EFFECTS OF THE USE OF ELECTRONIC CALCULATOR ON OUTCOMES OF MATHEMATICS INSTRUCTION

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ABSTRACT

The teaching - learning of mathematics in the primary and secondary schools is often characterized by algorithmic computations to the detriment of concept learning and problem-solving. Invariably pupils often become disinterested in the tedious mathematical computational chores. This study was therefore, set up to investigate the effects of the use of electronic calculators on the outcomes of mathematics instruction. The learning outcomes investigated were achievement in mathematics and attitudes toward mathematics and calculators.

A paradigm of 3 x 3 factorial design of three ability levels: high, average and low by treatment groups : two experimental groups - unrestricted calculator and restricted calculator groups, and a control group - the non-calculator groups were used. There were two stages of the study: Pilot and Main. The pilot study was carried out in only one school and lasted six weeks while the main study took place in three comparable schools and had a duration also of six weeks. The schools were mixed in all cases. These schools were selected by multi-stage random sampling from ninety-five secondary schools in Ibadan municipality at the time.

For the main study, 126 subjects selected from three schools completed the study. The following null

hypotheses were tested at $\alpha = .05$. There will be no significant difference in the achievement scores of pupils who use (i) calculators in instruction and tests (the unrestricted groups) (ii) calculators in tests only (restricted groups) and (iii) no - calculators at all groups. The null hypothesis one was rejected because there was significant difference in the mean post-test scores of those groups who used calculators in instruction and tests, calculators on tests only groups, and non-calculators groups ($F(2,123) = 16.234$, $p < .001$) (2) There will be no significant difference in the achievement scores of pupils of low, average and high mental abilities. The null hypothesis two was rejected because there was significant difference in the mean post scores of those groups of low, average and high mental ability levels ($F(2,123) = 14.776$, $p < .001$) (3) There will be no significant difference in the attitudes towards mathematics and calculators of pupils who use calculators in instruction and tests, (ii) calculators in tests only, and (iii) non-calculators at all. The null hypothesis three was not rejected in entirety because there was no significant difference in the post attitude scores of the groups who use calculators in instruction and tests, calculators in tests only groups and non-calculator groups ($F(2,123) = 1.217$, $p > .05$).

(4) There will be no significant difference in attitude towards mathematics and calculators scores of those groups of high, average and low mental abilities. The null hypothesis four was not rejected entirely because there was no significant difference in the mean post-attitude scores of those groups of high, average and low mental ability levels ($F(2,123) = 2.147$, $p > .05$).

(5) There will be no significant relationship between the attitudes of pupils towards mathematics and calculator-use in mathematics. The null hypothesis five was not rejected because there was no significant relationship between pupils' attitudes towards mathematics and calculator-use ($F(1,124) = 1.57$, $p > .05$).

(6) There will be no significant relationship in pupils' mathematics achievement scores and post-attitude scores. The null hypothesis six was rejected because there was significant relationship in the post-test scores of the groups and the post-attitude scores ($F(1,124) = 4.84$, $p < .05$). Generally, the results showed that there

were attitudinal changes between pre- and post-attitudes among all the groups, and that the calculator groups performed better than the non-calculator groups. The results have also shown that pupils within the same ability levels who use calculators will perform better than those who do not use calculators.

Most studies on the use of calculators including this one have not found calculators to have debilitating effects rather it has computational advantage and promotes high achievement gains in mathematics. Teachers and pupils in secondary schools should be encouraged to utilize the advantage of calculators in algorithmic computations, so as to reduce those computational chores which often led to loss of interest in learners. However, further research could be done into the effectiveness and efficiency of calculators in concept formation, and problem-solving in secondary schools. In addition, research could be done to find out its effects at primary school level in Nigeria.

D E D I C A T I O N

This work is dedicated to my wife, Ayoola, children: Omowumi, Olufemi, Abiola and Oluwadara, my parents and to the greater glory of God.

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PAGE

CERTIFICATION

I certify that this work was carried out by Mr. Alade Abimbade in the Department of Teacher Education, University of Ibadan.

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CHAPTER ONE

INTRODUCTION

1.1 The background to the study

The need for man to facilitate mental calculations, and the problem of arithmetic computation with stones in the sand, strokes on the wall, in all probability, were attempts which later gave rise to more sophisticated items, such as the Abacus. Thus, Abacus became the first attempt of a calculating device used to perform arithmetic operations such as addition, subtraction, multiplication and division.

The Egyptians and Greeks had used Abacus many thousands of years ago. Different forms of Abacus can be found among the Indians and Chinese. According to Herodotus, a Greek scholar, the Abacus of the type in (Fig. 1) was used by the Egyptians and the Greeks.[1]

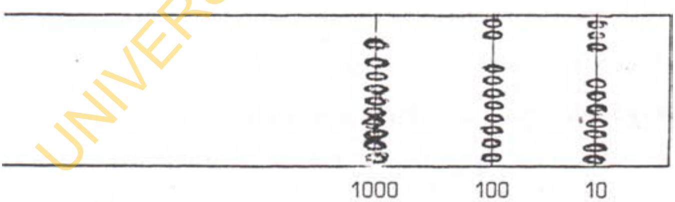

Fig. 1: Abacus No. 23

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1. The Encyclopedia Americana, International Edition, New York: Americana Corporation, Vol. 5, 1974, pp. 161 - 163.

Educationally Abacus is useful as a teaching device to give young pupils a better understanding of place-value in the decimal system of numeration. It is generally made up of several parallel wires running across the width of a frame, and the beads are strung on the wires and are used as counters (See Fig. 1). For example in a decimal system of numeration, the separate wires represent units of 10's, 100's, 1000's and so on. There are usually 10 beads on each wire, so that each bead stands for a unit of place-value in the decimal system of numeration.

The simplest kind of calculating machine is an adding machine which mainly performs addition and subtraction operations. However, machines that can perform other mathematical operations such as multiplication, division etc. are called calculators. Both calculators and adding machines are classified as digital devices because the numerical quantities in the machine are represented by a sequence of digits. The first true mechanical calculator, however, was more of an adding machine. It was designed by Blaise Pascal[1]. The adding machine had a series of wheels with the numbers of 0 to 9 engraved on their circumferences and could perform addition with 'carrying'.

Leibniz[1] designed a real calculating machine that could add, multiply, by repeating addition. In 1822 (Babbage, Charles)[1] built a small six-decimal place calculating machine which could perform arithmetic operations like addition, subtraction, multiplication and division. Most of the mechanical calculating machines built in the nineteenth century had register-full-key board (printing or non printing). Most of the full-key board printing or non-printing machines are now electronically operated instead of manual operations. There is also the mechanical rotary calculator.

1.1.1 <u>The Electronic Calculator:</u>

The electronic calculators, the subject of this study performs functions midway between those of a mechanical desk calculator and an electronic computer. It adds, subtracts, multiplies, divides and it also automatically stores intermediate answers for further calculation (Fig. 2).

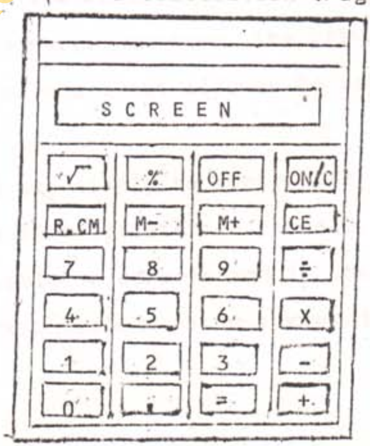

Fig. 2: Model of modern Electronic Calculator.

Most electronic calculators have a cathode ray tube as the out-put device, the computational results appear on the cathode ray screen, which can display as many decimal places as are provided in the calculator. However, the calculator used for this study, and like most hand-held electronic calculators, can display up to eight places of decimal. Many of these calculators have storage facilities with memory. Though some electronic calculators are programmable externally, most hand-held calculators are not, and the ones for this study were not programmable. Some other electronic calculators also have internally stored programmes. These programmes usually are shorter than programmes of the large automatic computers.

Hand-held calculators are used in this country in higher institutions, industry, commercial and business houses. It was not too long ago that the uses of calculators were allowed in mathematics and science-based courses in higher institutions of the country. However, the primary and secondary schools' pupils are not allowed to use calculators at all in the school.

Several factors are likely to contribute to the opposition of the use of calculator in schools. First, few calculato s are available in schools and in the country in general. In consequence most pupils do not have access to the use of calculators.

Also pupils are not allowed to use calculators in classroom instruction and in tests of mathematics in primary and secondary schools. There is a ban on the use of calculators in the West African School Certificate Examinations particularly the General Certificate of Examinations and the Joint Admission and Matriculation Board Examination into the Universities.

