An Investigation into Elementary School Teachers’ and High School Mathematics Teachers’ Attitudes Towards the Use of Calculators in Mathematics Instruction and Learning: A Study of Selected Schools in Ghana

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This dissertation titled
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ABSTRACT

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An Investigation into Elementary School Teachers’ and High Mathematics School Teachers’ Attitudes towards the Use of Calculators in Mathematics Instruction and Learning: A Study of Selected Schools in Ghana (136 pp.)

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Ghana’s educational reforms have not brought the much needed results in terms of the national objective of preparing its manpower potential to meet the growing demands of the national economy. Ghana’s adoption of the new educational system has led to a reduction by five years of pre-university education compared to the old system. Consequently, there is enormous pressure on high school mathematics teachers to cover school syllabi but this has not been too successful.

In 1993, 16% of the first group of 42,105 students who sat for the core mathematics in the Senior Secondary School Certificate Examinations got grades A through E. It appeared there was improvement in mathematics instruction and learning. However, the low standards of mathematics performance became clear on the international scene when Ghana ranked 44 out of 45 countries that participated in the Third International Mathematics and Science and Study (TIMSS).

Calculator use has not been encouraged despite the strong research evidence of the positive impact of calculators in instruction and learning. The successful adoption of instructional tools such as calculators depends to a certain extent on teacher attitudes.
Using the AIM-AT 4-point Likert scale, 179 elementary teachers and high school mathematics teachers were studied to determine their attitudes towards the use of calculators. Two supplementary open-ended questions on the benefits and setbacks of the use of calculators were included.

An overall mean of 2.460 indicated that Ghanaian teachers’ attitude was somewhat neutral or slightly positive towards calculator use. Most teachers (84%) believed that students should learn how to use a calculator; however 80% of the teachers wanted students to master concepts or procedures before being allowed to use the calculator. Ghanaian teachers declared that they do not teach with calculators currently yet they knew ways they could use calculators effectively in the classroom. High school mathematics teachers’ mean attitudes towards the use of calculators were more favorable than elementary teachers’ attitudes. There was no gender effect and no interaction effect.

The study concluded with the recommendation that public awareness of the importance of calculators should be enhanced.

Approved:_______________________________________________________________

George A. Johanson
Professor of Educational Studies
DEDICATION

This dissertation
is
dedicated in
ever loving memory to
my
enlightened illiterate parents,
Maame Afia Nsuoyaa
my mother
and
Opanin Kwabena Kusi
my father
who
showed me the light to literacy.
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Most importantly, I appreciate the enthusiastic support of Dr. Johanson, director of this study from the beginning to the successful completion. His countless stops at my office were the driving force that energized me to the final execution of this work.

As it has been written, if the Greeks had not cultivated conic sections Kepler could not have superseded Ptolemy. My candid appreciation also goes to Dr. Gregory D. Foley for his tremendous guidance, support and academic counseling. I express my appreciation for your tolerance and encouragement. Our meeting could not have occurred at a more opportune time. I recognize also the timely, miscellaneous academic inputs of Dr. Francis Godwyll and Dr. Kwadwo Asafo-Agyei Okrah in the course of my work. I thank you dearly for this invaluable voluntary gesture.

Dr. Francis Atuahene (a.k.a Xanthias)! You are my brother, a true nephew, and an accomplished academic colleague. Dr. Atuahene’s interest in my academic success and well-being epitomizes a very rare gem of humanity; I will tell this story wherever I go. In this same vein, I recognize the immense contributions of Dr. and Mrs. Atta-Fynn, Dr. and Mr. Adusah-Karikari, and Mr. Godwin Dogbey, my good friend and colleague. The extremely caring expressions of individual commitment and concern for our common
good in the course of our association remain relevant, and drown my gratitude however expressed.

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My ultimate special thanksgiving and adoration go to the Merciful and Gracious God. He gave me the strength, conscience, knowledge, perseverance… my total personality and my very existence to make things happen in fabulous and excellent ways. *While I have breath, I will continue to praise my Maker.*
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CHAPTER ONE: INTRODUCTION

Background of the Study

The current education system of Ghana was the outcome of structural reforms undertaken in the 1980s as part of the World Bank (International Monetary Fund [IMF]) Structural Adjustment Programs (SAP), in conjunction with the national objective of preparing its manpower potential to meet the growing demands of the global knowledge economy. Prior to the reforms, Ghana was operating an education system which was a legacy from the British colonial rule.

In the old education system, pre-university education took 17 years: that is, 6 years of primary education, 4 years of middle school, 5 years of secondary school (ordinary level), and 2 years post secondary (Advanced Level). Ghana’s educational reforms that ended the British type of educational system introduced in its place the junior secondary (JSS) and the senior secondary school (SSS) concept that involved 6 years of primary education, 3 years of junior secondary, and 3 years of senior secondary (6-3-3); this is a replica of the United States K-12 education system.

The adoption of the K-12 system is virtually a reduction by five years of pre-university education compared to the previous British type of education. These reforms have brought in its trail consequential implications for mathematics instruction and learning. The reason is that there is so much to be taught within a relatively short duration for pre-university education. Needless to say, these reforms have been carried out against the background of a general dislike for mathematics by learners in Ghana as in most countries, a phenomenon attributed to the ineffective traditional way of instruction being
out of sync with contemporary developments in instructional technology (Stodolsky, 1985; UNESCO, 2004).

Some of the initial criticisms that the reforms met were inadequate learning and teaching facilities. As a consequence, the first group of 42,105 senior secondary students who sat for the Senior Secondary School Certificate Examinations (Core Mathematics) in 1993, only 16.1% had grades $A$ through $E$ (Ministry of Education [MOE], 2002). There has been some improvement over the years with 58.6% pass rate in 2000 (MOE, 2002). With the predominance of teacher-centeredness in mathematics instruction, one possible contemporary strategy for improving instruction and student learning could be adopting empirical instructional practices such as the use of calculators. Appropriate use of calculators in instruction could address some of the problems of mathematics instruction and learning (Howe, 1999; UNESCO, 2004).

From a global perspective, UNESCO (2004) has invoked its diplomatic persuasion and impressed upon national education authorities about the need to make subjects and instructional methods interesting and relevant to students’ needs and aspirations. Other organizations have suggested the importance of integrating technological tools such as computers and calculators into instructional practice to improve mathematics learning and student performance (NRC, 1989; NCTM, 1991, 2000; British Broadcasting Corporation, 2006).

In addition Howe (1999) has argued for the integration of calculators in modern instructional practices. He opined that “the success of the traditional curriculum has fostered a mathematically based technology, which in turn has created conditions in which that curriculum is no longer appropriate” (p. 884). One of his reasons is that there
are cheap calculators which could conveniently handle any calculation of elementary mathematics. Furthermore, the prevalence of computer algebra systems is a development which handles all kinds of mathematical computations (Howe, 1999).

There is compelling research evidence (Fleener, 1995a, 1995b; Greer, 2006; Hembree & Dessart, 1986, 1992; Ruthven, 1990; Shamatha, Peressini, & Meymaris, 2004; Wu, An, & Wan, 2005) that the use of calculators in instruction could impact positively both on teachers’ and students’ attitudes towards mathematics instruction and learning respectively. Adopting calculators into instruction would engage learners in their own construction of knowledge through the exploration of mathematical processes and ideas; teachers also have the opportunity to enhance their own learning of mathematics and that of others (The Association of Mathematics Teacher Educators [AMTE], 2006).

Ghana has a unique situation. With the implementation of these reforms, the existing universities have maintained their standards but in the case of the pre-university education, its duration has been reduced alongside expanded reform curricula supposed to be handled by the ineffective traditional way of instruction (UNESCO, 2004). In light of this, it is reasonable for Ghana education system to adopt instructional practices that could face the challenges conceived and born out of these reforms.

Even though Ghana has secured a World Bank Group credit of $US 40 million to support selected components of its information and communication technology (ICT) for implementation towards an accelerated development policy, no provision has been made even towards a discourse on instructional technology that might give due consideration to the importance of calculators in mathematics instruction and learning (Ghana News Agency, Aug 3 2006).
Following the success of Ghana’s first ICT week in 2003, the second forum witnessed extensive presentations such as the role of ICT in education as the bedrock for sustainable national development (Turner & Yidana, 2004). In fact, a curriculum for ICT training and examinations at the high school level has been put in place. Yet, there is no mention of a policy towards the use of calculators in mathematics instruction and learning. The limited use of calculators for high school students is only for computational purposes but not incorporated into instruction for conceptual understanding. Thus, the volume of financial resources sunk into ICT projects might not bring any technological changes regarding mathematics instruction and learning in the Ghana education system.

According to Stigler and Hiebert (1999), teaching is embodied in a culture; and for that matter Ghanaian teachers teach the way they were taught. From their experience, the present generation of teachers would embrace or identify with the idea of paper and pencil computational rigor as a necessary training for mental mathematics discipline.

These teachers would generally agree with the view that paper and pencil computation correlates positively with higher mathematics achievement. (Gelernter, 1988; Klein, 1998; Loveless, 1997). In this regard, it should not be unexpected that a considerable proportion of Ghanaian teachers would not be inclined to adapt to technological advances in mathematics instruction much less encouraging the use of calculators among their students. Hence, introducing calculators in such a system could meet some form of resistance.

Considering the Ghanaian educational work force where generational differences prevail, one cannot overlook the attitudinal differences among educators in the use of calculators in the classroom. Hence teachers’ attitude towards the use of calculators
constitutes an irresistible invitation for an enquiry into the phenomenon as an area for a research study.

The objective of the current study was to investigate the feasibility of calculator use in the Ghanaian educational system. From the literature, a case has been made for the role of calculators in instruction and learning but their use has not been encouraged in Ghana except marginally in the high schools. Thus, the attitudinal predisposition of teachers should be ascertained to be able to justify any policy change for future adoption of calculators in mathematics instruction and learning at the basic school, high school, and on examinations.

This study examined the attitudes of elementary and high school teachers’ attitudes towards the use of calculators to determine the appropriate school level for integrating the calculator technology into mathematics instruction and learning. Gender was considered as a moderating variable. In Bruno’s (2003) opinion, female teachers tend to move towards the elementary schools while males are more inclined towards middle and high schools. The situation is different for the male composition in Ghana. In 2002 male teacher enrollment in teacher training colleges was 73.3% (Ministry of Education [MOE], 2002) and in 2006 males accounted for 69% the elementary school teachers.

In this study however, there were 53 elementary school female teachers (61.6%) and 33 male teachers (38.4%). Culturally, there have been higher concentrations of female teachers in the cities because most female teachers are given the privilege to join their spouses (managers, directors, and other departmental heads) most of whom are found in the cities. However, there were 93 high school mathematics male teachers
(93.5%) and only 6 high school mathematics female teachers (6.5%) (APPENDICES A & B).

**Survey Variables**

The study considered the following variables:

1. **Independent variable:** The school level of teachers, that is, elementary or high school.
2. **Moderating variable:** Gender of teachers – male or female.
3. **Dependent variable:** School teachers’ attitude towards the use of calculators.

Fleener’s (1995b), *Attitudinal Instrument for Mathematics and Applied Technology* (AIM-AT) was used to measure the attitude of teachers towards the use of calculators in mathematics instruction and learning. The instrument has three categories about using calculators in mathematics instruction namely; cognitive, experiential, and affective.

**Statement of the Problem**

During the immediate afterglow of independence various Governments of Ghana saw education as the main conduit for social and economic revitalization of the country. With its inherited colonial curriculum, education in Ghana has undergone a number of reforms with the primary objectives of improving access, quality, and relevance. Ghana’s adoption of the new system has led to a reduction by five years of pre-university education compared to the old system. The reduction in duration of the pre-university school system has brought with it new challenges in terms of compensating for the shorter period for pre-tertiary education.
The major problem lies with the transition from the high school to the university. With teacher-centeredness as the general mode of instruction there is enormous pressure on mathematics teachers to move faster to be able to complete school syllabi but not with much success. Appeals from the public for a one-year extension were not accepted by the President’s Committee on Review of Education Reforms in Ghana (MOE, 2002) but rather the committee recommended that, “primary and junior secondary schools should be strengthened with the provision of qualified, committed, and well motivated teachers, learning and teaching materials and facilities, so that the JSS leavers can have a sound base to do the 3-year SSS program.” (p. 62).

One notable pedagogical stipulation in the reforms is that, “teaching and learning is pupil centered, laying emphasis on role playing, cooperative learning, non-directive teaching, discovering, and problem solving” (MOE, 2001, p. 24). Unfortunately there was no indication of how to realize the lofty pedagogy suggested by the ministry of education. This study has recognized the graphing, computing, and exploration potentialities of the calculator that could address pupil-centered approach to learning mathematics (Almeqdadi, 1997; AMTE, 2006; Demana & Waits; 2000; Devantier, 1992).

The United States K-12 education system on which the Ghanaian education system is based has in place quality instructional technology associated with enriched curricula compatible with modern educational technology. Furthermore, the K-12 system has introduced instructional practices transforming the shortcomings of the traditional system of instruction into a learner centered technology integrated process (NCTM, 2000). The educational reform in Ghana has not brought into effect or embarked on a
program geared towards the institution of standards comparable to the old system of mathematics education.

Policy wise, Ghana needs to reorganize the current system of education in conformity with international standards. For example, Ghana’s performance in the *Trends of International Mathematics and Science Study* (TIMSS) could not have escaped public reaction, and accordingly serious concerns have been expressed. Anku (2005-2006) has commented on the abysmal performance of Ghanaian students in the 2003 study in which Ghana ranked 44 out of 45 countries. Most participating countries have successfully integrated calculators in their instructional practices. Students are at a disadvantage when they compete with their counterparts trained under technologically enriched curricula and instruction.

In a country where instructional practice is largely teacher-centered, and the use of calculators has not been encouraged beyond barely limited use, we need to provoke a discourse in the use of calculators and ascertain which school level in the pre-tertiary mathematics curriculum we could introduce calculators as instructional tools for instruction and learning.

**Research Questions**

This study examined elementary school and high school teachers’ attitudes towards the use of calculators in mathematics instruction and learning. The study was designed to get answers to the following questions:

1. What is the mean attitude of teachers in Ghana towards the use of calculators in mathematics instruction and learning?
2. Is there any difference in the mean attitude of elementary teachers and high school mathematics teachers towards the use of calculators in mathematics instruction and learning?

