling Procedures. In Grinnell, R. M (ed.). *Social Work Research and Evaluation*. Illinois: F. E. Peacock Publishers Inc.

Sfard, A. (2000). Steering (Dis)Course Between Metaphor and Rigor: Using Focal Analysis to Investigate and Emergence of Mathematical Objects. *Journal for Research in Mathematics Education*, 31(3): 296-327.

Shuard, H. (1992). CAN: Calculator Use in Primary Grades in England. In J. T. Fey (ed.). *Calculators in Mathematics Education.* Reston: The National Council of Teachers of Mathematics.

Smith, K. B. and Shotsberger, P. G. (1997). Assessing the Use of Graphing Calculators in College Algebra. *School Science and Mathematics*, 97(7): 368-376.

Swetz, F. (1991). Incorporating Mathematical Modelling into the Curriculum. *The Mathematics Teacher*, 84(5): 358-365.

Tall, D. and Bakar, M. (1992). Students' Mental Prototypes for Functions and Graphs. *International Journal of Mathematical Education in Science and Technology*, 23(1): 39-50.

UN Report (1994). *Development and Co-Operation: Eritrea*. Asmara: Unpublished Document.

Vinner, S. (1997). The Pseudo-Conceptual and Pseudo-Analytical Thought Processes in Mathematics Learning. *Educational Studies in Mathematics*, 34: 92-129.

Von Embese, C. (1992). Concept Development and Problem Solving Using graphing Calculators in the Middle School. In J. T. Fey (ed.). *Calculators in Mathematics Education.* Reston: The National Council of Teachers of Mathematics.

Von Embese, C. (1992). Visualisation in Pre-Calculus: Making Connections Using Parametric graphs. In J. G. Harvey, F. D. Demana and B. K. Waits (eds.). *Proceedings of the Third International Conference on Technology in Collegiate Mathematics*. Massachusetts: Addison-Wesley Publishing Company.

Von Embese, C. and Olmstead, E. (1993). *Exploring Introductory Algebra with the TI-81.* Massachusetts: Addison-Wesley Publishing Company Inc.

Wheatly, G. H and Shumway, R. (1992). The Potential of Calculators to Transform Elementary School Mathematics. In J. T. Fey (ed.). *Calculators in Mathematics Education*. Reston: The National Council of Teachers of Mathematics.

Wilder, R. L. (1981). *Mathematics as a Cultural System*. Oxford: Pergamon Press Ltd.

Appendix

Pre-test/Post-test

1. State the domain and range of the following functions.

a. $y = x^2 + 9x + 7$

b. $y = -x^2 + 3x + 2$

c. $y = -2x^2 - 4x + 5$

In question 2 from a-d graph the quadratic function. State where (x-intervals) the function is positive, negative, increasing and decreasing.

$y = -3x^2 - 4x + 3$

2.

a. Zeros: ______________

b. Turning points: ____________

c. For what values of x is the function increasing? ____________

d. For what values of x is the function decreasing? ____________

3 For the given quadratic function, f(x) = -2x2 – 3x + 2, determine

a. f (1)

b. The coordinates of the intercepts on the X- axis and Y- axis respectively.

c. Sketch the graph of f (x)

4 For the graph of $Y = x^2 - 4x + 4$

a. If the graph is moved vertically (upwards) by three units, write down the equation of the new graph in the form $Y = ax^2 + bx + c$

b. If the graph of $y = x^2 - 4x - 12$ is moved horizontally to the right by five units, determine the equation of the new graph in the form $Y = (x + b)(x + c)$

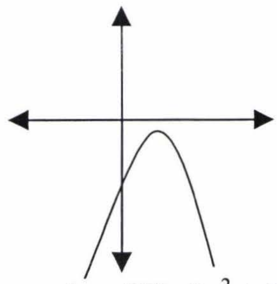
5 The sketch represents the graph of $Y = ax^2 + bx + c$. Which one the following is true.

a. $a > 0$, $b < 0$ and $c > 0$

b. $a > 0$, $b > 0$ and $c > 0$

c. $a < 0$, $b < 0$ and $c < 0$

d. $a < 0$, $b > 0$ and $c < 0$



6 Calculate the point (s) of intersection of the two graphs of $Y = 2x^2 + 2x - 4$ and $y = x^2 - 3x - 2$

7 According to one student, the x- coordinate of the vertex (the turning point) is half-way between the roots (zeros of the function). Explain why you agree, and use the following to check your answer.

a. $y = x^2 + 2x - 3$

b. $y = 5x^2 - x - 8$

c. $y = -x^2 + 5x - 5$

8 Derive the formula for the zeros (roots) of a general quadratic function $y = ax^2 + bx + c$. check your formula by finding the zeros (roots) of $y = 3x^2 + 2x - 8$.

9 Find the maximum or minimum value of the function $y = -x^2 + 5x + 6$.