Four-figure table and slide rule are available in schools and their uses are taught to pupils in the lower forms of secondary schools; and it would have been expected that electronic calculator could be used in the school system to do the same computations, even faster. Would this have been because of limited availability of the device in the country? Or would it be because of a fear of modern technology and its application that is, by teachers and educators? The design of this research was not meant to pursue the probable reasons for teachers' and educators' attitudes toward calculator usage (left to future researchers) rather it investigated the impact of calculator use on the instructional process. The study however, did try to find out it there were other empirical studies relating to the attitudes of teachers and educators vis-a-vis calculator usage in schools.

In developed countries and to some extent in N i g e r i a many voic s have been heard debating t h e v i r t u e s and dangers of calculator usage. A few have cried out in fear that the use of calculator would result in pupils who cannot remember basic facts or do traditional paper-and-pencil computation. Teachers, in particular, are concerned about how calculators will affect students computational skills (Palmer)[2]. However, this fear of "rot-the-mind theory" has not been supported by research (Suydam)[3]. Although long-term effects of sustained calculator usage are not yet known, there is ample evidence that frequent use of calculators in elementary schools has no detrimental effect on achievement in mathematics (Suydam)[3].

However, the rapid growth and sales of inexpensive calculators and their consequent widespread availability to pupils and teachers demand that the mathematics curriculum be re-examined and that teachers could use calculators as an instructional tool. Throughout the country, mathematics as a school subject has been made compulsory at both primary, secondary and teacher training levels. All school pupils have to take mathematics examination in their final year, and this has led to the general anxiety among most

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2. Palmer, H.B.A. Mini calculators in the classroom - What do Teachers Think? <u>Arithmetic Teacher</u> 25(7) 1978, 27 - 28.

3. Suydam, N. M. "The use of calculators in Pre-college Education: A state of the Art Review". Columbus, Ohio: Calculator Information Center, May, 1979.

pupils particularly those who find mathematics difficult. The results of pupils in mathematics examinations at primary and particularly secondary school levels of education have not been encouraging (See tables 1 & 2).

TABLE 1

Detailed WASC Result in Mathematics for Nigeria - June, 1970

Grades	F9	P8	P7	C6	C5	C4	A3	A2	A1
Percentage Performances	52	13	10	11	4	3	6	1	1
Total Candidates	13338	3319	2480	2704	915	763	1359	319	189

Source of Information: WAEC Annual Report, 1970.

TABLE 2

Percentage Failures in WASC Mathematics for Nigeria, 1965 - 1976

Year	1965	1966	1967	1968	1969	1970	1971	*	1973	1974
Percentage	33	33	34	37	51	53	39	*	55	49

Year	*	1976
Percentage Failure	*	51

Source of Information: WAEC Annual Reports, 1965-1977.

* No data were available for 1972 and 1975.

The Federal government of Nigeria through ministries of Education and other educational agencies had made efforts to improve the teaching-learning of mathematics in our school systems and these have been seen in the different programmes launched by government to bring about favourable results in mathematics performance. For example, there was the "traditional to modern mathematics" episode and yet there had been not much improvement.

Learning of mathematics involves computational and problem-solving skills. Pupils with good memory are generally proficient in basic computational skills even though they may fail to grasp what should be done in a problem-solving situation (Etlinger)[4]. A successful educational programme must try to include effective instructional materials, which would for a subject like mathematics incorporate the use of calculator. Mathematics is taught at all levels of education so that it can be used in-real-like situations, hence much emphasis must be placed on comprehension, analysis and reasoning than on mere memorization or computational skill which could be done with calculator. Researchers in developed countries like Japan, United State of America have shown that calculators have a greate advantage in computational use (Suydam)[3]. It would therefore be logical to integrate calculator-use in problem-solving situations and pupils would best be served of rigorous training is given in this area. It has also been

4. Etlinger, L. The Electronic Calculator: A new trend in School Mathematics. Educational Technology Journal, 14 Dec., 1974, 43-45.

found that pupils waste a lot of time on computation than the analytical part of problems and in many cases, the time-consuming computations involved in mathematics may invariably block the pupils' minds from even attempting to find the solution of the problem (Palmer)[2]. This is where the calculator has its greatest use because it would relieve pupils of the tedious computational factor in the problem and allow them to concentrate on how the problem would be attacked and solved. Problem-solving is in the higher hierarchy than the concept learning, (Gagne')[5] and it would therefore, be expedient to study how to integrate calculator-use into the school mathematics programme so as to find out most efficient and effective mode of learning mathematics concept which would bring about a positive attitude towards the subject.

The m a i n focus of this study was on electronic calculator-use and instruction with the primary objective of comparing groups that were allowed to use electronic calculators and those that were not allowed to use them. It should be emphasised that the purpose of this investigation however, was not to show pupils how to operate electronic calculators just for computational benefits alone, but rather to try to show how they could be more

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5. Gagne', R.M. The Conditions of Learning. New York: Holt, Rindhart & Winston, 1970, pp. 155 - 170.

effectively and/or effectively used to solve mathematical problems. One difficulty that has constantly surfaced in recent calculator research is the failure of most researchers to carefully build into their research design the experimental treatment in such a way that it would take advantage of the unique capabilities of electronic calculators (Suydam).[3] Also, in developing attitudinal criteria care would have to be taken about pupils' immediate reactions concerning their feelings about themselves and the problems they would have completed. The present investigation endeavoured to integrate calculator-use into the instructional process, and to administer Likert-type attitudinal measure to assess pupils attitudes towards mathematics as a school subject and their attitudes towards the use of electronic calculator and mathematics in the secondary schools.

1.2 Statement of Problem

What effects would the use of calculators have on our school programmes? Should they be used in elementary and secondary schools mathematics programme? If so, with what level of pupils? How do pupils feel about using calculators in the mathematics programme? Should calculators be used in test such as General Certificate Examinations, Joint Admission and Matriculation Board Examinations? Should the use of calculators be integrated into mathematics curriculum and textbooks?

Would the pupils who use calculators in instruction and tests perform better than pupils who do not? Would the use of calculators aid the pupils in the development of basic concepts in mathematics? Accurate answers to these questions are essential in assessing the current status of calculator and more importantly, preparing for calculator usage in the mathematics curriculum and for examinations in our schools systems.

This study endeavoured to find the effects of the use of hand-held electronic calculators in pupils' attitude and performance in mathematics instruction. Specifically answers were sought to the following questions.

1. Would there be any difference in the mathematics achievement scores of those students who use calculator (the treatment groups) and those who do not use calculators (the control group)?
2. Would there be any difference in the attitude of those students who use calculators (treatment groups) and those who do not use calculators (the control group)?
3. Do students differ in their mathematics achievement on the basis of differences in mental abilities?
4. Do students differ in their attitudes towards mathematics and calculator-usage on the basis of differences in mental abilities?
5. Is there any relationship between students mathematics achievement and attitudes?
6. Is there any relationship between students' attitudes towards calculator usage and mathematics?

In order to answer these questions the following null hypotheses were tested at .05 alpha level:

1.3 The Hypotheses:

1. There will be no significant differences in the achievement scores of pupils who use:

   (i) Calculators in instruction and tests (E_1) groups,

   (ii) Calculators in tests only (E_2) groups, and

   (iii) no-calculators at all (E_3) groups, i.e.

$$Ho: ME_1 = ME_2 = ME_3 \text{ at } \alpha = .05$$

2. There will be no significant difference in the achievement scores of pupils of high (C_1), average (C_2) and low (C_3) mental abilities, i.e.

$$Ho: MC_1 = MC_2 = MC_3 \text{ at } \alpha = .05$$

3. There will be no significant difference in the attitude towards mathematics and calculator scores of pupils who use:

   (i) Calculators in instruction and tests (E_1) groups,

   (ii) Calculators in tests only (E_2) groups and

   (iii) no calculators at all (E_3), groups, i.e.

$$Ho: XE_1 = XE_2 = XE_3 \text{ at } \alpha = .05$$

4. There will be no significant difference in attitude towards mathematics and calculator scores between pupils of high (C_1), average (C_2) and low (C_3) mental abilities, i.e.

$$Ho: XC_1 = XC_2 = XC_3 \text{ at } \alpha = .05$$

5. There will be no significant relationship between the attitudes of pupils to mathematics and calculator-use in mathematics as $\alpha = .05$.

6. There will be no significant relationship in pupils' mathematics achievement scores and post attitudes towards mathematics and calculators scores at $\alpha = .05$.