3. Is the mean attitude of teachers towards the use of calculators the same for male and female teachers?

4. Is there an interaction between gender and school level with respect to the mean attitude of teachers towards the use of calculators in mathematics instruction and learning?

**Significance of the Study**

Mathematics education research has indicated the positive effects the use of calculators has on instruction and learning. Thus, there is the need to accelerate the integration of calculators into the mathematics curriculum in Ghana. However, the role teacher attitude plays in the use of technology features considerably in the research literature. Hence calculator integration in instruction and learning cannot be dissociated from the attitude of teachers (Cornell, 1999; Currence, 1993; Fredua-Kwarteng & Ahia, 2004; Niess, 2006; Schwartz, 2000). The findings of the study would add to the pioneering work on raising the awareness of teachers about the importance instructional technology in general and the use of calculators in particular regarding mathematics instruction and learning (Deku, 200). As well, the findings of the study would become a reference tool for policy makers, government and education practitioners as a whole for future policy formulation and implementation of the use of calculators in mathematics instruction and learning based on the attitudinal predisposition of Ghanaian teachers towards calculator use.
**Definition of Terms**

**Technology**

Technology as used in this study refers to computers and their corresponding software, internet and other digital resources, handheld computing tools and their accessories and other forms of similar devices and applications (AMTE, 2006).

**Attitude toward Mathematics**

This construct is defined by the emotions that a person expresses either negatively or positively towards mathematics, by the beliefs that the individual has towards mathematics, and by how he/she behaves towards the subject (Hart, 1989).

**The Use of Calculator**

This will refer to the students’ use of calculators (basic, scientific, graphic) for any school work.

**Organization of the Study**

Chapter One is devoted to the introduction to the study. The chapter included the background of the study that gives a brief account of the Ghana educational reforms that ended the British type of pre-university and the rationale for the attitudinal study of calculator use in Ghana, statement of the problem, research questions, significance of the study, definition of terms, and the organization of the study.

Chapter Two addresses the review of the literature on the studies involving the relationship between attitudes towards calculators and mathematics anxiety on one hand and possible effect on mathematics learning and achievement, studies related to elementary school teachers’ attitude towards calculator use, studies related to high school mathematics teachers’ attitude towards calculator use, traditional mode of instruction and
technology integration, the theoretical framework of barriers against technology integration in mathematics instruction and learning, and conclusion for the chapter.

Chapter Three describes the methodology for the study. It indicates the target and accessible populations, the sample, instrumentation, validity and reliability of the AIM-AT scale, data collection procedures, and data analyses.

Chapter Four presents the tests of hypotheses, analyses of quantitative and qualitative results, and summary of major findings.

Chapter Five deals with summary, implications, and discussion of important findings both quantitatively and qualitatively, limitations of the study, recommendations, and a concluding statement.
CHAPTER TWO: LITERATURE REVIEW

This chapter was devoted to extensive discussion of studies on teachers’ attitudes towards the use of calculators in mathematics instruction and how they affect student learning. The attitude towards calculator use was also considered within the larger context of technology integration in teaching to better understand why in spite of the enormous investment in the area of educational technology, real barriers pose considerable threat towards technology integration in mathematics instruction and learning. Some paragraphs deal with traditional mode of instruction and the need for incorporating modern technology integration into instruction.

Since 1980’s to the present, the educational reforms on elementary and secondary education in Ghana have been geared towards the adoption of the United States K-12 system of education. Furthermore, since the use of calculators in instruction has not taken off yet in Ghana, the literature review on teacher attitude towards the use of calculators in instruction and learning was done within the context of the United States educational system.

Attitude, Anxiety, and Calculator Use in Mathematics Learning

According to Aiken (2000), “attitude is a learned predisposition to respond positively or negatively to a specific object, situation, institution, or person.” (p. 248). It could be argued that attitude plays a critical role in an individual’s behavior, since attitude affects essentially everything that people do or gives a reflection of what people stand for. How people see the world and how they come to accept and integrate new experiences cannot be dissociated from their attitudes (Galletta & Lederer, 1989).

Another study has identified attitude to be one of the obstacles or impediments to success
or failure in mathematics instruction and learning (Aiken, 1976). To introduce calculators into teaching, it would be important to ascertain the attitude of teachers towards the use of calculators in mathematics instruction and learning.

According to research, the major factor which influences student learning is the teacher (Roueche & Roueche, 1995; NCTM, 2000). The teacher must have positive attitudes both towards mathematics and the use of resources such as calculators to make mathematics fun and meaningful to students. Teachers need to have favorable attitudes towards relevant developments in educational technology to be able to impact positively on the students they teach (Cornell, 1999; Schwartz, 2000).

In the light of the critical role attitudes play in mathematics learning, much effort has been devoted to find the variables which could work towards developing positive attitudes toward mathematics learning. Researches have shown that instructional tools like calculators and computers improve students’ attitudes toward mathematics (Aiken, 1976; Collins, 1996; Funkhouser, 1993; Ganguli, 1992). Furthermore, studies have revealed the improvement students’ attitudes undergo through the use of graphing calculators in mathematics instruction (Acelajado, 2001; Almeqdadi, 1997; Devantier, 1992; Rodil, 2000; Schultz, 1994). These studies have been supported by related contributions by practitioner educators (Demana & Waits, 2000; Edwards, 1996; Embse, 1997). The reason is that mathematics avoidance is known to be associated with anxiety and fear for the subject (Acelajado, 2003; Sundararajan, 1995; Trichett, 1997; Ward, 1989). However, calculators can be used as intervention or anxiety reduction technique (Boers & Jones, 1993; Dunham, 1991; Dunham & Dick, 1994; Greer, 2006) to counter the dislike for mathematics.
Research in the literature has indicated that, teachers need to work on their own attitudes side by side those of their students in order to be able to deal effectively with anxiety encountered in mathematics learning (Black, 1998; Donlevy & Donlevy, 1997; Schwartz, 2000).

The negative beliefs and anxiety about mathematics have various causes traceable to poor or ineffective teaching, shyness, influence of mathematics anxious teachers, siblings, peers, or “the lack of confidence when working in mathematical situations” (Stuart, 2000, p. 24). Some studies have concluded that some pre-service teachers exhibited anxiety when their knowledge in mathematics came under evaluation or assessment (Tooke & Lindstorm, 1998). Also, Raymond (1997) has found that pre-service teachers’ mathematics anxiety originates from previous school life, that is, as learners, the influence of their instructors, and their teacher training programs. According to Cornell (1999) negative beliefs or anxiety might have resulted from the uncaring teachers who assumed mathematical calculations were easy and should be understood by learners.

The origin of anxiety could come from the secondary (Nicole, Gooya, & Martin, 2002; Trujillo & Hadfield, 1999) or the primary (Uusimaki & Nason, 2003) school level. Some teachers’ anxiety could have manifested in the secondary schools before their entry into primary teacher education programs and continue to display these attitudes towards mathematics after certification (Carroll, 1998; Levine, 1996). Ralston (1999) has also opined that many elementary schoolteachers exhibit higher levels of mathematics anxiety and comparably less mathematics skills than their other academic skills.
Using graphing calculators, Acelajado (2003) designed an experimental study to determine the cognitive and non-cognitive gains of 81 freshmen from the college of arts. Two groups, the high ability group (HAG) and the low ability group (LAG) consisted of 30 students each from the 81 students. The variables in the study were achievement scores, attitude towards, and anxiety in mathematics. Significant results were registered in the form of gains both from the cognitive and non-cognitive variables in the respective groups. There were significant differences in the pretest and posttest scores of the respective groups. That is, students showed improvements in mathematics achievement, better attitude, and reduced anxiety from using graphic calculators.

From the foregoing, we need to confront negative beliefs or anxiety from the outset in order to halt the anxiety cycle. If the origins of mathematics anxiety could occur either at the elementary or the secondary level, then exploring the feasibility of intervention programs such as the use of calculators at these school levels should be given the support it deserves. As an adjunct, teacher educators could also work on the negative beliefs of pre-service teachers in their training programs.

**Studies Related to Elementary School Teachers’ Attitude towards Calculator Use**

Fernsler (1983) studied in which type of pre-service class calculator use would elicit more positive attitudes in the elementary school classroom. Sixty-three pre-service teachers were assigned randomly to the classes T(1) and T(2) which used calculators, and the control group T(C) which did not. The analysis of variance (ANOVA) technique revealed in the post-hoc analyses that there were significant differences between T(1), T(2), and the control group. That is there were not differences between the groups T(1) and T(2), but both groups T(1) and T(2) showed more positive attitudes than T(C).
Porter (1990) conducted a descriptive survey to determine the extent calculators were being used and the attitudes of teachers toward their use. Three hundred and seventy elementary teachers were involved and there was 90% return rate. The following results were interesting:

1. Lack of teacher training coupled with inadequate calculators restricted their use.
2. Calculator use increased generally as students moved to higher grades.
3. Teachers indicated the need for staff training and the provision of more calculators.
4. No relationship between years of teaching experience and calculator use.
5. Teachers were quite naïve about the state or district policies for calculator use.
6. Many teachers were still grappling with the issue of whether to use calculators before students mastered their basic arithmetic skills.
7. Teachers did not exhibit positive attitudes toward calculators.

Miller (2004) investigated the extent to which elementary school teachers have implemented the NCTM recommendations for calculator use, particularly the contexts within which these calculators were used. The methodology consisted of curriculum maps and survey. Teachers who taught grades K-6 filled out a calendar-based curriculum map during the year, stating the objective of the lesson daily. The teachers answered 13 Likert type questions, 8 yes/no questions in rating how they complied with the NCTM recommendations on calculator use. Data analyses included t-tests, Pearson’s correlations, and descriptive statistics which came out with the following results:
1. The average teacher used a calculator in his/her mathematics class 6.6% of the time during the school year.

2. There was less usage of the calculator in lessons in the lower grades, but increased calculator use in the higher grades.

3. Calculator use was concentrated on *Number and Order* of the curriculum.

4. Teachers’ implementation of the standards was infrequent.

5. Teachers indicated that the most important factor that promoted or hindered their calculator use was their personal beliefs.

6. There was significant relationship between the grade level of a teacher and calculator use.

It was recommended that future research would address how teacher preparation institutions were training elementary teachers to use calculators especially, why these calculators were used for some topics but not others.

Portney (2000) did a qualitative case study using very time-consuming interviews, observations, critical journaling, field notes and artifacts supplied by the teacher. From the descriptive data, coded into categories, and then into themes revealed the reason for teacher’s beliefs:

a) The caring attitude toward her students originated from her affectionate family, specifically her mother who was an elementary school teacher and other rich elementary experiences,

b) Her implementation of the curriculum under the influence of strong reading habit, her fear for mathematics and standardized tests, and

c) Her attitude toward the workplace and school administrators.
From the results, her capacity as reading specialist for five years and exhibiting a phobia for mathematics could negatively impact the implementation of the mathematics curriculum.

Simon (1990) conducted a study to determine the extent to which lack of use of calculators in the elementary school classrooms could be attributed to the mathematics anxiety of the teachers involved. Ninety-eight teachers from communities in Southern California participated in the study under the administration of the Mathematics Anxiety Rating Scale (MARS) and Survey on Calculator Usage (SOCU). Using regression analyses and the Spearman Rank Correlation, the study reached the following significant results except the hypothesis which related district support of calculator use:

1. The non-use of calculators among elementary school teachers was found to be positively related to the teachers’ mathematics anxiety.

2. The non-use of calculators among elementary school teachers also showed positive relationship with the teachers’ attitude toward the use of calculators in the classroom.

3. The personal use of calculators among elementary school teachers was negatively related to their mathematics anxiety.

Wu, An, and Wang (2005) compared mathematics teachers’ confidence in integrating technology in the United States and China. One hundred and twenty-five elementary mathematics teachers, 48 from Southern California in the United States and 77 from Southern Jiangsu in China, constituted the sample. The Chinese teachers taught from first to sixth grade levels mostly mathematics only. The Unites States teachers taught from kindergarten through sixth grade and they were also involved in multiple
subject assignments. The categories of teachers in the sample had teaching experience from one to thirty years. A survey of 25 questions based on teachers’ beliefs and confidence and knowledge of integrating technology in teaching was conducted on the 125 elementary mathematics teachers in both the United States and China in spring 2005. There were 5 confidence related questions, 4 calculator-related questions, 13 beliefs related, and 3 open ended questions relating to knowledge.

Wu, An, and Wang (2005) used quantitative methods employing t-test and Pearson correlation test. Results indicated that there were significant differences in teachers’ knowledge about using technology in instruction among the two groups of teachers, and teachers’ knowledge had considerable influence on their confidence in using technology. From the results, Chinese had stronger confidence in using technology. Higher level of confidence was associated with fewer years of teaching experience among the Chinese teachers. Similarly the lower grade teachers tended to have more confidence.

The confidence in using calculators in the United States was different. Wu, An, and Wang (2005) found also that in the United States, the higher the grade level the teachers taught, the more confident they were in using the calculators. That is, the lower the grade level the less the teachers used the calculators. From the results, the Chinese demonstrated more knowledge and skills in using technology.
Studies Related to High School Teachers’ Attitude towards Calculator Use

Alzahrani (2004) investigated the attitudes of high school mathematics teachers in Saudi Arabia toward graphing calculators. The sample was 149 high school mathematics teachers. Two-way multivariate analysis (MANOVA), independent t-test and descriptive statistics were used for the data analysis of the responses to the questionnaire developed for the purpose. The results of the study indicated that teachers demonstrated moderate attitude toward calculators, and also showed concern about the probable decline in students’ basic algebraic skill and ability to think mathematically that the use of calculators could cause. Gender was not an influencing factor in the attitude toward calculators hence there was no significant difference between male and female teachers regarding their attitudes towards calculators. However, there were significant differences between teachers who graduated from education colleges and the science colleges regarding their attitude toward calculators with the science teachers showing more positive results. The t-test captured a significant relationship between teachers’ attitudes towards calculators and how frequently they use calculators. 18% of teachers had received a formal training in the use of calculators in mathematics while 78% of the teachers indicated they used calculators as instructional tools. The most important influencing factors of the use calculators were teacher training, mathematics curriculum, school district’s support, and teacher knowledge.