1.4. Significance of the study

From available records, no empirical studies have been undertaken in Nigeria as to the use of electronic hand-held calculator in our school system. However, comments, as to the use of calculator by elementary and secondary school pupils, by teachers, parents, educators, school administrators and concerned citizens have rather been mere speculations. Since there are no empirical studies in the country to back such speculations hence the need for this study.

According to Suydam[3], several stuuies on the use of electronic calculator in mathematics at all levels of education anound in many of the developed countries like the United States of America, Britain, yet few studies had been undertaken in the are of differential effects of the electronic calculator and instruction on concept learning in and attitudes to mathematics. Etlinger[4] reported studies carried out with respect to the use of calculators in the elementary school mathematics and some of the studies which bother on concept learning and attitudes had inconclusive results.

It is the growing awareness of the usefulness of electronic calculators on the part of Nigerians, and the availability of hand-held calculators in and outside school system in the country which have prompted this study. One would want to find out the impact the use of calculators would have on the school system. Some interesting and fundamental questions could be raised in respect of the use of electronic calculators in our school system. Does our school system need a calculator-use policy? Should calculators be available to pupils at all levels of education, primary, secondary and teacher training colleges? Should calculators be encouraged for the topmost classes in the primary school? Would the teachers allow the use of calculators in the classroom during instructions and tests? Should special training be needed to use calculators effectively? Would the use of calculators by school pupils not make them mentally lazy? Should mathematics textbook have activities written for calculator usage?

Before attempts are made to answer these questions, possible role(s) of electronic calculator in school mathematics programme should be identified. Etlinger[4] has characterized two differing views on the use of the calculators, a functional view and a pedagogical view. In the purely functional view, the calculator is considered as a device much like slide rule, log-table - a device that can do the chores involved in tedious arithmetic computation, thus saving time and frustration. The other view, a pedagogical one, looked at the calculator much like a textbook, flash cards, or manipulative device to facilitate learning. Both uses could be good or bad depending on the task to be performed and the age of the pupil.

It was on the basis of these views that issues were raised thus: (i) would calculator maintain a motivational value over several years of pupils' use or would it become a more common place household object?

(ii) Can the calculator be made to help with the learning of facts and algorithms or will its availability hinder mathematics learning?

(iii) Will experimentation with the calculator teach children about numbers and operations or merely about the calculator?

(iv) What types of directed activities would be most appropriate for pupils at various ages?

(v) Will pupils think less about different methods for solving a problem because it is now more expedient to find the easiest or shortest method? Or will children experiment with many methods of solving a problem because it is easy to try different methods on calculator, and interesting to compare solutions?

(vi) Will the idea behind the arithmetic operations be more widely understood because the pupils have immediate feedback from the calculators? Will the patterns be easier to grasp?

However, a somewhat philosophical question which has often been asked about any new teaching-learning devices be it programmed text, computers, calculators etc is this: Is modern technology providing a learning facility or a learning crutch? Here, it seems educators must become sensitive to the effects of modern technology on their pupils and in particular to whether pupils are becoming more dependent on motivational and educational devices for thinking and learning.

The issues raised above are pertinent to this study and one hoped that the results of this study would be able to offer some answers to these questions. Some studies which were carried out in developed countries like the United States of America and Japan that electronic calculators have some of those useful applications which are relevant to this study.

The hand-held calculator has been found to motivate and encourage students to be inquisitive and creative as they experiment with mathematics ideas e.g. solving relations-equations (Bell)[6].

For example: $\square^2 = 1125$ ($\square$ is the unknown)

Other useful application on the use of electronic calculator among the general public is that the calculator could assist individual consumer on how to become a wiser consumer in the ability to use calculator to compute percentage discount on article purchased in departmental stores. In the classroom instruction calculators can be used to reinforce the learning of the basic number facts and properties in addition, subtraction, multiplication and division. It can be used to serve as a flexible answer key to verify the results of computation, and as a resource tool, it can promote student

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6. Bell, M. Needed R and D on hand-held calculators, Educational Researcher, 977, 6(5), 7-13.

independence in problem-solving. It can be used to solve problems that previously have been too time-consuming or tedious to be done with paper and pencil e.g. to verify the value of exponential 'e' by computing its value in series approximation.

$$e = \lim_{n \to \infty} \left(1 + \frac{1}{n}\right)^n$$

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \text{------}$$

Despite the useful application of calculators, yet teachers, school administrators and educators are rather skeptical about any innovations which either find their way into schools or catch pupils' eyes outside the school. Such skepticism may arise as a result of what these people perceived would be the consequence of such innovations within the school system.

Educators have, for instance, argued that innovations like teaching machines would merely reinforce rote learning or memory associations rather than encourage pupils to solve problems creatively. While many have even seen television, at one time or another, as a menace to school learning. Some argued that time spent by pupils watching television probably means time lost from an activity like home-work (Bell)[6].

Most recently in the United States of America and Europe, the use of small electronic calculator in schools has come under similar barrage of skepticism and sporadic rejection in schools (Bell)[6].

Rather than planning careful investigations to seek answers to important questions relèvant to use of calculators in our school systems, some educators, examining bodies, school administrators have dismissed this new technological innovation as a mere gadgetry or device that is not good enough for the traditional classroom settings. Some people argued that such devices may not yet belong in the mathematics curriculum of primary and secondary schools in this country. Such attitudes suggest that a careful study on the impact of the use of calculators in mathematics instruction was necessary.

One of the major spin-offs of the space programme has been the miniature of electronic components to a level which allowed the small hand-held electronic calculators industry to flourish. In fact, current availability has reached the near-saturation point in Japan, Europe, United States of America, and has become popular in Nigeria. One can find them being hawked along every major road in the country.

The number of types in the market varies from programmable ones to the non-programmable types but all equipped with different numerical notations and mathematical functions. While the use of calculator is widespread, the debate continues as to what performance and psychological benefits may accrue from calculator utilization.

However, Bell[6] had indicated a number of important areas where research and development efforts are needed for better understanding of the impacts of calculators. The groups of people who may be concerned about the effects of calculator usage in schools are parents, teachers, school administrators, educators and examining bodies like West African Examination Council (WAEC) and Joint Admission and Matriculation Board (JAMB) etc. Opponents to the usage of calculators, argued that calculators might have deterimental effects on the development of children's mathematical abilities. Conversely, proponents did assert that calculators may actually facilitate mathematical learning.

However, to throw more light on such a debate, the investigator became interested and carried out this study. Already research efforts in this area are rather scanty in the country, hence the need, in this study, to carry out - carefully planned empirical investigation on the use of electronic calculators in our school system. The

6. Bell, M. Needed R and D on hand-held calculators. Educational Researcher, 1977, 6(5), 7 - 13.

genre of this study was to provide answers to probable advantages of the calculator to the learner in facilitating the teaching learning process of mathematics in the school system. The focus of this study was on pupils in the secondary schools, their learning of mathematical concepts, attitudes as regards calculator-usage and mathematics learning.

This study raised issues on what added advantages the probable calculator-usage ahad on the instructional strategies such as algorithmic computations and problem-solving.

1.5. Limitations of the study

The following constitutes the major limitations of the study:

1. The experiment was carried out only in Ibadan. The situation as to the implication of this study may be different in the rural areas of the country or in other highly industrilised cities of the world.
2. The duration of the study may have not produced the needed attitudinal changes of this kind of study. For attitudinal changes may take a longer time than six (6) weeks the study covered.
3. It was difficult to ascertain whether the subjects in the restricted calculator groups (RCU) and Non-Calculator groups (NCU) were using calculators

privately especially to practise. This may possibly affect the pupils' attitudes towards the use of calculator.

CHAPTER TWO

REVIEW OF RELATED LITERATURE AND RESEARCH

The hand-held calculator is a tool used in society today for calculations. Educators hitherto who have been resisting the use of electronic calculators at primary and secondary school levels may be willing to admit the use of calculators if only, where the calculator adds a "new dimension" of learning to the experience of the pupils and it allows a child to do something or learn something that could not before.

The most common argument against the use of calculators in the schools is that their use would lead to decay of the understanding of arithmetic and loss of computational skills in student. The aversion of many people to the use of calculators is simply the resistance to a change in "instruments' in calculation brought about by advancing technology.

Technological changes are hard to accept at first and one can easily muster up all sorts of specters of doom when first presented with them. The aversion and resistance to calculators-use in primary and secondary schools have precedence in history.

In the Phaedrus, Plato had a short discussion on the value of reading, which was at that time just coming into vogue. The tradition before then was oral, that is, one memorized stories and recited them. One of the participants in Plato's dialogue expressed the fear that the coming of written materials would lead to the decay of the ability to memorize and recite works. He was quite right. The ability to do this had generally been lost. But look at what has been gained. The amount of literature that one can absorb has been increased 10,000 fold. One would think it will prove to be the same with calculators. Children would lose the ability to do sums and products on paper with pencil, however, at a very early age they would have gained the ability of doing problems with very large numbers quickly and very accurately, and this could be a very exhilarating experience.

One should think of the time that will be saved on drill and simple arithmetic computations. This time could be put to good use doing more complicated word problems. According to Immerzeel[7] students would not be

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7. Immerzeel, G. et. al.: Teaching mathematics with the hand-held calculator. In M. Suydam Electronic Hand Calculators: The Implications for the Pre-College Education. Final Report for NSF Grant No. EPP 75-16157, 1976.

dependent on the calculator rather, students will undertake much more complex problems and students can solve verbal problems using the calculator at about three times the rate the problem could be solved with pencil and paper alone.[8]

2.1 <u>Electronic calculator and the school system</u>

Despite the availability of the mini-calculator and its ever increasing public usage, there still exists controversy among educators as to its proper usage in the school or whether it should be allowed in the school setting at all. It's advocate refers to it as an essential implement in the newest mathematics (Higgins)[8], as a motivating device (Mastbaum)[8], as a means toward immediate reinforcement of results and a significant learning strategy (Lewis)[9].

Opponents of calculator like James Mckinney, Professor of mathematics at California Polytechnic State University in Pomona, U.S.A. states his case in the "Great Calculator Debate", 1974 as follows:

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8. Roberts, D. M. The impact of Electronic Calculators on Educational Performance. Review of Educational Research 1980, 50(i), 70(i), 71-98.

9. Lewis, P. "Minicalculators Have Maxi-Impact". Nations Schools 93: 60, 1974

> If what we are talking about is reducing tedious calculations then perhaps mini-calculators can be an aid, but teaching a student to push buttons won't help him if what he needs is more instruction in actual addition, substraction, multiplication and division - I can't think of any reason why a fourth or fifth grader* should even see one, after all that's when we are trying to teach basic arithmetic (p. 12)9.

This pungent argument holds against the use of electronic calculator in elementary school, whereas this does not go to say that calculator cannot be used in the secondary or higher education levels where the pupil would have mastered the basic concepts of addition, subtraction, multiplication and division of numbers. Here, differences in opinion on the calculator usage bothers on grade-level at which it should be used.

However, studies carried out by Schur and Lang[10] with a group of youngsters of elementary school age found that improvement on computational ability of the youngsters

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* Equivalent of Nigeria Primary 4 or 5 pupil.

10. Schur, J. O. and Lang, J. W. Just pushing buttons of learning? A case for mini-calculators Arithmetic Teacher 23(7), 1976, 559 - 563.

was traceable to the mini-calculator regardless of the learner's sex, and they went on to suggest that mini-calculator does have a place in the elementary school. Similarly in the U.S.A. the Board of Directors of the National Council of Teachers of Mathematics has adopted the following position:

> With the decrease in cost of the mini-calculator its accessibility to students at all LEVELS OF EDUCATION is increasing rapidly. Mathematics teachers should recognise the potential contribution of this calculator as a valuable INSTRUCTIONAL AID* In the classroom, the mini-calculator should be used in imaginative ways to reinforce learning and to motivate the learner as he becomes proficient in mathematics (NCTM, Newsletter, December 1974).

Studies so far, reviewed are from U.S.A. and Britain and it would be shown that calculator-usage researches have been carried out at all levels of education, elementary (primary), secondary and higher schools in these countries.

2.1.1 Elementary School

Most of the studies carried out at this level of education were of the general pre-test-post-test design.

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* Capital letters by the authors: are used to emphasis the relevance of the portion of this study.

Hohlfeld[11] examined the effect of a calculator programmed to provide immediate feedback on working simple multiplication problems. Using fifth grade pupils and pre-test-post-test design with experimental and control groups it was found that the experimental group that used calculator on the test and during instruction performed significantly better than the control group that did not use calculator at all. Whitaker[12] explored calculator impacts with first grade children in the elementary school. Pupils were randomly assigned to experimental and control groups while the experimental groups used calculator and the control group did not. The treatment lasted for thirty instructional days, and it was found that the experimental group had two gain scores to one gain score of the control group but no attitudinal differences to mathematics were found between the groups.

Thus, the majority of the studies completed at the elementary school showed computational advantages for ages 6 - 11 years for the introduction of calculator usage into the mathematics instruction while the attitudinal benefits

11. Hohlfeld, J.F. Effectiveness of an immediate feedback device for learning basic multiplication facts (Doctoral Dissertation, Indiana University, 1973).
12. Whitaker, W.H. A study of change in achievement, interest, and attitudinal variates accompany the use of electronic calculators in a first grade mathematics curriculum. Unpublished Ph.D Thesis, University of Southern California, 1977.

were limited. There was scarcely any conceptual benefits due to calculator-usage.

2.1.2 Secondary Level

Most of the studies at the secondary school level reviewed were of the pretest-post-test design. Quinn[13] used eighth and ninth grade students to observe whether the use of programmable calculator would facilitate algebra achievement and attitude towards mathematics. There were experimental and control groups, using some classes from two schools - one experimental and the other control. The experimental classes used programmable calculator while the control did not use calculator. However, no achievement differences were found between experimental and control groups, but the experimental group showed more favourable attitudes than the control group. Majority of the secondary level studies found computational benefits due to calculator use. However, as the case in the elementary school studies, very little support was found for the hypothesis that calculator benefits improved development as regards conceptual and attitudes areas. It, therefore, remains for future researchers to explore conceptual benefits of calculator at secondary school level of education.

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13. Quinn, D. R. The effect of the usage of a programmable calculator upon achievement and attitude of eight and ninth grade algebra students. Doctoral Dissertation, Saint Louis University, 1975.

2.1.3 Higher education level

The use of calculators at this level of education seems to be an accepted norm today. In Nigeria and other parts of the world, the use of calculators is permitted during instruction and on tests. However, there has been no empirical studies on calculator-usage at this level of education in Nigeria. In developed countries such as United States of America and Britain, many studies have been carried on impacts of calculator in the college mathematics (Suydam)[3]. Sosebee and Walsh[14] investigated whether students who had used calculators on in-class chemistry examinations would do better than those not using calculators. Using the mean scores from the examinations no differences were found in their scores.

Roberts, Seaman and Lerner[8] were interested in estimating the discrepancy in performance and attitudes of less calculation condition (hard work) against calculation condition (advanced calculator). Using ANOVA, results showed large differences between calculation modes in favour of the advanced calculator.

Most of the studies at this level provided support for the computational benefits of the calculator. In addition, affective (attitudinal) effects were found favouring groups

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14. Sosebee, J. F. and Walsh, L. M. Pocket calculators and test scores in introductory chemistry. Journal of College Science Teaching, 1975, 4,324.

which had used calculators. This was especially true when the dependent measure tapped specific task, affective responses. Reviewed in this study were some findings on the conceptual impact of calculator use in the studies carried out by Roberts and Glynn[8]. According to Stultz[15] calculator can be used at any grade level not only to check answers but also to debug a problem. Calculator can serve the same purpose as flash cards with quick oral or written response and immediate reinforcement. One of the more practical uses of a calculator in high school mathematics is in the evaluation of formula. At higher education level calculators are needed in statistical problems.

2.1.4 Learning outcomes in mathematics instruction

In this study one endeavoured to highlight the computation, conceptual and attitudinal effects of calculator use on learning outcomes of mathematics instruction at the secondary school level. Gagne' and Briggs[16] have identified five categories of learning outcomes which are relevant to this study such as:

(i) intellectual skills,

(ii) cognitive strategies,

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15. Stultz, L. Electronic calculators in the classroom. Arithmetic Teacher, 21, 1975.

16. Gagne', R. M. and Briggs, L. J. Principles of Instructional Design, 2nd Ed., New York: Holt, Rinehart and Winston, 1979.

(iii) verbal information,

(iv) motor skills and

(v) attitudes.

In trying to study the intellectual skills one examined the individual competency of the learner by measuring the 3 Rs - reading, writing and arithmetic. These competencies were measured in the study using mental ability test of verbal and numerical nature. Writing on cognitive strategies Bruner, et al[17] described it as mathemagenic behaviours while Skinner[18] called it self-management behaviours. Precisely, it is the capability of individual's learning, remembering and thinking behaviour. Gagne[16] defined cognitive strategy as a control process, an internally organized skill which governs the learners' own intellectual processing. It selects and guides the internal processes involved in defining and solving new problems. It is this strategy that is needed in problem-solving. It can however, be measured using achievement tests. A mathematics achievement test was used to measure this area of learning outcomes.