Johnson (1991) conducted research with the high school mathematics teachers in Erie County, New York about the ways they used computers in their teaching for the 1989-1990 school year. The research centered on their attitudes, degree of knowledge about calculator and computer related manipulatives used in high school classes, and
Forty out of the 67 high schools representing categories of size (small, medium, large), type (public, private, parochial), and location (urban, suburban, rural) were involved in the study. This was a two-stage data collection process which first used the interview approach to obtain the overview of the school’s practices through the chair of the mathematics department, and a survey questionnaire completed voluntarily by members of the department. From the findings, teachers generally showed positive attitudes toward the use of computers and calculators in mathematics teaching, however, their integration into teaching was inadequate due to time factor, lack of facilities, absence of technology adoption curriculum, and their fear of students’ losing the mastery of basic skills. Almost all teachers involved in the study expressed the need for practical, urgent in-service training for technology integration in their teaching as well as continuous departmental support to sustain what they learn. There were encouraging signs for technology application in instruction. Three schools were found to be teaching pre-calculus course with graphing utilities and calculators and considerable number had planned to do the same the following year. A number of districts had decided to adopt computer adapted instruction (CAI) and the use of calculators in their remedial mathematics program and in their final examinations. Furthermore, Technology Infusion Program for mathematics teachers had begun in one district and a number of area teachers had started small scale experiments on the use of computers and calculators.

Currence (1993) found teacher attitude towards calculator use to be positive. He had three objectives in his study of delivery systems in calculator training namely video cassette, television, regular class, and summer institute. The objectives were:
1. To identify and describe how teachers perceive the calculator training of teachers involved in each of the delivery systems;

2. Be able to understand the attitude of teachers toward graphic calculator and its application in the mathematics classroom; and

3. Ascertain any relationship between mathematics instruction and each of the four delivery systems.

In this study, three surveys were mailed to 485 participating teachers in programs or classes at the Ohio State University, Central Michigan University, Clemson University, and the University of South Carolina. Results indicated that teachers were excited about the delivery systems, and no indication of any ineffectiveness of the delivery systems was expressed. Teachers had positive attitude toward the training and the many uses of the graphic calculator. All the four delivery systems had an impact on mathematics teaching and were reflected in the way some teachers teach mathematics. Furthermore, novice teachers in the use of calculators appeared to need more support than intermediate or experienced users.

Dean (1980) conducted an experimental design to compare the effectiveness of students’ performance in basic multiplication arithmetic using hand-held calculator to the learning of multiplication by the traditional paper and pencil computation. The study also considered any interaction effect between one’s prior mathematics achievement/performance and the influence of various levels of calculator use on achievement/performance.

Dean (1980) used 134 fourth grade elementary students in a rural district for the study. The students were categorized into low, average, and high on the basis of a
standardized achievement test conducted earlier. Each of the seven classrooms was assigned to one of three treatments. Two intact classes were assigned to use the calculator for all calculations. Three classes were asked to use the calculators to check the problems only, that is, after they have given an initial answer. The remaining two classes were restrained from the use of calculators. Instruction was provided by the classroom teachers on the multiplication module in the students’ fourth grade mathematics textbook. Pretest, post-test, and retention test were conducted from 50 item samples of the 100 basic multiplication tasks.

According to Dean (1980), teachers kept anecdotal records of how calculators affected their classes. The pretest was used as the covariate for the post-test and the retention test in separate analyses of covariance with the post-test and retention test as the criteria. The results of the analyses showed no significant differences in the treatment levels. There was no interaction effect. The results indicated varied attitudes on the part of teachers towards the use of calculators but with differing applicability in their classrooms. The teachers also found calculator use motivational for their students. Dean (1980) documented that the teachers were concerned about their loss of control over their students as the students’ engagement with calculator work provoked in the teachers considerable discomfort and frustration. Also the teachers said they did not save time out of teaching multiplication with calculators.

Nikolaou (2001) conducted a meta-analysis to synthesize and extract the major findings of individual original studies on the effects of the use of hand-held calculators on mathematics achievement and problem-solving abilities of elementary, middle, and high school students. The questions addressed in this study were, whether the use of hand-
held calculators in mathematics education influence achievement and problem-solving, whether there are any relationships between calculator effectiveness and students characteristics, and under what conditions was calculator use most effective. Twenty-four individual studies were reviewed from the years 1987 to 1999 using the objective and replicable procedures to locate the respective studies, coding of study features and study outcomes, and statistical methods to summarize overall findings and ascertain relationships within the studies. A total of 103 effect sizes were calculated. With reference to mathematics achievement, 15 studies were collected and coded, while for problem-solving 9 studies were collected and coded. The results of the 24 studies showed an overall effect size of .4961 with a standard deviation of .9291. The conclusion was that, calculators should be used in mathematics instruction. However, the extent and how they should be used remains to be answered. Limited use of calculators was recommended to restrain students from the false notion that learning mathematics is simply pressing buttons on an electric device. Furthermore, increased calculator use should match progression to higher grades as they are made aware of the calculators as tools for mathematics learning other than the total solution for the problems associated with achievement in mathematics education.

**Traditional Mode of Instruction and Technology Integration**

It appears there is abundant evidence in support of calculator use in instruction yet the practical usage has not realized its full potential. Among the myriad of reasons such as lack of awareness on the part of parents and classroom teachers of the gains from the use of calculator uses, lack of funds for implementation of technology integration, and inadequate administrative support (Hope, 1997; Johnson, 1991; Porter, 1991), the most
important is the interaction of teacher beliefs concerning mathematics itself and how the subject is taught. The nature and goals of mathematics combine and work on teacher beliefs and could affect the adoption of technology in instruction (Fleener, 1995; Schmidt & Callaghan, 1992).

The fear expressed by some teachers that the use of calculators would become crutches for students and weaken their mastery of basic concepts, limit their potential for calculator use in mathematics (Smith, 1996; Zand & Crow, 1997). Considerable number of teachers prefer withholding calculators from students prior to the mastery of skills (Spiker, 1991; Fleener, 1995) although evidence exists to the contrary that conceptual learning can result before the mastery of skills (Heid, 1997).

According to Simmt (1995), teachers’ beliefs about mathematics cannot be separated from their beliefs about calculator use. Teachers who advocate for mastery of paper and pencil computation before conceptual understanding miss the mathematics learning process as involving patterns, reasoning, and problem-solving other than as a mere computation. According to Civil (1990) pre-service teachers’ notions about mathematics instruction seem to border on neatness, rule-based algorithms, and authoritarian attitudes. Romberg and Carpenter (1986) found that some mathematics teachers’ view about mathematics is the knowledge obtained from textbooks. This category of teachers refer to the textbook based mathematical ideas as coming from experts and the teachers’ task is to cover the content in the text emphasizing procedures with little or no explanation. On the other hand, teachers who believe in individual discovery and initiative and for that matter the constructivist approach to learning would provide teaching situations that portray this attitude (Simmt, 1995).
Darling-Hammond (1993) has drawn the analogy that, the change from the agrarian to an industrialized society could not retain the outdated single room schools thus leading to today’s large school system; similarly the century’s technological development resulting in the high-technology Information Age has brought in its trail a significant impact on the current system of school organization incapable of perpetuating the traditional form of education. Thus, the present society requires people who can manage complex situations and willing to embrace new technologies, methods, and occupations. The complex nature of the society also requires citizens who are prepared to handle diverse problems and express alternate views on challenging social situations. However, these changes would not accommodate the educational system that packages instructions to students but rather one which affords the student the advantage of higher order learning; a system which does not require teachers only to cover a curriculum but also to ensure that in the instructional process, students are involved in their own knowledge construction and the development of their talents in a variety of ways.

Niess (2006) in her assessment states that most teachers by 2006 have not learned within an environment where technology tools served as the media, and questions how teachers would acquire the technology know-how to be able to employ this knowledge development in mathematics instruction. Shulman (1986) takes a look at what future teachers need to do to change by using teaching methods which provide easy access to mathematics knowledge for learners, and envisages a comprehensive knowledge structure developed by teachers about mathematics as a subject, the students, instruction, and curriculum in what Niess (2006) has termed technology pedagogical content knowledge (TPCK). Corroborating the opinions of Ma (1999) and Georghegan (1994), Niess (2006)
has stressed that mathematics teachers “need an in-depth understanding of mathematics (the content), teaching and learning (the pedagogy) and technology” (p. 196) to teach the important ideas arising out of mathematics with the technology acting as the catalyzing agent for the realization of the students’ understanding of the ideas involved. Other studies have also shown more support for the development of TPCK in student teaching practices and the importance of applying it through various coursework in instruction and learning (Margerum-Leys & Marx, 2002; Pierson, 2001; Zhao, 2003).

Technology is one of the principles of the NCTM (2000) standards; and this principle has indicated the importance of instructional technology in a variety of ways bringing into focus how best technological tools can aid mathematics instruction. Niess (2006) has this to say about calculators, “they appear to be tools for adults to use as they wish but not for children to use in learning mathematics” (p. 198). Furthermore, the important task to be addressed by educators would be helping learners to think while their calculators assist in their thought processes but not a situation where learners refuse to think when using calculators. Teachers could achieve this objective if they have the right predisposition to technology integration and for that matter the appropriate use of calculators in mathematics instruction and learning (Niess, 2006).

The current view of curriculum-based technology integration implies effective integration in instructional practices which aid students’ learning process to meet the set standards and other instructional activities. In this perspective, the teachers’ role changes to that of a facilitator or guide who would be able to combine product and idea technologies to help students in the course of learning. This will require adequate computer information and integration literacy. It is argued that the facilitating role of
teachers might not seem pleasant or satisfactory to them, nevertheless students could become responsible learners who are motivated to be better problem-solvers (Papert, 1980; Moersch, 1995; Niess, 2006).

Helping learners acquire technology savvy has engaged the attention of school authorities, yet access constitutes a major problem (Rieber & Cooper, 1995; Norton, McRobbie, & Cooper, 2000; Niess, 2006). However, Cuban (1999) holds a contrary view that in some instances access is not the problem.

Hart (2004) did a follow-up on an earlier study (Hart, 2002) on the basis that a group of 14 teachers in an alternative preparation program had cultivated beliefs in consonance with contemporary expectations of mathematics education. The current study followed 8 of these teachers into their first year of instructional practice in an elementary school. Qualitative data were collected from three sources namely, reflection logs, mathematics case discussions and field notes taken when teachers were observed in class. The rational was to verify how some pre-service teachers were implementing NCTM (1989, 1991, 1995, & 2000) standards. These sources of data produced a triangulation which depicted teachers’ views of themselves, the teachers’ views of others and the university faculty members’ views of them. The teachers completed the NCTM Standards Beliefs Instrument at the end of Phase I and Phase II. Qualitative analysis of the results from the instrument indicated that in spite of their strong belief in the reform agenda, their teaching practices did not portray pedagogy consistent with those beliefs.

As the proposed study investigates the attitudes of teachers about their use of calculators with the objective of instituting a policy for the adoption of calculators in instruction, it is important to situate teachers’ attitudes, beliefs or philosophies within the
theoretical framework of barriers to contemporary technology integration in mathematics instruction.

**Theoretical Framework of Barriers against Technology Integration**

In spite of billions of dollars invested in educational technology, integration of innovations by teachers has not lived up to the much anticipated outcome (Rieber & Cooper, 1995; Niess, 2006). Two reasons have been assigned to the slow access to technology integration namely: teachers’ lack of technology expertise and their beliefs about how mathematics learning takes place.

In their investigation, Norton, McRobbie, and Cooper (2000) concluded that teachers’ resistance to technology use could be associated with their beliefs about the mathematics learning and their teaching practices. Some teachers’ discomfort with the use of technology and the absence of success cases to learn from could also explain their negative tendencies toward technology use (Norton, McRobbie, & Cooper, 2000).

Putnam and Borko (2000) question whether teachers are ready to engage in technology-based instructional practices in mathematics learning. Whatever the challenges, teachers could still make the effort utilizing the experiences they might have acquired in their training. Norton, McRobbie, and Cooper (2000) argue that taking the first step to overcome beliefs could be rather difficult in that beliefs are not only the toughest factor but also significant obstacle to effecting pedagogical changes in mathematics instructions.

Niess (2006) has advocated for continued research into real barriers in order to come up with remedies when preparing teachers and planning professional development programs. The task of knowing how students learn and coming up with the curriculum
that assists students in learning mathematics with technology could also constitute a 
barrier to technology use (Niess, 2006).

Other empirical evidence points to the fact that in spite of the enormous 
investment in technology to improve mathematics instruction and performance, results 
have fallen well below expectation. The abysmal performance of technology integration 
is not a recent phenomenon and has prevailed since the last century (Cuban, 1986). 
Recent developments with regard to technology use in schools have not been any better. 
Extensive research work has chronicled in much detail, the low performance of 
technology integration in a considerable number of schools. For example in some schools 
where computers and instructional software are available in significant quantities, there is 
documentary evidence of lack of use or under use (Becker, 2000; Cattagni & Farris, 
2001; Cuban, 1999, 2001; Loveless, 1996; Zhao, Pugh, Sheldon, & Byers, 2002) which 
poses an enormous challenge to effective integration.

Other studies have researched why teachers are reluctant to use available 
technology. These studies have come to the conclusion that, a good number of teachers 
are resistant to change because the infrastructure and management of the schools do not 
provide a congenial atmosphere for technological integration (Sarason, 1991; Collins, 
1996).

In a related perspective, some educators are quite apprehensive about the benefits 
of technology in instruction and learning to the extent that teachers come under 
considerable tension when it comes to staying current with the ever changing technology 
in mathematics instruction (Cuban, 1999; Zhao, Pugh, Sheldon, & Byers, 2002). Many 
other studies have delved into teachers’ adeptness in, and their attitudes toward the use of
technology. These studies have also concluded that, teachers who have low inclination towards technology, and would not want to spend time to learn how to use technological devices are not very likely to incorporate technology in their teaching (Sandholtz, Ringstaff, & Dwyer, 1997; Becker, 2000).

Hodas (1993) argues that the school as an organizational unit would be reluctant in accepting new technologies, and would remain resistant to the pressure that innovation would bring. An innovation which might be intended for positive changes in the organization could be interpreted as a disruption of the organizational practices, especially if the organization would need to sacrifice changes in their cultural values in order to adopt such innovation (Hodas, 1993; Cohen, 1987; Cuban, 1986). Furthermore, other studies on teachers’ integration of educational technology have concluded that teachers spend at least three to five years to acquire professional competence and confidence in teaching with technology (Dwyer, Ringstaff, & Sandholtz, 1991). Quite a number of models have been developed from the stages teachers go through in a bid to adopt technological innovation in mathematics instruction and learning.

A notable study of Zhao and Frank (2003) about technology integration has resulted in a three-stage model. The first stage covers the introduction of the technology to the school and the internal and external issues raised by the adoption of the technology in the schools. The second stage outlines the blend of old practices with the new ones, and the final stage assesses the organization after the technology has become integrated in the cultural practices of the organization.

Another framework developed by Myhre, Popejoy, and Carney (2005) is the model, New outcomes: Learning in Mathematics Integrating Technology (NO LIMIT)
which captures relatively, the cognitive, behavioral and the affective dimensions of technology integration in instruction. The model spells out the various processes of teachers’ progression in technology use in the following stages: identification of preconceived perceptions about technology in instruction; clarification of the impact on the teacher’s own practice; acceptance of own practice; exploration of innovations and new practices; understanding and ability to alternate between new and existing approaches to teaching and, ability to implement and make appropriate decisions about when to use technology (Myhre, Popejoy, & Carney, 2005).

Myhre, Popejoy, and Carney (2005) outline six chronological stages for teachers who join NO LIMIT either not prepared, somewhat prepared, or very much able to use technology. Some teachers would claim the use of calculators would even harm students’ achievement in mathematics. Such teachers would not dispute the claim that the use of paper and pencil in solving problems benefits students more than the use of calculators in similar problem-solving tasks. Myhre, Popejoy, and Carney (2005) indicate that teachers in stage two would be eager about the use of technology yet uncertain if technology adoption would be useful in practice. Technology use found to be problematic at this stage might accentuate teachers’ aversion to the innovation being introduced; otherwise there would be a smooth transition to the next stage. Myhre, Popejoy, and Carney (2005) point out that self-awareness is the hallmark of stage three. That is, teachers at this stage take dispassionate stock of their classroom activities, bringing the whole instructional exercise under close scrutiny and assessing their relationship with their students. As a result, teachers would be in a better position to make the right choices with regard to the technology suitable for their situation. Myhre, Popejoy, and Carney (2005) contend that
beyond stage three, teachers could adapt technology to existing practice. This would lead to skill development on the part of the teachers and as a result, confidence building in their ability to adopt technology in math instruction would have had a major boost. Teachers at stage four of this model would take instruction beyond their traditional teaching practice, and consider alternative mathematics methods that might use technologies to support students’ knowledge construction and learning. Myhre, Popejoy, and Carney (2005) conclude that the fifth and the sixth stages are considered logical sequence of the fourth stage. The teachers would now feel at ease and comfortable in interchanging technologies and also make a final determination of the effects of the various methods within their corresponding contexts, as a result of the explicit transformation from the traditional behavioral instructional practices. Hence teachers’ attitudes toward technology use according to this model would depend on their prior professional engagement with technology (Myhre, Popejoy, and Carney 2005).

The adoption model of Hooper and Rieber (1995) draws a distinction between teachers’ beliefs or philosophies by identifying five stages of technology integration in educational instruction namely: familiarization, utilization, integration, orientation, and evolution. In these stages, the authors compare the traditional and the contemporary views on technology integration in education. The practice of the traditional role is that educators might familiarize themselves with an innovation without going further than the awareness of the innovation. Hooper and Rieber (1995) state from experience that some educators could utilize the innovation for a period of time and abandon it when faced with the least impediment, or integrate the technology in which case the absence or removal of any such innovation would halt or thwart the execution of any planned
instructional unit. According to Hooper and Rieber (1995), books, worksheets, and chalkboard could be the most obvious technologies which have reached the adoption characteristic of the integration stage in the sense that their absence or removal would render any instructional effort virtually impossible. At this stage the main focus is either on the teachers’ instruction or the technological innovation. In contrast the contemporary view on technology adoption progresses beyond the integration stage where educators adopt the reorientation and evolution phases (Hooper and Rieber, 1995).

Perkins (1992) has discussed three cognitive results associated with students’ learning. These are students’ ability to understand, recollect learned material, and use the learned information when they are out of school. Perkins (1992) reiterates that as teachers adapt technology to their instruction, the ultimate concern is how technology fosters the appropriate engagement between the students and the subject matter in a variety of ways. “The benefit of technology is not simply its potential to replicate existing educational practice, but its ability to combine idea and product technologies to encourage students to engage in deeper cognitive activity” (Hooper & Rieber, 1995, p. 99).

The slow adoption rate of computer (or calculator) use in schools has been given a metaphorical exposition by Zhao and Frank (2003) in an analysis in which the authors dub the school as an ecosystem, with teachers and computers as species, and computer (or calculator) innovations as an invasion of the school environment. The contrast Zhao and Frank (2003) portray in this metaphor is that while ecologists, environmental professionals, policy makers, and other practitioners observe the zebra mussels vigorously invade the Great Lakes on one hand, educational researchers, practitioners, policy makers and the general public watch with disappointment the slack in the adoption
of modern technologies in the schools. Zhao and Frank (2003) explain that the zebra mussels compare to the computer (or calculator) and other technological uses could all be regarded as foreign agents into their respective environments. In this study which focuses on the attitudes of teachers toward the use of calculators, the ecological metaphor of the computer use could also apply to the use of calculators in schools. Similarly, idea technologies associated with calculator use could be regarded as invasion of the traditional practices of the school system (Zhao and Frank, 2003).

In ecological terms, Zhao and Frank (2003) have created four metaphorical equivalents in their analysis of computer (or calculator) uses in schools; that is, classrooms as ecosystems, computer (calculators) uses as living species, teachers as members of keystone species, and external educational innovations as invasions of exotic species.

According to Zhao and Frank (2003), the classroom presents a common forum for teachers, students, parents, principals, books, desks, grades, and subjects. Their individual roles affect each other in a continuous interaction among themselves during instruction and learning. Computer uses (in this study, calculator uses) follow a process akin to organic species, and their diffusion or integration also follows the principle of survival of the fittest. Some uses are more likely to exhibit a higher level of endurance and propagation.

Taking teachers as the keystone species, they interact with many other members in the teaching environment and also assist each other as they apply innovations in the classroom. Each member mutually acts as each other’s keeper in what is ecologically referred to as “reciprocal altruism,” and in the process, teachers are able to build social
capital for their own use. Zhao and Frank (2003) identify four likely scenarios as innovations are introduced to invade the existing practices. One such scenario is that the invader could win and exterminate the existing species. The second possibility is that both guest and host species could win at the demise of some other species. Another outcome is that the alien species could suffer destruction; and lastly both species could undergo a process of variation, modification, and selection. Zhao and Frank (2003) conclude that the adoption of the use of calculators would depend on the purpose and the extent to which it is compatible with the teaching and learning environment.

Zhao and Frank (2003) consider the two main types of computer use (or calculator use) in terms of purposes in the classroom environment are for students and for teachers. When teachers happen to be the sole users, they benefit as individuals to the detriment of the school system. When students are made to participate in the use of the innovation, the new practice takes a firmer root and there would be higher chance of its adoption and continual existence (Zhao & Frank, 2003).

Zhao and Frank (2003) The issue of permanence of the innovation raises the possibility of competition between the innovation and existing practice for the limited resources in the school system. For example, more frequent use of the internet could lead to less patronage for the school library’s print media. In a similar manner, Zhao and Frank (2003) state that the use of the calculator in providing student-centered instruction such as cooperative learning in support of constructivism could be tantamount to the abolition or departure from the traditional behavioral approach of teacher-centeredness in math instruction. In another sense, the calculator use for student-centered instruction
might not augur well for the preparation of students for standardized tests (Zhao & Frank, 2003).

Zhao and Frank (2003) conclude that teachers’ adoption of calculator use would depend on the perceived costs or benefits in relation to the technological application; teachers would form value judgments based on the teachers’ existing beliefs and attitudes rooted in their philosophies and cultural practices of the school. Zhao and Frank (2003) state further that teachers would make a determination whether the technology adoption benefits the student, enhances the teachers’ status, or is time-wasting. As keystone species, teachers’ decisions are basic to the success of technology integration; and motivating their actions are their beliefs and perceptions regarding the value of technology (Zhao & Frank, 2003).

Rogers (1995) outlines the stages teachers would have to go through in accepting or rejecting a particular technological innovation in instruction, and these are:

*Knowledge*, where teachers become aware of integrating technology with learning mathematics and have some idea of how it functions;

*Persuasion*, where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with technology;

*Decision*, where teachers engage in activities that lead to the choice of either adopting or rejecting teaching or learning with technology;

*Implementation*, where teachers actively integrate teaching and learning with technology; and

*Confirmation*, where teachers evaluate the results of the decision to integrate teaching and learning with technology.
Rogers (1995) distinguishes five categories of adopters on a continuum which displays a bell-shaped curve. These are the innovators, early adopters, early majority, late majority, and laggards. Moore (1991) refers to the adopters in terms of selling the instructional technology on a market. He divides the technology markets into an early market comprising the innovators and early adopters, a mainstream market consisting of the early and late majority, and a late market that corresponds to the laggards. Each of the early and late markets constitutes 16% of the total population while the mainstream represents 68% of the total population. Rogers (1995) describes the adopters in the following:

**Innovators**

This group welcomes new technology as soon as it comes up. Its interest is in the technology itself other than its application to specific problems. The innovators have in-depth knowledge of the hardware and software and also are mutually aware of their presence in their institutions and disciplines.

**Early Adopters**

These adopters blend the innovation with the solution of particular problems or tasks. They explore ways and means for effective mathematics instruction that the new application could promote. As risk-takers, they tolerate failure and tend to be inclined towards the innovators and also well connected in the academic community.

**Early Majority**

These members constitute the pragmatic category which makes the first half of the mainstream. Although quite comfortable with technology, they are preoccupied with issues of the profession rather than the innovation. It is their custom to adopt the “wait-
and-see” attitude toward the new innovation to be assured of proven success before adoption. Their preference is to evolve a modification of the prevalent practice through the innovation and not a radical change of the status quo.

**Late Majority**

They share some similarities with their early counterparts except that they are the unadventurous or disbelieving other half of the mainstream. They adopt the innovation very late, usually after the change has taken root among the early majority.

**Laggard**

Members of this group form the last 15% of the population and are very likely never to adopt the innovation; and might even protest its use by others.

Rogers’ (1995) and Moore’s (1991) adoption models recognize the distinction between the early adopters and the early majority (or between the early and the mainstream markets) and as a result, these two groups are likely to have different considerations in determining whether or not to adopt a technological innovation once it is introduced. These groups would require different approaches from marketing point of view. This has created a significant gap which hampers the smooth adoption of innovations in the light of heavy investment towards their use.

Geoghegan (1994) identifies four reasons why the adoption process has failed generally to move past the early adopter phase to the mainstream. These are the ignorance of an existing gap, the technologists’ alliance, alienation of the mainstream, and the lack of a compelling reason to adopt the innovation.

Geoghegan (1994) contends that if both the early and the mainstream adopters are assumed to be homogeneous that, could preclude the recognition of an existing gap
between them. Furthermore, the failure to discern an existing gap in turn misses the alertness to detect the possibility of disparate categories with different attitudes in teaching. Geoghegan (1994) indicates that, there are varied degrees to which faculty or adopters would resist technology innovation. Recognizing the mainstream as distinct from the early adopters and selling the concept relevant to their beliefs and perceptions would bring them to the level of the innovators or early adopters (Geoghegan, 1994).

In addition, Geoghegan (1991) points out that, the apparent union of innovators, early adopters, Information Technology support organizations, and vendors of technology products tend to alienate the larger mainstream category. Geoghegan’s (1994) reason is that the members in the union connect well on matters of technology especially when new products are introduced on the market.

Geoghegan (1994) argues that the union has a common language with similar interests. Based on their commitment to the use of technology, they hold the wrong assumption that others in the mainstream would perform similarly as them. Hence little or no consideration would be given in practice towards the provision of technical support needed by the early majority. Yet the mainstream would be expected to provide a radical change in teaching methods rather than the evolutionary change they prefer. Members of the mainstream tend to be interested in the process not the technology per se. Hence it is prescribed that the peer support approach should have a better chance of success in the adoption process (Geoghegan, 1994).

The differences between the early adopter and the mainstream could foster the possibility that the successes of the early adopter could estrange the early majority. Moore (1991) has also stated that, the radical commitment of the early adopters could
alienate and enrage the mainstream adopters. Geoghegan (1994) has argued that, “One fairly obvious step is to recognize achievements in the improvement of teaching and learning through technology, so long as care is taken to insure that the focus is on instructional improvement or teaching excellence, not technical innovation alone” (p. 14).

Moore (1991) has pointed out that, if an innovation does not offer a compelling reason for purchase, it would not move from the early market to the mainstream. Thus an innovation meant for adoption should provide value above the monetary cost, be easy to use, and produce minimum side-effects if any.

**Conclusion**

The review of the entire chapter points to the fact that in totality a very strong case has been made for the application of calculators in the mathematics teaching and learning. Introducing innovations in teaching requires that the teachers involved demonstrate positive attitude towards the innovation because teachers play a crucial role in technology integration into instruction. Secondary school teachers are more likely to welcome the use of any form of calculators if they are offered considerable help (Kissane, 1995) and the literature shows also that increasing use of calculators occurs at higher grade levels of learners.

No doubt the use of calculators in mathematics instruction and learning has provoked intellectual debate, and according to Ralston (2004) some educators might tend to assume an inconclusive process regarding the effect of using calculators in mathematics instruction and learning. However, many studies tend to support the position that calculator use does not inhibit the learning of traditional mathematics but rather enhances it.
Furthermore, there is international collaboration to expedite the process of bringing global mathematical curricular issues within a close circuit for international attention as envisaged by TIMSS under the auspices of ISC. The goal for the concerted effort is seeking new and more effective ways and means other than the well tested but apparently inadequate traditional mode of instruction to confront and stem the problematic mathematics avoidance before it could get out of control.
CHAPTER THREE: METHODOLOGY

In this study, the researcher investigated Ghanaian elementary school teachers’ and high school mathematics teachers’ attitudes towards the use of calculators in mathematics instruction and learning by employing quantitative methods supplemented by two open-ended questions. The study sought to compare the attitudes of teachers of elementary school and high school mathematics teachers and determine the school level it was relatively feasible to consider the integration of calculators into instruction and learning of mathematics.

This chapter is used to describe the methodology that addressed the research design, that is, the population and sample; instrument used in the study, the data collection procedures, and the data analyses.