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17. Bruner, J. et al. A study of Thinking, New York: Wiley, 1956.

18. Skinner, B. F. The Technology of Teaching, New York: Appleton, 1968.

On verbal information, the learner usually acquires needed information from formal instruction or on incidental learning and such information would be stored in learner's memory not by memorization, but by constant practice through repetition-practice. Since this study required the subjects to go through an instructional process designed for them it was possible for the learner to acquire the necessary verbal information on the mathematical concepts. This was measured through the teacher-students classroom interaction incorporated into the study design.

Motor skills involve writing, and handling. In this study, some groups of subjects used calculators which they had to manipulate but such skill was not measured in this study.

Attitudes: It is an aspect that was measured in this study. One was interested in studying the attitudes of pupils only towards mathematics as a school subject and their attitudes toward the use of calculators in mathematics. One did not measure such socially approved attitudes as respect for other people, cooperativeness, personal responsibility, self-esteem, but rather attitudes toward knowledge and learning situations. Likert-scale type of attitude questionnaire was developed and used. Other attitude questionnaire that was appropriate for this study was also used.

Flanders[19] recognised the most common learning outcomes as content achievement, skill performance attitudes. This study had therefore recognised these human capabilities, intellectual skills and attitudes. The other learning outcomes; verbal information and motor skills were demonstrated during the instructional process and they involved the computational effects of using calculator in mathematics instruction.

2.1.5 Computational effects of calculator

Computational benefits would occur when pupils who had used calculators during a treatment could perform routine computations (not solutions to word problems or equations that would be conceptual development or problem-solving) more accurately and/or rapidly than those not having access to calculators during the treatment. Such benefits might occur when either the pupils were allowed to use calculators on the actual task (on test or/and instruction). Sometimes the judgement as to what criterion tests were more computational than conceptual would appear to be instructive.

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19. Flanders, N. Analyzing Teaching Behaviour, Reading, Mass: Addison-Wesley Publishing Company, 1970, pp. 317 - 319.

At elementary level, Spencer[20] used fifth and sixth graders to observe the impact of calculators on computational skills and arithmetic reasoning abilities. The experimental group was allowed to use calculator on tests and on all in-class work but the control group was not. At the fifth grade level the experimental group had gain scores on the problem-solving test whereas in the sixth grade, the experimental group had gain scores on the arithmetic computations. In two studies, Jone and Allen[8] investigated the effects of using hand-held calculators on mathematics achievement, attitudes and self-concept.

In Jone's work pre-test gain scores with post-test attitude and self-concept were analysed, whereas in Allen's work metric measurement and decimal test gains were examined. In Jone's work experimental group performed better on the post-test, however, there was no difference on attitudes and self-concept. With fourth through seventh-grade summer school pupils, Nelson[8] investigated impacts of calculators on computational skills and attitudes. The experimental groups which used calculator were superior for both compu-

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20. Spencer, N. N. Using the hand-held calculator in intermediate grade arithmetic instruction (Doctoral Dissertation) Lehigh University, 1974.

tation and attitudes. Sutherlin[8] used fifth and sixth grade pupils to investigate the effect of calculators on decimal estimation skills. Pupils in experimental and control groups were pre-tested, post-tested and given retention tests. Employing the method of Analysis of Variance (ANOVA) for the data analysis significant gains in estimation skills were found in both experimental and control groups. However, there was no difference between experimental and control groups on both the post-test and retention test.

Shumway et al[21] found no measurable detrimental effects for calculator use. Pupils learned basic facts, and achievement was good despite calculator use at grades 2 to 6. Eikmier[8] investigated the use of calculators with low achieving 4th grade pupils in mathematics achievement test and attitudes. He found no significant difference in attitude or achievement gains between calculator and non-calculator groups at this level. Kasnic and Kobrin[8] found the same results - no significant difference in achievement between calculator and non-calculator groups. Most other findings at this level of education support this position.

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21. Shumway, R. J. et al. Initial of calculators in Elementary school mathematics. Journal for Research in Mathematics Education, 12, 119, 141, 1981.

At the secondary school level, Gaslin[8] compared the achievement and attitudes of nineth grade pupils using either conventional or calculator based algorithms for operations on positive rational numbers. Significant treatment effects were found on both post-test achievement measures with experimental group gaining scores on retention tests and achievement measures; however, no difference on attitudes were found. Similar results were found by Wajeeh[8] and Hutton[8]. Whereas Wajeeh found differences between two levels of experimental groups and control groups on both achievement and attitudes, little difference was found between the experimental groups. In Hutton's study no differences were found between any of the experimental and control groups on any of the achievement or attitudinal variables and these findings were corroborated by Jamski and Anderson[8] in their studies on the impact of hand-held calculators on seventh grade learning of decimal/percent conversion algorithms and effects of restricted versus non-restricted use of calculators on mathematics achievement and attitudes. Both studies, like the others tend to show that pupils perform significantly better on computational skills when using calculator but no differences as regards attitudes toward the subject. However, in a study involving a non-mathematics area, Bolesky[8] investigated the influence of calculators on achievement in chemistry. Using 2 x 2 factorial design: E experimental condition, calculators on the post-test; E_1 condition, no calculators on the post-test, control, C condition, calculators on the post-test, and C_1 condition, no calculators on the post-test. Results showed no significant main effects or interaction.

At the higher education level, a series of investigations reported by Roberts and colleagues[8] found computational benefits of using calculators. For all five studies carried out by the group, they found that introductory statistics students worked numerous statistical problems (mean, standard deviations, correlation co-efficient, etc) under a variety of conditions. Three criteria that were common to all studies included the number of correct answers, the time to work problems, and efficiency (number correct per unit of time). In four of the five studies, a post-test attitudinal measure was also administered. Results from these studies showed that the amount of pre-practice had no effect on the number correct, time, or efficiency dependent measures. Roberts and Glynn[8] found for the calculator made: the advanced machine group was consistently superior to the basic machine group. Roberts and Glynn[8] found that for the instructional work set; that is, instructions to work fast or work accurately groups who produced more correct answers, longer working times, and less efficient problem solution than the work fast group. Roberts and Fabrey[8] found that the advanced machine condition produced more positive ratings on four of the five attitudinal clusters than non-calculator condition.

Thus it appears that most of that data and studies reviewed would support the hypothesis that using calculators during instruction benefits routine calculation and that the benefit is most pronounced when students continue to use the machine while actually performing test computations. Most of the studies were pretest - post test design and this may constitute some problems in integrating calculator usage in the experimental and control groups, thereby making comparisons difficult. Majority of the studies reviewed still found the experimental groups performing better than control group which lends support to the computational benefits of the calculator. However, there is need to investigate effects of calculator on concept learning.

2.1.6 Effects of calculator on concept learning

According to Suydam[3], calculators can be used to re-inforce and expand many mathematics concepts that may be introduced. However, no research evidences exists to support the claim that concepts must be developed prior to calculator-use. Hence the notion of developing, understanding through examples followed by explanation and discussion is a common technique in mathematics teaching. Almost all of the studies in elementary school mathematics comparing achievement of groups using or not using calculators favour the calculator groups or reflect no significant differences (Suydam)[22]. In certain types of mathematics problems, calculator might facilitate concept formation abilities. For example, some mathematical principles which require numerous, labourious calculations in order to be well understood, then concepts would be acquired faster if calculators can aid the student to leap through the computations. In addition and perhaps more importantly, if calculators can reduce frustrating computational errors, then the quality of the concept attainment may be improved. Roberts[8] states that the proposition that calculator usage can have an impact on mathematical concept formation seemed reasonable.

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22. Suydam, M. N. Researches in Mathematics Education, Journal for Research in Mathematics Education 10(4), 1979.

But, it is not yet supported by the empirical data available. This is so since few studies made any real attempt to carefully integrate calculator use into the curriculum that would illustrate how calculator can facilitate concept learning. Some studies have been carried out on concept learning but positive results relating to conceptual benefits of calculator usage would not be expected to occur as often as simple computational benefits because conceptual acquisition is a more complex task.

Kasnic[6] studied the effect of calculator usage on mathematical problem-solving in relation to three levels of ability of the six-grade students tested and using a 2-fact ANOVA analysis with Pretest and ability as a blocking variable he found there were no differences between experimental and control groups, nor were any differences found for the different ability levels between experimental and control groups. This design of using different ability levels has held to substantiate the need for the use of calculator in concept learning. Though the results were not conclusive a similar research design could help to clarify this important area of mathematics learning.