Research Questions

The research questions to which quantitative methods were applied were the following:

1. What is the mean attitude of Ghanaian teachers towards the use of calculators in mathematics instruction and learning?

2. Is there any difference in the mean attitudes of elementary teachers and high school mathematics teachers towards the use of calculators in mathematics instruction and learning?

3. Is the mean attitude of teachers towards the use of calculators the same for male and female teachers?
4. Is there an interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning?

**Research Hypotheses**

In response to the research questions the following hypotheses were stated for the quantitative methodology. The hypotheses were denoted by null hypotheses (H$_{0i}$) and alternative hypotheses (H$_{Ai}$) where, $i = 1, 2, 3$.

H$_{01}$: Null hypothesis:

There is no significant difference in the mean attitudes of elementary and high school mathematics teachers towards the use of calculators in mathematics instruction and learning, versus

H$_{A1}$: Alternative hypothesis:

There is significant difference in the mean attitudes of elementary school and high school teachers towards the use of calculators in mathematics instruction and learning.

H$_{02}$: Null hypothesis:

There is no significant difference in the mean attitudes of female and male teachers towards the use of calculators in mathematics instruction and learning, versus

H$_{A2}$: Alternative hypothesis:

There is significant difference in the mean attitudes of female and male teachers towards the use of calculators in mathematics instruction and learning.

H$_{03}$: Null hypothesis:
There is no significant interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning, versus

$H_{A3}$: Alternative hypothesis:

There is significant interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning.

**The Population and Sample**

The elementary school teachers in Ghana constituted the target population for the sample of elementary teachers, and similarly, the high school mathematics teachers in Ghana formed the target population for the sample of high school mathematics teachers. For practical purposes, elementary and high school mathematics teachers in the Kumasi metropolitan area formed the accessible populations for the sample of elementary and high school mathematics teachers used in the study.

The researcher realized the monetary implications of transportation costs associated with a study involving a particular region let alone one that covers the whole country. In this light, the Kumasi metropolis was selected because it is the most cosmopolitan city of Ghana apart from the fact that it is the second largest city and the most populous city in Ghana. The researcher had lived in Kumasi for appreciable length of time prior to gaining admission to pursue graduate studies at the Ohio University and for that matter very familiar with the Kumasi metropolitan area. Thus, financial and time constraints, familiarity with, and easy mobility within the metropolis, in combination
with easy accessibility of large sample units for the study informed the decision to choose Kumasi for this research.

The sample size for the study was considered according to the effect size, power, the significance level, and the number of variables used in the study (Stevens, 1996). According to the literature, small effects are difficult to detect and in practice researchers would generally not invest in studies where small effects exist. Medium-sized effects are worth the effort of researchers where a sample of size between 100 and 200 could establish differences depending on the power of the test (Light, Singer, & Willet, 1990).

To facilitate comparisons across levels, the researcher decided on a sample of 80 high school mathematics teachers and 80 elementary school teachers for the hypothesis tests. The complete lists of elementary and high schools in Kumasi were obtained at the Regional Education Office. Eleven high schools and 13 elementary schools within the Kumasi metropolis were used for the study.

Altogether, a sample of size 80 was chosen both from the high schools and elementary schools to ensure medium effect size at .05 level of significance with a power of .80 (Light, Singer, & Willet, 1990). In expectation of an 80% return rate, 110 copies of AIM-AT were distributed to selected high school mathematics teachers and the same number was given to the elementary school teachers.

**Instruments**

Fleener’s *Attitude Instrument for Mathematics and Applied Technology* (AIM-AT) (APPENDIX C) was used to measure elementary and high school mathematics teachers’ attitudes towards the use of calculators in mathematics instruction and learning. The researcher sought permission for the use of AIM-AT from the designer (Fleener,
Two open-ended supplementary questions (APPENDIX E) were also given to the participants. The AIM-AT has 23 questions on a 4-point Likert Scale. Examples of some of the items are:

1. Calculator use will cause a decline in basic arithmetic facts.
2. Students should not be allowed to use a calculator while taking tests in mathematics.

Fleener (1995), who adapted AIM-AT from Huang (1993) has reported that the validity of many of the items of the instrument have been reported by Bitter and Hatfield (1992) in their two-year project that focused on calculator integration into instruction and learning, and students’, teachers’, and parents’ attitudes toward the use of calculators. The AIM-AT has three categories: “affective results of using calculators, the experience and teaching with calculators, and teachers’ beliefs about the cognitive effects of using calculators.” (Fleener, 1995, p. 55) (APPENDIX F). Using Cronbach alpha, Fleener (1995) reported internal consistency of these three categories respectively as 0.77, 0.71, and 0.76. Abdullah, Abdullah, and Tap (2005) recorded internal reliability of 0.57 for the cognitive and affective categories, and with systematic deletion of 4 items brought the internal reliability to 0.71 in a study meant to determine the dominant factors in exploring students’ attitude toward calculators.

In the current study, the internal reliabilities for the cognitive, experiential, and affective subscales were 0.73, 0.64, and 0.44 respectively. Litwin (1995) has suggested that Cronbach alpha of 0.70 or better could generally be acceptable as good reliability. Even though the internal consistency of all the items in the AIM-AT for the current study was 0.757, which was good by Litwin’s (1995) criterion, the internal reliability on the
affective and experiential subscales did not meet Litwin’s (1995) benchmark. It might be of interest to point out that hypotheses tests involving these subscales produced quite interesting results as we shall see in the following chapter.

The researcher supplemented the AIM-AT instrument with the following open-ended questions:

1. What benefits will the use of calculators in teaching accrue to your students?
2. What setbacks will the use of calculators in learning cause your students?

The reason was that open-ended questions have the potential of eliciting additional information that might not have been covered by the survey instrument.

**Data Collection Procedures**

The Ministry of Education (Ghana Education Service, Kumasi) was contacted for a written letter of permission (APPENDIX G) to conduct the study in Kumasi after the researcher had introduced himself as a member of the service on study leave in the United States. The researcher also supported the purpose of his visit with the *Institutional Review Board’s* letter authorizing the current research (APPENDIX H). After the permission was granted, the heads of institutions of the selected schools were contacted in person, briefed on the importance of the study and their consent sought for teachers’ participation in the study.

The researcher used the lists of elementary and high schools in the Kumasi metropolis as the sampling frames for the two school levels. Almost all the high schools in Kumasi were selected for this study. Mathematics teachers who took part in the study were identified through the solicited assistance of the mathematics departmental heads with the initial involvement of the headmistress or headmaster as the case might be. In
the case of the elementary schools, the head teachers’ assistance was sought. A short introduction preceded the research instrument requiring the teachers to participate voluntarily in the study. To ensure the anonymity of the teachers, no identification was required of them in answering the survey instrument and the open-ended questions.

In selecting a sample from the list of elementary schools the researcher zoned out the Kumasi metropolis into four quadrants and selected one quadrant at random. For this study, the south-eastern quadrant was selected. The elementary schools in Kumasi have been built in the form of clusters within the suburbs of the city. I identified 15 clusters of schools in the quadrant and selected 10 at random. Willing teachers in the selected cluster of schools were given the AIM-AT instruments to complete and also respond to the two open-ended questions attached to the survey instrument.

A simple protocol was followed throughout the data collection exercise. The researcher would meet the participants after seeking clearance from the head of school through a letter of introduction obtained from the Regional Director of the Ghana Education Service, Kumasi. In all 86 elementary school teachers, 53 females and 33 males responded to the survey instrument voluntarily. The instruments were hand delivered to all the participants by the researcher.

Unlike the elementary schools, the high schools were quite spread out. Sample selection was judgmental with the purpose of having enough female respondents. Two girls’ high schools were purposely chosen before a random selection of 9 out of the remaining schools was carried out. Unfortunately, there were no female mathematics teachers in one of the girls’ schools; and there was only one female teacher in the other
girls' school. Out of a total of 93 high school mathematics teachers who completed the survey instruments, only 6 of them were females.

Data Analysis Procedures

The analysis of the research questions was conducted using Statistical Package for the Social Sciences (SPSS) Version 15. The SPSS version 15 was used for the following analyses:

1. The Cronbach’s alpha reliability test was performed on the dependent variable the attitude towards the use of calculators in mathematics instruction and learning. Descriptive statistics of the responses to the items in the instrument namely, the arithmetic means, standard deviations, frequencies and percentages were reported for the dependent and independent variables.

2. The first hypothesis H₀₁, “There is no significant difference in the mean attitude of elementary and high school mathematics teachers towards the use of calculators” was tested to determine whether the school level has significant main effect on attitude towards the use of calculators.

3. The null hypothesis, “H₀₂: There is no significant difference in the mean attitudes of female and male teachers towards the use of calculators” was investigated to determine whether gender had significant main effect.

4. Another test was performed “H₀₃: There is no significant interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning.

Two-way analyses of variance (ANOVA) was conducted to determine any main effects between the attitudes of the elementary school teachers and the high school
mathematics teachers and examined further whether gender had interactive effect on the attitudes of the elementary teachers and high school mathematics teachers. The unit of measurement was the mean scores of all the item responses in the AIM-AT for each respondent. The reason for the two-way analyses of variance was that there were two factor levels, that is, gender (male or female) and level of teaching (elementary or high school teachers).

The first of the two supplementary questions was: (1) What benefits will the use of calculators in learning accrue to your students? The second question was: (2) What setbacks will the use of calculators cause your students? The purpose of these questions was to capture more information from the teachers concerning their attitudes towards the use of calculators that the survey instrument might not have covered. The responses to the open ended questions were analyzed by employing the thematic coding analysis (Patton, 2002).

The responses given by the elementary teachers and the high school mathematics teachers to the open-ended questions were entered in the Microsoft Office Excel spreadsheet. The researcher needed to find the frequency distribution of the emerging themes for the purposes of inductive analysis and creative synthesis within the context of holistic perspective (Patton, 2000). Using the edit pull down menu and find feature, the themes that emerged were counted to form the frequency distribution table of these themes. Some respondents gave compound sentences that had multiple themes. These responses which had multiple themes were categorized accordingly.
Summary

The chapter discussed the methodology of the study. It started with a brief introduction, the research questions and research hypotheses. It also discussed the population and sample especially why the Kumasi metropolis was used for the study. Cluster sampling technique was chosen and used in a two-stage process. The reliability and validity of the AIM-AT instrument were discussed to justify the use of the instrument without piloting it. The approach followed for data collection included seeking permission from the Regional Education Office and furthermore soliciting the assistance of heads of institutions in carrying out the study. The SPSS version 15 was used for the analyses of the collected data.
CHAPTER FOUR: ANALYSIS OF RESULTS AND FINDINGS

This chapter presents statistical analyses of the survey data with a focus on the research questions introduced in Chapter One. The study addressed the research questions: (1) What is the mean attitude of Ghanaian teachers towards the use of calculators in mathematics instruction and learning? (2) Is the mean attitude of elementary teachers the same as the mean attitude of high school mathematics teachers towards the use of calculators? (3) Is the mean attitude towards the use of calculators the same for Ghanaian male and female teachers? (4) Is there an interaction between gender and school level with respect to the mean attitude of teachers towards the use of calculators in mathematics instruction and learning? In addressing these questions, the researcher administered the AIM-AT survey instrument using a sample of elementary and high school teachers selected independently from schools in the Kumasi metropolis in Ghana.

The objective of using this instrument was to determine through statistical analyses the extent to which elementary teachers and high school mathematics teachers’ attitudes towards the use of calculators could necessitate some policy initiatives concerning the integration of calculators in mathematics instruction and learning in the pre-university school system. More importantly, the core of the objective was to determine whether it would be appropriate to introduce calculators into instructional practice in all pre-tertiary institutions or whether the integration of calculators into instruction should be a gradual process based on the attitudes of teachers in the elementary school and the attitudes of high school mathematics teachers.
Supplementary questions were used to gather more information on the attitudes of the elementary teachers and high school mathematics teachers to probe further into their predisposition towards the use of calculators in mathematics instruction and learning. The supplementary questions were: (1) What benefits will the use of calculators in learning accrue to your students? (2) What setbacks will the use of calculators in learning cause your students? The researcher also analyzed the responses from the supplementary questions using “content analysis for recurring themes or words.” (Patton, 2002, p. 453).

**Reliability**

It was necessary to ascertain the internal consistency of the AIM-AT instrument which has 23 items consisting of 15 positive items and 8 negative items. The internal consistency of an instrument is crucial in a research because it is important to use scales that produce reliable results. The internal consistency of a scale is the extent to which items in the scale are related. The AIM-AT instrument has had extensive use in researches and has been found to measure variables consistently; it tends also to have a high validity (Bitter & Hatfield, 1992). In general, the commonly used measure of internal consistency is Cronbach’s alpha. Using Cronbach’s criterion, the internal consistency of the AIM-AT in this study was 0.757 (APPENDIX I). Litwin (1995) has suggested that Cronbach’s alpha of 0.70 or better could generally be acceptable as good reliability.

**Results of the Statistical Analyses**

The researcher used descriptive statistics to analyze the degree of consensus among Ghanaian teachers regarding their attitudes as measured by the items in the AIM-AT instrument. In this analysis, a minimum of 70% was chosen to describe the degree of
consensus agreement or disagreement among teachers. A consensus agreement of an item has been described as the total number of teachers that ‘Strongly Agree’ or ‘Agree’ on an item in the AIM-AT. The consensus disagreement is defined similarly and the total number of teachers in each case was expressed as a percentage. However, other researchers have used greater cut-off percentages in their studies (Fleener, 1995).

In Table 1, teachers demonstrated considerable consensus agreement on the following items:

- All students should learn to use calculators (84%).
- Mathematics is easier if calculators are used to solve problems (70%).
- More interesting mathematics problems can be done when students have access to calculators (71%).
- Students should not be allowed to use calculators until they have mastered the concept or procedure (79%).
- Calculators are only tools for doing calculations more quickly (70%).
- I know ways I can use the calculators effectively in my classroom (72%).
- I have lots of ideas about how I can make use of this calculator (72%).

However, there was consensus disagreement on the following items:

- When students use calculators, they don’t need to show their work on paper (76%).
- I have calculators available for my class(es) to use (97%).
- I have used graphing calculators in my classroom before (82%).
Table 1

*Consensus of Teachers' Attitudes Towards the use of Calculators*

<table>
<thead>
<tr>
<th>Consensus item response in the AIM-AT survey instrument</th>
<th>Percent</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When students use calculators, they don’t need to show their work on paper.</td>
<td>76</td>
<td>Disagree</td>
</tr>
<tr>
<td>2. Mathematics is easier if calculators are used to solve problems.</td>
<td>70</td>
<td>Agree</td>
</tr>
<tr>
<td>3. More interesting mathematics problems can be done when students have access to calculators.</td>
<td>71</td>
<td>Agree</td>
</tr>
<tr>
<td>4. Students should not be allowed to use calculators until they have mastered the concept or procedure.</td>
<td>79</td>
<td>Agree</td>
</tr>
<tr>
<td>5. All students should learn to use calculators</td>
<td>84</td>
<td>Agree</td>
</tr>
<tr>
<td>6. I have calculators available for my class(es) to use.</td>
<td>97</td>
<td>Disagree</td>
</tr>
<tr>
<td>7. Calculators are only tools for doing calculations more quickly.</td>
<td>70</td>
<td>Agree</td>
</tr>
<tr>
<td>8. I have used graphing calculators in my classroom before.</td>
<td>82</td>
<td>Disagree</td>
</tr>
<tr>
<td>9. I know ways I can use the calculators effectively in my classroom.</td>
<td>72</td>
<td>Agree</td>
</tr>
<tr>
<td>10. I have lots of ideas about how I can make use of this calculator.</td>
<td>72</td>
<td>Agree</td>
</tr>
</tbody>
</table>
Descriptive statistics were used to address the first research question, (1) What is the mean attitude of teachers in Ghana towards the use of calculators in mathematics instruction and learning? There were a total of 179 male and female teachers in the elementary and high schools who participated in this study. Out of 220 AIM-AT instruments distributed to participants, 179 were returned (86 from the elementary teachers and 93 from the high school mathematics teachers). The mean attitude of the 59 female teachers was 2.3508 with a standard deviation of 0.3717; and the mean attitude of the 120 male teachers was 2.5181 with a standard deviation of 0.3620. The total mean attitude for the entire group of teachers was 2.4630 with a standard deviation of 0.3727 (Table 2). The range of items in the instrument is 1 to 4; hence a mean value of 2.4630 portrays a neutral or slightly positive attitudinal disposition towards the use of calculators.
Table 2

*Means and Standard Deviations of Ghanaian Teachers’ Attitudes Towards the use of Calculators*

<table>
<thead>
<tr>
<th>School level</th>
<th>Gender</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary School</td>
<td>Male</td>
<td>2.3215</td>
<td>.33730</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2.3380</td>
<td>.37977</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.3316</td>
<td>.36211</td>
<td>86</td>
</tr>
<tr>
<td>High School</td>
<td>Male</td>
<td>2.5927</td>
<td>.34434</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2.4638</td>
<td>.29317</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.5844</td>
<td>.34135</td>
<td>93</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>2.5181</td>
<td>.36204</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2.3508</td>
<td>.37173</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.4630</td>
<td>.37266</td>
<td>179</td>
</tr>
</tbody>
</table>
Analysis of Variance Test

In this study gender was treated as a moderator variable in a two-factor analysis of variance. The other factor of primary interest was the school level, that is, elementary and high schools. The range of items in the AIM-AT instrument was 1 to 4. The mean score of the 23 items in the instrument was the unit of measurement. From the analysis the assumptions for the use of ANOVA were not violated:

1. By the administration of the survey instrument, respondents completed AIM-AT instrument independently of one another thereby taking care of the independence assumption.

2. The histogram superimposed with a smooth curve of the mean attitudes of teachers gave a reasonable approximation of a normal distribution (APPENDIX N).

3. Levene’s homogeneity of variance test did not produce significant result, \(F(3,175) = 0.368, p > .05\) (APPENDIX J).

The first null hypothesis was:

\(H_0_1\): There is no significant difference in the mean attitudes of elementary school and high school teachers towards the use calculators in mathematics instruction and learning. That hypothesis was tested against,

\(H_{A1}\): There is significant difference in the mean attitudes of elementary school and high school teachers towards the use of calculators in mathematics instruction and learning.

The mean of the elementary school teachers’ attitudes was 2.3316 with a standard deviation 0.36211, and the mean of the secondary school teachers’ attitudes was 2.5844
with standard deviation 0.34135. The total number of teachers in the elementary schools and secondary schools were 86 and 93 respectively. From the ANOVA test results (Table 3), there was a significant difference in the mean attitudes of elementary school teachers and high school mathematics teachers towards the use of calculators, \( F(1, 175) = 5.574, p < .05, \eta^2 = .031 \) (APPENDICES K & L).

The second null hypothesis was:

\[ H_{02}: \text{There is no significant difference in the mean attitudes of female and male teachers towards the use of calculators in mathematics instruction and learning.} \]

That hypothesis was tested against,

\[ H_{A2}: \text{There is significant difference in the mean attitudes of female and male teachers towards the use of calculators in mathematics instruction and learning.} \]

The mean of all female teachers’ attitudes towards the use of calculators in mathematics instruction and learning was 2.3508 and the standard deviation was 0.3717. Similarly, the mean of all male teachers’ attitudes towards the use of calculators in mathematics instruction and learning was 2.5181, and the standard deviation was 0.36204. From the ANOVA test results presented in Table 3, there was no significant difference in the means of female and male teachers’ attitudes towards the use of calculators in mathematics instruction and learning, \( F(1, 175) = 0.447, p > .05, \eta^2 = .003 \) (Table 3) (APPENDIX M).

The third hypothesis that was investigated involved,

\[ H_{03}: \text{There is no significant interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning.} \]

That hypothesis was tested against
Hₐ₃: There is significant interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning.

From the ANOVA results in Table 3, there was no interaction effect between school level and gender with regard to teachers’ attitudes towards the use of calculators in mathematics instruction and learning, $F(1, 175) = 0.748, p > .05, \eta^2 = .004$.

Even though sample sizes were chosen a priori to ensure medium effects for practical detectability of significance, the post-hoc effect sizes ($\eta^2$) reported in the ANOVA table (Table 3) were smaller than expected (Cohen, 1988).

When the 3 sub-scales (cognitive, affective, and experiential) of attitudes towards the use of calculators were analyzed using the ANOVA technique, the related tests concluded significant school level effect in the case of the cognitive and experiential subscales. The affective scale was even quite close to significance. Thus, overall these analyses on the sub-scales appeared to be consistent with the overall ANOVA results obtained from the whole AIM-AT.
Table 3

*Analysis of Variance for Teachers’ Attitudes Towards the Use of Calculators by School Level and Gender*

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>$\eta^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>School level</td>
<td>.693</td>
<td>1</td>
<td>.693</td>
<td>5.574</td>
<td>.031</td>
<td>.019</td>
</tr>
<tr>
<td>Gender</td>
<td>.056</td>
<td>1</td>
<td>.056</td>
<td>0.447</td>
<td>.003</td>
<td>.505</td>
</tr>
<tr>
<td>School level *gender</td>
<td>.093</td>
<td>1</td>
<td>.093</td>
<td>0.748</td>
<td>.004</td>
<td>.388</td>
</tr>
<tr>
<td>Error</td>
<td>21.760</td>
<td>175</td>
<td>.124</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22.602</td>
<td>178</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results of the Supplementary Questions

One of the benefits of integrating open-ended qualitative questions in a quantitative study is that they are intended to elicit respondents’ perceptions about the research questions that survey data might have overlooked. It provides additional information about the “why question.” As a result, this section is devoted to the responses to the supplementary open-ended questions that were used to obtain additional information from the teachers. The first of the two supplementary questions was: (1) What benefits will the use of calculators in learning accrue to your students? The second question was: (2) What setbacks will the use of calculators cause your students? The purpose of these questions was to elicit more information from the teachers concerning their attitudes towards the use of calculators. Out of 86 elementary school teachers who completed the AIM-AT, 82 of them responded to question one and 81 of them responded to question two. In the case of the high school mathematics teachers, the respondents to Questions 1 and Question 2 were 78 and 79 respectively.

Elementary Teachers’ Responses to the Supplementary Questions

Using thematic coding (Patton, 2002) the major themes that emerged from the perceptions of elementary school teachers about the use of calculators in the classroom are summarized in Table 4.
Table 4 indicates the frequency distribution of the themes of responses to the supplementary questions given to the elementary teachers.

The first theme related to the fact that the use of calculators makes mathematics problem solving easier. One teacher stated that “Mathematics will become easy for students,” and another indicated that “It will make learning of mathematics easier.”

For the second theme, elementary teachers were of the view that students are fast when they use calculators in computation. “Solving mathematics problems become easier and faster if calculators are used,” was indicated by a teacher. Another wrote, “It will
reduce the burden in thinking for the students. It will help the students to save time in working.”

The third theme was that students get accurate answers when they use calculators in computation. One teacher said, “It gives accurate results. Calculators enhance students’ basic knowledge in computational skills.” Another opinion was that, “Students provide correct answers to questions with the help of calculators.” Another said, “It does not consume much energy. It will enable them to get the accurate answer they are after.”

The fourth theme addresses complex and difficult arithmetic that can be solved using calculators. One of the teachers stated that “Students can solve more sophisticated or difficult mathematical problems easily and quickly with the use of calculators.” Another teacher also stated that “The use of calculators will enhance students’ speed in solving complex/difficult mathematical problems and also help them to compare answers they obtain from working it themselves.” One response was that, “It will help them with the correctness of solved problems.”

There were other interesting responses that provided insights into teachers’ attitudes. A teacher pointed out that “It also makes the subject interesting thereby eliminating the fear students have in the subject.” Another said, “At least they must be allowed to use calculators to some point to enable the children know how to use them.” One teacher presented the big picture when she stated that “The use of calculators is scientific and as such an advancement in technological thrust. It will put pupils in conformity with ICT age.” A teacher stated that “Calculators help students to skip the monotonous steps in mathematical problems and concentrate more on the analytical processes.” While a teacher indicated that “They will be introduced to new scientific
ideas,” another teacher stated that “It will prepare them for the future, since calculators are used at the work places. It is the first step to the use of computer.”

The second supplementary question used to obtain more information from the elementary school teachers was: “What setbacks can the use of calculators cause your students?” From Table 4, the dominant theme was that the use of calculators made students lazy. One teacher wrote about calculators that, “It will make the pupils lazy. It will make them lose some basic mathematical skills. Without calculators in any given time the pupils cannot solve any simple mathematics problem and this can affect them in the near future.” It was the contention of another teacher that, “It makes the students lazy whenever working mathematics without the use of calculators.”

An issue of concern expressed by some teachers was the possibility of students getting wrong answers because calculators could become faulty. A teacher wrote that “Calculator being a machine may develop fault and give students wrong results.” Another teacher’s view was that, “In certain cases the calculator might malfunction and wrong answers would be given.”

Affordability of the calculators was an issue that came up in teachers’ responses. A teacher intimated that, “It will be an additional cost for the poor parents.” In a related response, one teacher’s opinion was that, “It could be costly on the poor student,” while another contended that, “Not all students can afford to buy a calculator for themselves.”

Other interesting concerns were expressed about teachers’ attitudes towards the use of calculators. A teacher noted that, “A time will come when they would not like to use their brain on any calculations.” The opinion of one teacher about the use of calculators was that, “It has the potential of making them dependent on the calculator.
And another teacher’s view about calculators was that “It helps students to cheat in examinations for ideas and formulas are copied on it.”

**High School Mathematics Teachers’ Responses to the Supplementary Questions**

The high school mathematics teachers gave their responses to the two supplementary questions namely: (1) What benefits will the use of calculators in learning accrue to your students? (2) What setbacks can the use of calculators in learning cause your students? The purpose of these questions was to elicit more information from the high school teachers concerning their attitudes towards the use of calculators. A summary of the themes of these high school teachers’ responses is indicated in Table 5.

The first theme was related to the idea that students were fast when they used calculators in computation. It was expressed by one teacher that “The use of calculators by students will help them to arrive at a solution to a problem faster.”

The second theme was concerned with the ease with which computations were carried out with the use of calculators. One teacher wrote that “It also makes mathematics interesting and easy for students to solve difficult mathematical problems.” Another teacher was of the view that, “It also makes difficult calculations or questions in mathematics to be calculated with ease.” It was the opinion of one other teacher that, “Basic mathematical computations can quickly be solved with calculators,” and one response was that, “The use of calculators will enable students to be faster and help them to solve complex and computational problems more easily in no time.”
Table 5

*Themes of the High School Teachers’ Responses to the Supplementary Questions*

<table>
<thead>
<tr>
<th>Questions</th>
<th>Themes</th>
<th>Freq</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>What benefits will the use of calculators in learning accrue to your students?</em></td>
<td>Computations with calculators are fast or saves time</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Using calculators in computations is easy</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Accurate results are assured when working with calculators</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Complex and difficult arithmetic can be solved with calculators</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Calculator use is a foundation to the use of computers</td>
<td>10</td>
</tr>
<tr>
<td><em>What setbacks can the use of calculators in learning cause your students?</em></td>
<td>Loss of computational skills</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>The use of calculators makes students lazy</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Malfunction of calculators will give wrong answers</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Affordability of calculators</td>
<td>5</td>
</tr>
</tbody>
</table>

In a similar response, a teacher opined that the calculator “Helps students to work faster during examinations.” Some responses were that, “Calculators enable pupils/students to learn IT fast outside school work,” and calculator users will have the “Ability to work and solve problems faster with little or no mistakes.” Other teachers confirmed that the calculator “Makes teaching and learning process easier, faster, and motivational,” and “It makes the activities of the class move faster.”
For the third theme, the high school teachers mentioned that, “Accurate results are assured when working with calculators.” A teacher said that, the calculator “Ensures accuracy in answers to mathematics problems.” In multiple responses, one teacher indicated that, “Mathematical or computational accuracy, enhances mathematical interest, reduces time spent in calculation or makes computation faster, allows students to solve many (more) problems i.e. enhance practice, promotes technological development in mathematics learning.” Another teacher said, “Comparing the use of calculators to the use of tables (four figure tables), students stand working faster using the calculators on some problems involving the trigonometric identities and terms, logarithms and square roots. The calculator therefore facilitates in working in the above mentioned and stands to give accurate results.”

The fourth theme related to the notion that complex and difficult arithmetic can be solved with calculators. In this regard, one teacher said that, “It helps students during examination to compute complex problems like trigonometry.” One view was that “Difficult numerical calculation can be done neatly and easily e.g. calculation involving decimal fraction and statistics.” Another response was that, “It enables the students to solve more difficult works. It makes the learning and teaching of mathematics more lovely.” One teacher noted, “It helps me in my computational skills hence more proficient in dealing with more difficult scientific or mathematical problems.”