Fischman, Wajeeh, add Hutton[23] investigated effects of a newly developed programme of meaningful and relevant mathematics on achievement and attitudes at secondary school level. Using both ANOVA and ANCOVA for analysis, results showed superiority for both the two experimental groups over the control groups on both achievement and attitudes but little difference was found between the two experimental groups. These results support other findings on achie e-ment and attitudes at this level. However, Hutton[23] used t-tests analysis and no differences were found between any of the experimental and control groups on any of the achieve ment or attitudinal variables.

Lenhard[23] worked on pre-test and post-test design-experimental and control groups at secondary school level mathematics, with a variety of analysis using t-test and ANOVA procedures, it was shown that the higher ability students made fewer concept and computational errors than did the lower ability students; and they also had more positive attitudes.

In addition, studies by Bolesky and Boling[24] at secondary school level on whether the use of

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23. Fischman, M.L. et. al. The Impact of Electronic Calculators, Review of Educational Research, 50(1) 71 - 98, 1980

24. Bolesky, E.M. and Boling, M.A. The impact of Electronic Calculators in Roberts, O.M. Review of Educational Research, 50(1), 1980, 79.

calculators would influence students' achievement and attitudes in chemistry and in consumer mathematics respectively. Bolesky used 2 x 2 factorial design and the results showed no significant main effects or interaction between, experimental and control groups while Boling findings on achievement and attitudes also showed no significant differences between the experimental and control groups. It would appear, at this level, that most of the findings on studies in the use of calculator for concept learning in mathematics did not show any difference between the calculator-use and non-use- vis-a-vis achievement and/or attitudes.

Most of the studies reviewed at higher education level seem to lay more emphasis on computation and attitudes rather than concepts. Ayers[25] was interested in the effects of situational problem-solving and calculators on statistics performance. Using several analytical procedures (ANOVA, Mann Whitney U-test etc.), results showed better achievement in the calculator groups and more positive attitudes in the situationals realistic teaching of heuristic groups. No attitudinal differences were found between the groups using or not using calculator.

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25. Ayers, S.W. The effects of situational problem-solving and electronic calculating instruments in a College level introductory statistics course Dessertation Abstracts International, 1977, 37A.

O'Loughlin[23] investigated the effects of using a programmable electronic calculator on the achievement of students in a calculus course. Using a 2-factor ANOVA (blocking over three ability levels based on previous mathematics achievement), differences were found in favour of the experimental group, but no differences favoured the control group. It would appear that there was some support for the conceptual impact of calculator use at higher education level.

Problem-solving forms a substantial portion of concept development in mathematics. The problem-solver must comprehend the facts, clearly understand what is needed, and analyze the problem in order to arrive at how the problem is to be solved. Pupils with sharp, analytical minds may do superior work when solving verbal problems, although they may sometimes lack the basic computational skills needed for problem-solving. It would therefore, biological to integrate calculator-use in problem-solving situations so that pupils would best be served if rigorous training is giving in this area. Abdelsamod[26] found that the calculator was considered effective in mathematics problem-solving at secondary school.

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23. Calculator Information Centre. Research on Hand-held Calculators. K-12 Bulleting No. 9 Columbus, Ohio, 1982.

A calculator can also be used very effectively in concept development since many examples can be explored quickly. Consider for example, the concept of the prime numbers. A number can be tested for primeness quickly by dividing on a calculator. The concept of decimal can be introduced quite early and developed through calculator activities. Many motivational calculator games can be used to develop important concepts such as place-value, estimation, integers and functional rules (Guthrie and Wiles)[26].

According to Cook[27] students receiving both positive and negative instances (examples) in teaching mathematical concepts did significantly better on an algebraic concept test than those given only positive instances only. It would therefore, be worthwhile to explore the use of calculators in the concept formation techniques - examples and non-examples. It would appear from studies carried out on concept learning and calculator-use that the learning settings in which these studies were conducted did not generally emphasize concept-formation skills, thereby providing a partial explanation.

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27. Cook, W.C.: Teaching of Concepts, Journal for Research in Mathematics Education ed. Suydam, N.M. Vol. 13, No. 7, 1982.

From studies reviewed it would appear that most findings on calculator-use when students used calculator on pre-test and were not allowed on post-test showed no difference. Thus, if the calculator-use were to be successful in facilitating learning, the concept attained should really be at the understanding level. Then utilization of calculator in application to principles and concepts have had relatively little bearing on obtaining the correct solution on a post-test. According to Roberts[8], the concept formation benefits of calculators will only be resolved when investigators used calculators as a strategy for solving problems.

2.1.7 Effect of Calculator on Attitude

Finding attitudinal impact of calculator in instruction may be problem-ridden because of the difficulty in finding the attitudinal criteria to use. For the vast majority of the studies reviewed; three factors may have worked against finding attitudinal impacts. First, the measures used were too oriented toward general traits rather than characteristics which were more task specific and sensitive to calculator influences.
Second, the time frame for most studies was too short to expect any real change in attitudes. Third, since many of the

investigations did not allow the experimental groups to use calculators on the post-test, many of the students might have lost interest which in turn, might have influenced the rating on the attitude scales. Most of the studies did not investigate attitudes toward calculator per se but rather in component with achievement and, , in most cases, there was no correlation between the achievement and attitudes.

Smith[6] examined achievement and attitudinal impacts of calculator usage in teaching methodology to business and economics students. The instructional period lasted for 10 days with Pre-test-post-test design-experimental and control groups. The experimental group was allowed to use calculator on pre-test and during instruction but they were not allowed on the post-test. It was found that there were no achievement or attitudinal differences between experimental or control groups

Roberts, Szaman and Lerner[8] in their study on simple calculation condition (hardwork) versus, best calculation condition (advanced calculator) and the attitudinal data showed large and significant differences between calculation modes with more positive task and self-perceptions being expressed by students using the advanced calculator. Standifer and Maples[28] investigated the achievement and attitude of third grade students using two types of calculators and found that the hand-held calculator group scored significantly higher on achievement and attitude than the programmed-feedback calculator group at grade level 3. (Elementary School).

Connor[29] investigated a calculator dependent on trigonometry programme and its effect on achievement and attitude towards mathematics of eleventh and twelveth grade college-bound students, and found there were no significant differences on attitude between calculator and non-calculator groups at secondary school level.

It would appear from most of these studies that there seems to be evidence that calculators influence immediate and specific perceptions, but there was no evidence to support any significant differences between experimental and contr groups or to support more general and lasting attitudinal changes.

2.1.8 Use of Calculators on Tests

One of the most peculiar aspects of calculator research is the extent to which investigators have allowed/ disallowed students to use calculators on tests. According

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28. Standifer, C.E. and Maples, E.G. Achievement and attitude of 3rd Grade student ...in School Science and mathematics 81, 17-25, 1981.

29. Connor, P.J. A Calculator department Trigonometry Programme and its effect on achievement in and attitude toward mathematics of Eleventh and Twelveth Grade College Bound Students. Un-published Ph.D. Thesis, Temple University, 1981.

to Carpenter et al[30] reported on the results and implications of 1977 - 1978 mathematics assessment of the United States of America National Assessment of Educational Progress (NAEP) on "how does the availability of hand-held calculators influence performance in testing situation?" In the report, several issues related to calculators were raised, for example: timing on exercise; it was found that students took longer time to do problems with calculators than with paper and pencil. This would be surprising because calculators should presumably make computations easier and less time-consuming. The reason for this may be that students lacked confidence in their results, so they did the problem more than once. Or perhaps students did not know how to interpret the value shown on the calculator's display. Perhaps students with calculators sought to do the problem in more than one way. The behaviour of seeking alternative solutions to problems when calculators are available has been reported in several calculator research studies (Carpenter, Wheatley and Shumway, Coburn, Fays and Schoen, Wheatley and White)[31].

2. Problem-Solving: On exercises requiring problem-solving techniques, the performance of 9 and 13 year

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30. Carpenter, T.P. et al Calculator in testing situation, Arithmetic Teacher 28 65-65, 1981.

31. Carpenter, T.P, et al. Claculators in testing situations: Results and Implications from National Assessment Arithmetic Teacher, 28 34-37 Jan. 1981.

students with calculator were generally poorer than that of students without a calculator. Hence calculators do not solve problems, people do. Strategies such as trial and error that take special advantage of the calculator need to be introduced, developed and encouraged. Problem-solving requires far more than computation it demands understanding, correct choice of operations, and selection of values to operate in a particular order. Carpenter et al[30] found that students performed routine computation better with aid of a calculator, but problem-solving scores were poorer with calculator at ages 9, 13, 17.