The fifth theme that emerged was that, the use of computers served as the foundation for computers. One teacher said that, “It heightens their desire to use computer to solve math problems.” It was also stated that, “It gives students the idea of using computers,” and another statement was that, “It is a prerequisite skill to the use of
personal computers.” Similarly, it was the opinion of one teacher that, “Calculator use introduces students to computers.”

There were quite interesting responses from some teachers. One such response about the use of a calculator was that, “It will make students do away with the perception that math is a difficult subject.” Another was that, “It's indeed an electronic mathematical and statistical formulae tables which has completely supplanted the traditional four-figure tables. It is a must-have-handy cum accurate teacher/student support material (i.e. it is the sine qua non of mathematics).”

The second supplementary question used to obtain more information from the high school teachers was: “What setbacks can the use of calculators in learning cause your students?” From Table 5, one of the dominant themes was that students would lose their computational skills from continuous use of calculators. One teacher indicated that, “Over reliance on calculators makes students lose their basic computational skills in mathematics.” Another response was that, “Students will miss the skills in calculations.” It was indicated by a teacher that, “It causes the decline of computational skills of students thereby letting students not able to do simple arithmetic problems mentally.”

Another outstanding theme was the reflection of the notion that the use of calculators makes students lazy. One teacher contended that the calculator “Makes students lazy at solving problems without calculators.” Another teacher had this to say about a calculator: “It does not make them to be critical thinkers. The students become lazy.” It was also said that, “Over reliance on calculator makes students lazy and they do not want to use pen and paper alone to solve simple mathematical problems in the absence of the calculator.”
Teachers indicated their concerns about wrong answers resulting from faulty or ineffective use of calculators, and this became the third theme in their responses. “One teacher stated that, “Most students sometimes get wrong answers.” In one response a teacher’s view was that, “Where the student does not know the use of the calculators well he or she gets final results wrong.” A teacher’s assessment of students’ use of calculators was that, “They always take answers from calculators to be correct and final irrespective of any reservations that may go with it.” It was also said that, “Some of the students are also not conversant with the scientific keys thereby not able to use the calculators more effectively and efficiently in solving problems.” It was the conviction of a teacher that, the use of calculators “can bring unexpected failures if calculators develop a fault during its use especially in examinations.”

The additional cost that the acquisition of calculators could impose on parents was the fourth theme teachers’ showed concern about. One teacher indicated that, getting a calculator “increases cost in education,” and it was also stated that “It costs money to acquire a calculator.” And one teacher responded that, “It is extra cost to parents.”
Summary of Major Findings

1. The mean attitude of 2.4630 seems to suggest that Ghanaian teachers tend to have neutral or a slightly positive attitude towards the use of calculators. However, the analysis of their responses to the supplementary questions seemed to tilt towards the likelihood that any policy attempt at attitudinal intervention might not be a difficult task to achieve positive change in attitude towards the use of calculators among Ghanaian teachers.

2. About 80% of teachers would want students to master concepts or procedures before they are allowed to use calculators. The mastery of concepts argument on the part of a considerable number of teachers identify them with United states K-12 teachers involved in a century feud of basic skills versus conceptual understanding. Most teachers believed students should learn how to use the calculator (84% consensus agreement)

3. An overwhelming number of teachers do not use calculators in their classrooms (97%). However, they declared that they knew ways they could use calculators effectively in the classroom (72%).

4. Ghanaian teachers think the use of calculators makes students lazy and the acquisition of these calculators places additional responsibility on parents. However, some teachers contend that calculators are the answer to the computation of complex arithmetic. Opinions were expressed about the use of calculators serving as the springboard to the use of computers.

5. The first hypothesis $H_{01}$ that investigated no difference in mean attitude of elementary school teachers and the mean attitude of high school mathematics
teachers was rejected at $\alpha = .05$ significance level. Hence, there was significant school level difference in teachers’ attitudes towards the use of calculators in mathematics instruction and learning, with high school mathematics teachers having more positive attitudes than elementary teachers, (Appendices K & L).

6. The likelihood of a gender effect was addressed by the second hypothesis. The null hypothesis ($H_{02}$) which stated there was no significant difference between the mean attitudes of female and male teachers was not rejected at the .05 significance level. What appeared as gender effect was rather a school level difference as inferred from the ANOVA test result of $H_{01}$ in Table 3, and also pictorially represented (APPENDICES, K, L, & M).
CHAPTER FIVE: SUMMARY, IMPLICATIONS, AND DISCUSSION

In this study, the researcher investigated the attitudes of elementary teachers and high school mathematics teachers towards the use of calculators in mathematics instruction and learning. Chapter One discussed the importance of calculators as an instructional tool for generating interest and improving achievement in mathematics learning; it also discussed the need for teachers to have positive attitudes towards the use of calculators. In this connection this chapter stated the reason why the use of calculators in instruction should prevail as a matter of policy after many years of lack of support for its practice in mathematics instruction and learning; furthermore which school level the introduction of calculators into instruction and learning was feasible. Thus, this chapter addressed the research questions of the study. Chapter Two reviewed the research literature on the attitudes towards the use of calculators and the how calculator use in mathematics instruction serves as anxiety reduction technique, thereby effecting positive attitude towards mathematics learning. Chapter Three outlined the various steps taken in the methodology for the design, data collection, and analyses of data. Chapter four reported the major findings of the study.

The subjects involved in the study were a sample of 179 elementary teachers and high school mathematics teachers. There were 53 female and 33 male elementary school teachers; and among the 93 high school mathematics teachers, 6 were females. The AIM-AT instrument and two supplementary questions were used respectively to collect data for quantitative and qualitative aspects of the study. For the quantitative part the 23-item *Attitudinal Instrument for Mathematics and Applied Technology* (AIM-AT) was the
survey instrument administered to 179 elementary school and high school mathematics teachers.

The qualitative aspect of the study was addressed by the responses of both the elementary teachers and high school mathematics teachers to the two supplementary open-ended questions. The data were collected in Ghana between July and August, 2007. It is important to mention that at the time of data collection, elementary schools in Ghana had to go on vacation earlier than that indicated on the school’s calendar year 2006/2007. This implied that elementary teachers involved in the survey had to do end of year assessments of their students in the form of class tests at the time they were participating in the study, and this limited their participation. High school mathematics teacher were also scoring (marking) Core and Elective Mathematics of the Senior Secondary School Certificate Examinations, and their participation in this study was affected.

For the quantitative part of the study, the researcher used the 2-way ANOVA to analyze the survey data. In the case of the qualitative aspect, the researcher used thematic coding and classified the major themes that emerged in a frequency table for the analysis of the qualitative data.

In this study the researcher tested three hypotheses using the significance level \( \alpha = .05 \). The first null hypothesis was:

\[ H_{01}: \text{There is no significant difference in the mean attitudes of elementary teachers and high school mathematics teachers towards the use of calculators in mathematics instruction and learning.} \]

That hypothesis was tested against,
H_{A1}: There is significant difference in the mean attitudes of elementary and high school mathematics teachers towards the use of calculators in mathematics instruction and learning.

The result from the 2-way ANOVA was that there was significant difference in the mean attitudes of elementary teachers and high school teachers towards the use of calculators in mathematics instruction and learning, with high school mathematics teachers having more positive attitudes.

The second null hypothesis was:
H_{02}: There is no significant difference in the mean attitudes of female and male teachers towards the use of calculators in mathematics instruction and learning.

That hypothesis was tested against,
H_{A2}: There is significant difference in the mean attitudes of female and male teachers towards the use of calculators in mathematics instruction and learning.

The finding from the 2-way ANOVA was that there was no significant difference in the mean attitude of female and male teachers towards the use of calculators.

The third hypothesis that was investigated involved,
H_{03}: There is no significant interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning.

That hypothesis was tested against
H_{A3}: There is significant interaction between gender and school level with respect to the mean attitudes of teachers towards the use of calculators in mathematics instruction and learning.
The available evidence from the 2-way ANOVA did not contradict the null hypothesis that stated that there was no interaction between gender and school level with regard to teachers’ attitudes towards the use of calculators in mathematics instruction and learning.
Implications of the Results

The results from this study raise some implications to underscore its usefulness. There is the need to share the outcome of this study with recognizable stakeholders who have some role to play in improving instruction and learning of mathematics regarding the use of calculators.

1. High school and elementary school teachers in Ghana might express interest in these results and join the discourse on the rationale for introducing the use of calculators in mathematics instruction and learning.

2. Mathematicians and mathematics educators might share some ideas in the adoption of calculators in instruction and learning especially coming out with suggestions that could help promote a smooth transition towards integration of calculators in instruction and learning in Ghanaian schools.

3. Decision to integrate calculators in instruction and learning would involve curricular concerns leading to the formulation of appropriate curricula incorporating the use of calculators in instruction and learning. Other concerns would be the nature of implementation of calculator integration into the curriculum and assessment issues regarding the use of calculators in examinations. The Ghana Education Service should play a leading role in the event of integrating calculators into instruction.

4. Technology integration such as the use of calculators in instruction and learning would involve enormous budgetary considerations to cater for the overhaul of the educational system. The classroom environment would need electrical facilities and instructional technology equipment, and that would constitute substantial
financial strain on the national budget. Thus, the calculator integration in instruction and learning would require top-level engagement of the Ministry of Education.

5. The cost of education to parents would naturally increase with the type of calculator to be decided on. The responses of teachers to the supplementary questions touched on the additional cost parents would have to deal with when calculators are introduced into instruction and learning. In Ghana, scientific calculators are quite expensive and for that matter parents would be concerned about the increasing cost of education.

**Discussion of Quantitative Results**

The descriptive analysis of the data that addressed the attitude of Ghanaian teachers indicated that Ghanaian teachers showed slightly positive attitude towards the use of calculators in mathematics instruction and learning. That is, there are as much teachers who exhibit positive attitude towards the use of calculators as those who do not. In this situation, it could be possible to pursue awareness programs to change the attitudes of the section of teachers which has negative perception about the use of calculators.

It could be pointed out that the predisposition of Ghanaian teachers towards the use of calculators does not tend to conflict the research literature regarding the role teacher attitude plays in technology integration in mathematics instruction and learning. The major factor known to influence student learning is the teacher (Roueche & Roueche, 1995; NCTM, 2000). In relation to this, the mathematics teacher should have positive attitudes both towards mathematics and the use of resources such as calculators to make
mathematics fun and meaningful to students (Cornell, 1999; Currence, 1993; Niess, 2006; Schwartz, 2000). The slight demonstration of positive attitudes among Ghanaian teachers could be considered a development in the right direction.

Most teachers believed students should learn how to use the calculator (84%). However, 80% of teachers would want students to master concepts or procedures before they are allowed to use calculators. In the United States, prominent mathematics educators and mathematicians have begrudged this dichotomy between conceptual understanding and the acquisition of basic skills; and as a result conventional wisdom has moved towards a common ground settlement (Mathematical Association of America [MAA], 2006). The mastery of concepts argument on the part of a considerable number of teachers constitutes a philosophical orientation that tends to de-motivate some teachers from using calculators for mathematics instruction and learning (Fleener, 1995).

From the literature, a case has been made for the use of calculators in instruction and learning (Acelajado, 2003; Almeqdadi, 1997; Demana & Waits, 2000; Hembree & Dessart, 1986, & 1992; Kilpatrick, 1992; Schultz, 1994), yet its use in mathematics instruction and learning has not been encouraged by policy in Ghana. Given the fact that the attitudinal predisposition of Ghanaian teachers does not appear negative towards calculator use, a shift in policy change in favor of calculator integration in mathematics instruction and learning could have a positive impact on teachers’ perception about calculator use and consequently improve mathematics instruction and learning.

According to findings from this study, even though considerable number of teachers do not use calculators in their classrooms (97%), the teachers nevertheless declared they knew ways they could use calculators effectively in the classroom (72%).
The two-way analyses of variance concluded that there was significant difference in the mean attitudes of elementary and high school teachers towards the use of calculators in mathematics learning and instruction. Similarly, in the research literature, more positive attitude among high school mathematics teachers has been documented compared to elementary school teachers (Alzahrani, 2004; Miller, 2004; Wu, An, & Wang; 2005).

From the ANOVA analyses, gender was not an influencing factor in the attitude towards calculators, hence there was no significant interaction between gender and school level and for that matter no difference between male and female teachers regarding their attitudes towards the use of calculators. This outcome does agree with a similar study conducted by Alzahrani in 2004. From the literature, the gender disparity in attitude towards the use of calculators that favored males in the 1970s and 1980s appears to have closed (Mullis, Martin, Fierros, Goldberg, 2000), and even reversed in some instances in favor of females (Dunham, 1991; Ruthven, 1990). This study confirms the same finding with regard to teachers in Ghana.

Discussion of Qualitative Results

The results from the supplementary questions gave expression to generally positive attitudes of Ghanaian teachers towards the use of calculators. Teachers’ responses to the supplementary questions which asked their views about the benefits and setbacks of the use of calculators were quite revealing. In their responses to the supplementary questions both elementary and high school teachers gave equivalent responses regarding the benefits and disadvantages associated with the use of calculators.
Among the disadvantages or setbacks were that students become lazy and also that the malfunction of the calculator could give wrong results or answers. Teachers were of the opinion that scientific calculators are not readily affordable and could add to the burden of parents’ sponsorship of their wards’ education. The affordability of scientific calculators has been an issue in the literature. A major incentive for the acquisition and use of calculators is that it should be considerably cheap for users (Howe, 1999). In the absence of more affordable graphing calculators, the immediate alternative is a switch to the usual traditional paper and pencil computation of complex arithmetic. A situation where calculators are not relatively affordable could impact negatively on teachers’ attitudes towards the use calculators in mathematics instruction and learning.

Teachers indicated that the use of calculators by students in computation would make students lose their mental computational skills. This might partly account for the reason why the elementary teachers were less favorably inclined towards calculator use; a position quite at variance with contemporary literature. Research evidence has indicated that the use of calculators has positive effects on students’ mental computation and could even sharpen their estimation skills (Acelajado, 2003; Almeqadi, 1997; Demana & Waits, 2000; Hembree & Dessart, 1986, & 1992; Kilpatrick, 1992).

Teachers perceived that the benefits calculator use could offer students appear to outweigh the disadvantages they expressed about using calculators. Both elementary and high school mathematics teachers responded that the use of calculators is fast or saves time, makes computation easy, and facilitates complex arithmetic computation. This perception conforms to the literature on the learning and instructional gains that
calculator use could bring to the user (Acelajado, 2003; Almeqdadi, 1997; Demana & Waits, 2000; Kilpatrick, 1992; NCTM, 2000).

High school mathematics teachers shared additional views on the use of calculators with the revelation that calculator use serves as a foundation to computers. There is not much doubt about the correspondence between scientific calculators and computers because computer algebra systems are mini computers explicitly stipulated in the research literature (Aiken, 1976; Collins, 1996; Funkhouser, 1993; Ganguli, 1992)

It is worthy of note an opinion expressed by one high school teacher that calculator is simply *sine qua non* for mathematics. The role the calculator plays in mathematics instruction is highlighted in the NCTM (1991, 2000) standards. Furthermore, AMTE (2006) has emphasized “that the computational and graphical capabilities of current technologies (including calculators) enable users to efficiently generate and manipulate a variety of representations of mathematical ideas and processes.” (p. 1). In addition, instruction that makes effective use of technology can provide the necessary encouragement and support for students’ mathematical concept exploration and knowledge construction. The teacher’s attitude aligns considerably with current developments in calculator use in mathematics instruction and learning (AMTE, 2006; Demana & Waits, 2000; Foley, 2007; Kilpatrick, 1992; Pierson, 2001).

The significant difference between high school mathematics teachers’ attitude and their elementary school counterparts could not have found a better expression than an assertion of a high school teacher in response to one of the supplementary questions. The teacher stated that calculator use will decrease students’ perception that mathematics is a difficult subject. The literature is unequivocal about the attempts to enrich the traditional
mode of instruction for effective mathematics instruction and higher student achievement or performance using instructional tools such as calculators (British Broadcasting Corporation, 2006; NRC, 1989; NCTM, 1991, 2000; UNESCO, 2004). The role of calculator use in reducing mathematics anxiety both among teachers and learners (Astin, 1993; Bitter & Hatfield, 1993; Sundararajan, 1995; Trichett, 1997; Uusimaki & Nason, 2003) is also captured in the teacher’s statement.

Limitations of the Study

1. The study was conducted in suburb of the city of Kumasi, thus a very large section of the population of teachers was left out. In particular, teachers in rural schools were not included.

2. The study coincided with the time elementary teachers had to comply with a directive of doing their end of year class assessments. Some teachers completed the AIM-AT but said they did not have time for the supplementary questions. Also some high school mathematics teachers who were scoring (marking) SSS examinations could not attend to the open-ended supplementary questions.

3. The data collection was done within three weeks between July 12 and August 17 2008 which was quite short raising the concern about the possible effect insufficient time could have had on the study. For instance, extension in time could have permitted participants who declined responses to the supplementary questions to do so.

4. Junior high schools and post secondary institutions were not involved in this study and their inclusion could have had some impact on the outcome of the study.
5. The study implies policy considerations and should have involved heads of educational institutions, policy makers and the university communities to obtain their inputs for comprehensive and varied opinions.

6. Sample of participants was not truly random; this could have affected the ANOVA assumptions.
Recommendations

1. This study should be replicated in other regions of Ghana and in larger number of institutions to have a national reflection of teachers’ attitudes towards the use of calculators in mathematics instruction and learning.

2. The study should be pursued over an extended period to have better participation of teachers. The shortcomings of the current research in terms of its participation compromised by teachers’ professional assignments should guide future replication of this study.

3. The Ministry should set up a task force and review its policies regarding the use of calculators in mathematics instruction learning by introducing calculators systematically in the high schools because the high school mathematics teachers are comparatively more favorably inclined towards calculator use.

4. Prior to the effecting the integration of calculator use in instruction and learning, future workshops on ICT should have resource persons address specifically current developments in calculator use in mathematics instruction and learning.

5. Policy formulation of integrating calculators into instruction and learning should be preceded by experimental research comparing the achievement of control and experimental groups of students that will use calculators in learning. The model high schools that have been set up in the various regions could serve this purpose with the expectation that higher achievement in the experimental group could in turn have a positive impact on high school mathematics teachers’ attitudes towards the use of calculators in instruction and learning.
6. Ghana’s mathematical instructional delivery is teacher-centered, a major problem of mathematics instruction known to be the major cause of mathematics underachievement and boredom. Having regard to the position of UNESCO on traditional instructional practice, the use of calculators in mathematics instruction and learning should be encouraged to ensure student self- and group participation in mathematics engagement.

7. The discourse emerging from the conclusions of this study should engage the attention of educational associations such as Mathematical Association of Ghana (MAG) and Ghana Association of Science Teachers (GAST), and National Union of Ghana Students (NUGS).

**Concluding Statement**

There is an enormous contribution of technological development to all facets of our lives. In the field of education, educators are concerned with how to integrate technology into instruction to improve the quality of mathematics instruction and also enhance student performance. There is increasing evidence of the impact of calculators (especially graphing calculators) on mathematics instruction and learning. Apart from the study of Giamati (1991) where the control group performed better than the experimental group that used calculators, and a couple of studies (Army, 1993; Tolias, 1993) which did not find significant difference between the experimental and control groups regarding the use of calculators in learning, the literature is pregnant with the positive impact of calculators on mathematics instruction and learning (Acelajado, 2001; Almeqdadi, 1997; Demana & Waits, 2000; Dunham & Dick, 1994; NCTM, 2000; NRC, 2001; Rudil, 2000).
The research literature has consistently concluded that students who used graphing calculators achieved greater performance in and more favorable attitudes towards mathematics than those who did not use calculators. According to the literature, students are able to compute faster and therefore have more time to explore for conceptual understanding. Almost all studies that were carried out found a significant difference between the experimental group and the control group.

Ghanaian teachers have indicated that even though they do not teach currently with calculators, they declared that they knew ways they could use calculators effectively in the classroom. This declaration especially by high school teachers strengthens the contention of the fact that privately, they have been using calculators in a considerable way.

In this light it is high time policy makers took a detour from their relaxed posture and came out with policies that would create the awareness of the important role calculators play in mathematics instruction and learning. This awareness would be a prelude to the pursuit of a globally consistent policy on instructional technology, specifically improving teacher attitude towards the use of and eventual adoption of calculators in mathematics instruction and learning.
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APPENDIX A: DESCRIPTIVE STATISTICS (DEPENDENT VARIABLE: MEAN ATTITUDE OF TEACHERS)

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<th>LEVEL OF SCHOOL</th>
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### APPENDIX B: BETWEEN-SUBJECTS FACTORS

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<td>59</td>
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</table>
APPENDIX C: ATTITUDINAL INSTRUMENT FOR MATHEMATICS AND APPLIED TECHNOLOGY (AIM-AT)

1. Students should not be allowed to use a calculator while taking math tests.
   
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE  
   (D).STRONGLY DISAGREE

2. Calculator use will cause a decline in basic arithmetic facts.
   
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE  
   (D).STRONGLY DISAGREE

3. Calculators are motivational.
   
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE  
   (D).STRONGLY DISAGREE

   
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE  
   (D).STRONGLY DISAGREE

5. When students work with calculators, they don’t need to show their work on paper.
   
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE  
   (D).STRONGLY DISAGREE

6. Mathematics is easier if a calculator is used to solve problems.
   
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE  
   (D).STRONGLY DISAGREE

7. More interesting mathematics problems can be done when students have access to calculators.
   
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
(D).STRONGLY DISAGREE

8. Students understand mathematics better if they solve problems using paper and pencil.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

9. Students should not be allowed to use calculators until they have mastered the concept or procedure.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

10. All students should learn to use calculators.
    (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
    (D).STRONGLY DISAGREE

11. Using calculators will make students try harder.
    (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
    (D).STRONGLY DISAGREE

12. Calculators should be used only to check work once the problem has been worked out on paper.
    (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
    (D).STRONGLY DISAGREE

13. Calculators should be used on mathematics homework.
    (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
    (D).STRONGLY DISAGREE

14. Using calculators will cause students to lose basic computational skills.
15. Using calculators makes students better problem solvers.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

16. Continued use of calculators will cause a decrease in student estimation skills.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

17. I have calculators available for my class(es) to use.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

18. Most of my students have access to their own calculators.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

19. Calculators are only tools for doing calculations more quickly.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

20. I have used graphing calculators in my classroom before.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

21. I am proficient at using scientific calculators.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE
22. I know ways I can use the calculators effectively in my classroom.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE

23. I have lots of ideas about how I can make use of this calculator.
   (A).STRONGLY AGREE   (B).AGREE   (C).DISAGREE
   (D).STRONGLY DISAGREE
--- M Jayne Fleener <fleener@lsu.edu> wrote:

> Dear James,
> 
> > I apologize for the delay in responding. I'm glad
> > for the prompting of your second email.
> >
> > I am honored and am pleased to provide you with my
> > permission to use the instrument. All I ask is that
> > you share your results when you study is completed.
> >
> > Best wishes,
> >
> > Jayne Fleener
> >
> > -----Original Message-----
> > From: "James Adabai" <adabai1@yahoo.com>
> > To: "fleener@lsu.edu" <fleener@lsu.edu>
APPENDIX E: SUPPLEMENTARY QUESTIONS

1. What benefits will the use of calculators in learning accrue to your students?

2. What setbacks can the use of calculators in learning cause your students?
APPENDIX F: CATEGORIES OF AIM-AT

Category 1: Cognitive

Description: Beliefs about effect and appropriate use of the calculator.

Items: 1, 2, 5, 6, 8, 9, 10, 12, 13, 14, 15, 16, 19

1. Students should not be allowed to use a calculator while taking mathematics tests.

2. Calculator use will cause a decline in basic arithmetic facts.

5. When students work with calculators, they don’t need to show their work on paper.

6. Mathematics is easier if a calculator is used to solve problems.

8. Students understand mathematics better if they solve problems using paper and pencil.

9. Students should not be allowed to use calculators until they have mastered the concept or procedure.

10. All students should learn to use calculators.

12. Calculators should be used only to check work once the problem has been worked out on paper.

13. Calculators should be used on mathematics homework.

14. Using calculators will cause students to lose basic computational skills.

15. Using calculators makes students better problem solvers.

16. Continued use of calculators will cause a decrease in student estimation skills.

19. Calculators are only tools for doing calculations more quickly.

Category 2: Experiential

Description: Experience with the use of calculators in teaching.
Items: 17, 18, 20, 21, 22, 23

17. I have calculators available for my class(es) to use.
18. Most of my students have access to their own calculators.
20. I have used graphing calculators in my classroom before.
21. I am proficient at using scientific calculators.
22. I know ways I can use the calculators effectively in my classroom.
23. I have lots of ideas about how I can make use of this calculator

**Category 3: Affective**

Description: Beliefs about affective results of using calculators in the classroom

Items: 3, 4, 7, 11

3. Calculators are motivational.
8. More interesting mathematics problems can be done when students have access to calculators.
11. Using calculators will make students try harder.
APPENDIX G: LETTER OF INTRODUCTION TO ELEMENTARY AND HIGH SCHOOLS

GHANA EDUCATION SERVICE

In case of reply the number and Date of this letter should be quoted
Tel. No. 247/81, 24544/0, 24545

Our Ref.:  
Your Ref: .........................  Date: 19 July, 2007

REGIONAL EDUCATION OFFICE
P. O. BOX 1996
KUMASI

GOVERNMENT OF GHANA

LETTER OF INTRODUCTION

MR. JAMES KOFI ADABOR (5996/73)
(ASSISTANT DIRECTOR OF EDUCATION)

Mr. James Kofi Adabor an Assistant Director prior to his departure to under-take post-graduate studies in Mathematics Education in the United State of America was a Principal Instructor at Kumasi Polytechnic.

James needs to carry out a research into teachers’ attitudes towards the use of calculators in mathematics teaching and learning; a requirement for the completion of his program of study. This research is to be conducted in the 1st and 2nd cycle schools in Kumasi.

I would appreciate it if you could give Mr. Adabor the support he deserves.

.........................
Festus Biodi-Suadwa
Deputy Regional Director.

For: Regional Director/Ash.

TO WHOM IT MAY CONCERN.
APPENDIX H: INSTITUTIONAL REVIEW BOARD (IRB) SUBMISSION

APPROVAL

A determination has been made that the following research study is exempt from IRB review because it involves:

Category 2 - research involving the use of educational tests, survey procedures, interview procedures or observation of public behavior

Project Title: An Investigation into Elementary School Teachers' and High School Teachers' Attitudes towards the Use of Calculators in Mathematics Instruction and Learning: A study of selected schools in Ghana.

Project Director: James Adabor

Department: Teacher Education

Advisor: George Johanson

Robin Stack, C.I.P., Human Subjects Research Coordinator
Office of Research Compliance

Date: 07/05/07

The approval remains in effect provided the study is conducted exactly as described in your application for review. Any additions or modifications to the project must be approved by the IRB (as an amendment) prior to implementation.
APPENDIX I: RELIABILITY STATISTICS

<table>
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<th>Cronbach's Alpha</th>
<th>Cronbach's Alpha Based on Standardized Items</th>
<th>N of Items</th>
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<td>.757</td>
<td>.751</td>
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APPENDIX J: LEVENE’S TEST OF EQUALITY OF ERROR VARIANCES

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<th>F</th>
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<th>df2</th>
<th>Sig.</th>
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<tr>
<td>.368</td>
<td>3</td>
<td>175</td>
<td>.776</td>
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</tbody>
</table>

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
Design: Intercept+LEVEL+gender+LEVEL
APPENDIX K: LINE GRAPH OF TEACHERS ATTITUDES BY SCHOOL LEVEL

NAME OF SCHOOL

LEVEL OF SCHOOL
- ELEMENTARY
- HIGH SCHOOL

NAME OF SCHOOL

MEAN2
APPENDIX L: BAR GRAPH OF ATTITUDES OF TEACHERS BY SCHOOL LEVEL
APPENDIX M: PROFILE PLOT BY GENDER

LEVEL OF SCHOOL

Estimated Marginal Means

GENDER

- MALE
- FEMALE

LEVEL OF SCHOOL

ELEMENTARY SCHOOL

HIGH SCHOOL
APPENDIX N: HISTOGRAM AND FITTED CURVE OF ATTITUDES OF TEACHERS

Mean = 2.463
Std. Dev. = 0.37266
N = 179