Some of the studies did not allow students to use calculators on post-tests. According to Roberts[8] the assumption is that this reflects the philosophy that the real question is whether the use of calculators will harm students' performance when they are faced with doing calculations by paper and pencil methods. While such an approach is certainly a legitimate way to test theory, it appears to be a negative orientation rather than a positive one. Instead of examining potential positive impacts, the focus is on demonstrating the lack of negative effects.

However, it would seem more realistic, as it is being done, to assume that calculators may have more positive benefits than negative. This assumption could be supported, in cases where computational benefits were more when students were allowed to use calculators on tests. On the other hand, it would have been instructive to test for more conceptual benefits (as it is being carried out in this study) by allowing calculator-use on those types of criterion tests-pre-test and post-test. It would therefore be appropriate to use calculators on the post-tests, assuming, of course, that the treatment properly integrated calculators on instrtion, and see if there would still be any significant difference between the experimental and control groups.

2.2 Integrating Calculator into Mathematics Curricula in Schools

Before integrating any educational devices into school instruction there must be agreement on what role(s) such devices would play in the school. But viable school roles of electronic calculator will not be established without finding solutions to many problems: problems of philosophy, problems of curriculum and methodology, problems of design, and school management of the calculator themselves.

In the belief that solutions to many of these problems could be worked out in actual classrooms, the design and methodology of this research would try to explore classroom uses of calculators by integrating calculators in the instruction and tests. According to Palmer[32] attempts to introduce calculators in the classroom, particularly at the elementary grades had been greeted with cautious responses. Teachers and educators could be worried over such innovations and investigations by Palmer[32] revealed the reasons for their caution as follows: (1) erosion of the teacher's roles - mechines taking over teaching functions; (2) impersonalization of the teaching - learning process, reduction or elimination of the humane aspects of teaching and learning, (3) stifling of creativity - emphasis on precision, measurement, and mechanization inhibits creative expression.

Despite the anxiety expressed by teachers and educators researchers in the area of Calculator-integration into curriculum had progressed. Using ninth-grade general mathematics classes, Vaughn[8] examined effects of calculator useage when they were specifically integrated into the curriculum. The design was pre-test-post-test experimental and control groups with the subjects in the

32. Palmer, H.B.A.: Mini Calculators in the Classroom - What do Teachers Think? Arithmetic Teacher 25(7) 1976, 27-28.

experimental group using calculators. Using a stepwise regression analysis, results indicated that the experimental group performed better than the control group on achievement at the post-test but there was no difference on attitudes of the two groups at the post-tests. Casterlow[8] who studied the effects of calculator instruction on the knowledge, skills and attitudes of prospective elementary teachers found that the treatment in which students received teacher-guided instruction with the calculator was more effective than treatments without teacher guidance for preservice elementary teachers. The calculator was considered effective with 13 to 60 problems strategies at secondary school level. In studies carried out by Hopkins[8] on the effect of a hand-held calculator curriculum in selected fundamentals of mathematics classes he found that students using calculators for instruction gained equally as well in computation and significantly higher in problem-solving as students not using calculators at secondary school level. Similarly studies by Smith[8] on a study of the effectiveness of the use of the electronic calculators in teaching simplex method to business and economics majors found, regardless of sex or mathematics aptitude level.

little difference in mathematics achievement and attitude between students using or not using calculators in the classroom at college level.

Most of the studies so far, reviewed have not established any differential effects as regards calculator instruction vis-a-vis achievement and attitude. However, studies by Laursen[33] on the use of calculators in High School General Mathematics which compared achievement, attitude and attendance of general mathematics students who used calculators with students who did not, found that students using calculator had greater achievement and no significant differences in attitude or attendance were found among the groups. Lawson[34] in a study of the calculators and altered calculator's effect upon student precaution and utilization of an estimation algorithm found that calculator-use did not affect performance in estimation. Students of lowest ability made the most errors when using calculators compared with other ability levels at secondary school level.

There could be no appropriate word(s) to describe the problems surrounding the integration of calculator in the

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33. Laursen, K.D.: A study of Calculators in High School General Mathematics ... Unpublished Ph.D. Thesis Brigham Young University, 1978.

34. Lawson, T.J.A.:- A study of the calculators and altered calculators effect ... Unpublished Ph.D. Thesis State University of New York at Buffalo, 1977.

curriculum than the suggestion reflected in Recommendation (6) of the Report of the Conference on Needed Research and Development on Hand-held Calculators in school mathematics[35]

> Materials should be developed to exploit the calculator as a teaching tool at every point in the curriculum to test a variety of ideas and possibilities pending emergence of calculator - integrated curriculum (P.7).

From available research reports there seem to be little doubt about the computational value associated with calculator use. Sufficient calculator-pretraining enables one to work problems more accurately, rapidly and efficiently. Also calculators would allow one to complete more problems per unit of time thus in effect affording greater amount of practice Suydam[22]. However, for conceptual and attitudinal impacts due to calculator use, there is less concensus as to what facts can be gleaned from the research literature, and it would appear that this is the issue being raised in this study. Also, at a curriculum level, there is less agreement as to what should be done regarding the question of whether to incorporate calculators into instruction. For those who believe that calculators should be used in the schools, the question may still remain as to when, class and level of education for calculator to be introduced into the school mathematics programme.

2.3 <u>Definition: Concepts and Concept Learning:</u>

Sultz[34] defined a concept as a "bounded region in the cognitive space which is reacted to as an entity".

35: Calculator Information Center: Research on Hand-Held Calculators, K-12. Bulletin No. 9, Columbus, Ohio 1977.

34. Sultz, see copeland, R.W. Mathematics and its elementary teacher Philadelphia: W.B. Saunders Company, 1976, 15-65.

Saltz also went further to define concept learning as, "the association and bounding of the set of attributes. The first step in learning is perceiving through the sensory modalities which leads to both concept formation and concept utilization, in any teaching and learning or problem solving situations.

Saltz could mean "bounded" here as referring to those common characteristics which justify the inclusion or exclusion of anything within the frame of reference of the entity, idea, objects, event etc. A concept is not formed in a vacuum. This is why the instructor should provide the learner with the real object or event to perceive. According to Bolton[35] "concept learning is the process whereby one comes to distinguish between those elements which are an essential part of the concept and those which are not".

Concept learning as a process presupposes the learner is active, can justify the characteristics which bound them together and the words to describe them, time is saved as the learner interacts directly with his environment, and avoids unnecessary interaction, and can recognise and generalise. For example, a student who has a true concept of equation will be able to generalise to all forms of equations be it simple, simultaneous or quadratic.

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35. Bolton, N. Concept Formation: U.K.: Pergamon Press Ltd., Pp. 84 - 139, 1977.

When concept of an entity has been formed it has to be tried out. At this stage, there should be minimum interaction between the learner and the instructor. The need for instructional material would be essential so as to facilitate the definitive properties of the concept.

Expounding on problems of conceptual learning (Engleman)[36] defined concept as "a set of characteristics shared by all instances (examplers) in a particular set and only by these instances" (p.87). Thus, when the relationship between teaching and concept analysis is made explicit, the teaching sequence can be evaluated more precisely. Markle [37] defined defines concept as a class or category where all the members share a particular combination of critical properties not shared by any other class. Gagne' defined concepts as a capability that makes it possible for an individual to identify a stimulus as a member of a class having some characteristics in common, even though such still may otherwise differ from each other markedly. There are concrete and abstract concepts. Concrete concepts identifies an object properly or object attribute(s) (Colour, shape e.g. round, square, blue, three etc.). A b s t r a c t concept

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37. Markle, S. M. Problems of conceptual learning. Journal of Education Technology Vol.1, No. 1., 11-19 1970.

needs to identify the referents of the language used in concept concept definition, to discriminate and generalise. Thereby the subject formulates rules as in problem-solving.

For example, the concept of fruit can be concrete, and is shared by all classes of fruit and nothing more. Here, most referents to concept are noun-like particularly for tangible objects. However, concepts learned before, during and after school years vary widely in ways which make generalisations about them unsafe. Concepts which are abstract like "equation" in algebra can be distinct from other mathematical concepts.

Hence "language" plays a key role in achieving concepts especially abstract ones and in using attained concepts to learn related principles and to solving problems. How then do we learn concepts?

2.3.1 Criteria For Conceptual Learning

A learner who has fully grasped a concept can give two relevant kinds of responses. He can generalise to instances (examplars) and discriminate non-instances (Machner)[35]. Generalisation, by definition, involves a new situation, one that the learner has never encountered before. Conceptual learning is therefore easily discriminated from rote learning.

Concept learning should be taught with examples and non-examples so that the learner can generalise and discriminate either overtly or convertly. Teaching concepts would require a strong focusing strategy on those examples and non-examples and the mode of generalisation. For mathematical concepts the use of instructional materials like electronic calculator could be useful to illustrate examples and non-examples in word-problems. This would allow the learner a greater exposure to the full range of referents. Lack of sufficient discrimi-nation or undergeneralisation may lead to the concept not being learnt. Here adequacy or otherwise of the instructional strategy would determine whether the concepts have been learnt or not.

In designing an effective instructional situation in the school, the learning of concepts is of central concern since school learning is predominantly conceptual in nature. Modes or concept presentation and acquisition that could be found in research literature are comparing "inductive versus deductive mode", "rule-example versus example-rule", and "discovery versus guided discovery or deductive mode" (Clark)[36], and the amount of time, a learner is exposed to an example in a critical information processing variable in concept acquisition (Horland and Weiss)[35], Yudin and Kate .[35] In most studies time, has frequently being held constant while exploring mode of presentation. Koran and Freeman[35] found that for school instruction when biological concepts are being taught a deductive approach is more efficient. However, as concepts become more complex or abstract, and can contribute to higher levels of learning or a wider range of objectives, inductive method should be useful strategies to explore (Gagne)[37].

2.3.3 Concept Formation and Attainment: Concept Learning

Working on the theory of abstraction Locke [38] and Hume[39] stated that concept was formed through a process in which the person recognizes similarities or identical elements in a set of objects, the person thus abstracts these resemblances away from the other properties of the set of objects that are not relevant to the concept e.g. concept of man - features of man. According to Turner[40] once a concept has been formed or attaine the person will be able to do two distinct things: firstly he recognise its relevant attributes and secondly he will know how they are related to one another. There can be three forms of relationship between attributes: a conjunctive relationship when the concept requires all the r e l e v a n t

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37. Gagne, R.M. Categories of human learning, N.Y. AcademicPPress, 1966.
38. Locke, J.: Essay on the Human Understanding. Oxford: Clarendon Press, 1690.
39. Hum , D.A. Treaties of Human Nature, Oxford: The Clarendon Press, 1739.
40. Turner, J.: Psychology for the Classroom. London Metheven, 1977, p.48.

attributes to be present. Secondly, there can be disjunctive relationship when either one or other attribute or both are present, the concept then exists. The third form of relationship is the relational one when it is the relationship between two attributes which defines the concept. Bruner, Goodnow and Austin[41] made important distinction in learning concepts, that is, between concept formation and concept attainment: Concept formation is an initial creative action which results in the formation of super-ordinate classes or abstract categories. However, concept attainment is more often of interest to teachers and this means the activity of finding examplars of a concept which is already in the mind; or attempting to reconstruct the concept that is already in someone else's mind. Concept formation is more of the fundamental process while concept attainment is the more familiar, which teachers examine on tests.

For attaining concepts, Bruner et. al.[41] itemized the followings:

(a) identifying objects

(b) reducing the necessity of constant learning,

(c) reducing the complexity of the environment

(d) providing direction for useful activity, and

(e) ordering and relating different types of events.

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41. Bruner, J. Et. al.: A Study of Thinking: New York; Wiley, 1956.

Concepts are therefore, building blocks for understanding after correct perception has been made, and using principles which in turn, are critical in solving problems.

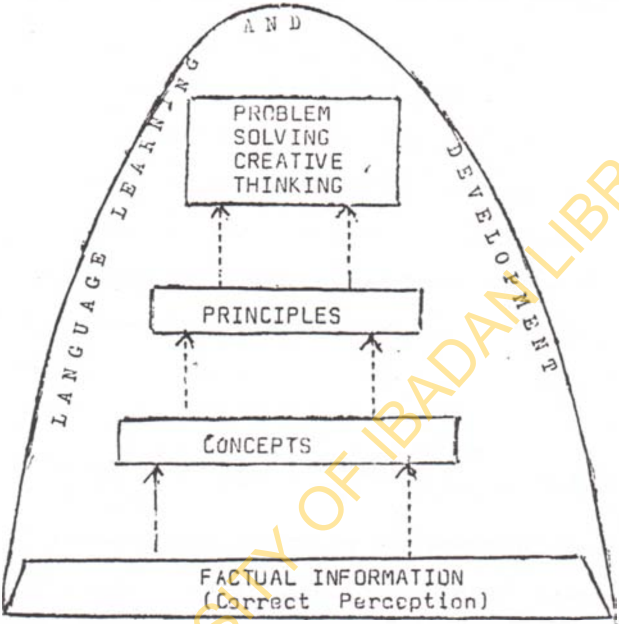

Fig. 3: Sequential bases for learning various outcomes (Adapted from Bruner, J.S. Creative Thinking)

Language plays a key role in achieving concepts and in using attained concepts to learn related principles and to solving problems. From the sequential basis one can define concept as ordered information about the characteristics of one or more things - objects, events or processes that enables any particular thing or class of things to be differentiated from also related to other things or classes. Concepts can therefore, be thought of as both mental constructs of individual and also identifiable public entities (Bruner)[41].

Each individual attains mental construct or concepts according to his unique learning experiences and maturation pattern. Once attained concepts play a key role in his thinking about the word in a language, and in the intellectual growth. Concepts are the fundamental agents of intellectual work.

2.3.3 Associative Versus Mediational Theories of Concept Learning

The simplest theory is the associative one which sees concept learning as a matter of associating positive and negative instances of stimuli, to reward or punishment. For example, in developing the concept of a bird the subject can associate pictures of birds with a positive responses whereas mediational theory says the subject uses covert cues with which he organizes his behaviour.

STIMULUS	MEDIATIONAL RESPONSE	AND NEW STIMULI	RESPONSE
3 (FIGURE)	- R_1 Number - 3	- S_1	+ 1-
YELLOW (COLOUR)	- R_2 Colour - Yellow	- S_2	+ 1-
SQUARES (SHAPE)	- R_3 Shape - Square	- S	+ 1-

Fig. 4: Mediational Model (Adapted from Turner, J. in <u>Psychology for the Classroom.</u> London: Metheuen 1977, p.48)

Some theorists, especially those within the S-R. tradition, regard associative learning or conditioning as the major, if not the only form of learning. While some have brought in connectism 'O' i.e. S ⟶ O ⟶ R:S for stimulus, R for response, and O is believed as a set of concepts or mediators in learning others have suggested that there are types of learning, some more advanced than others, and that associative learning occurs at early stage in development but is superseded by structured or cognitive learning (Bolton)[35].

Kendler and Kendler[35] maintained that two theories are necessary to explain concept learning. A single unit S ⟶ R theory to account for the behaviour of animals and children who cannot make use of symbolic mediation, a n d mediational S ⟶ R theory for older children and adults.

Higher-order concept formation would depend on:[35]

(i) organisation of the material to be learned

(ii) the motivation for concept learning and

(iii) creativity in formation and

(iv) individual differences.

2.3.5 Mathematical Concept Formation

Psychologists who have investigated mathematical concept formation have identified the inadequacies of traditional "stimulus-response" learning theory, and the need for a theory of structured learning. Biggs[35] asserted the necessity of constructing theory which will account for the process by which the learner acquires meaning or structure, rather than a response or action

Draws upon Piagetian theory for this purpose, Skemp [35], distinguishes between primary and secondary concepts: A primary concept is derived from other concepts; for instance, some mathematical concepts, such as "three", are primary, since they are formed through inspection of collection of three objects while others are secondary for they consist of generalizations about the properties of individual members. Thus, 8 x 7 = 56 is understandable on the primary conceptual level, whilst $8(x + y) = 8x + 8y$ is a secondary concept. Skemp believed that many of the difficulties experienced in mathematics learning stem from the transition from primary to secondary modes of representation and understanding, ana he proposed a schematic theory of learning to account for the way in which successful instruction should progress from structured primary to structured secondary knowledge.

However, Dienes[35] argued for the existence of a number of stages in mathematical concept formation. In the first state, the person's behaviour is playful and haphazard, at the second stage it becomes more regular and purposeful,

It is confined to practice in handling situations in which the rule-structure of the subject matter is relevant and results in a more or less unconscious stamping-in of the rule. At the third stage, analytic thinking about the rule becomes possible, and it exists now as an object of thought. Thereby forming the basis for the conceptual attainment. Dienes' apparatus consists of the Multibase Arithmetic Blocks which is structured in geometrical progression and these blocks are used to teach place-value in number system. How do we ·each concepts to pupils today?

At the present time, there are a number of different methods in use in the classroom for teaching mathematical concepts. There are the traditional methods with their emphasis upon repetition, the early use of symbolism, computational efficiency and extrinsic motivation. In contrast to these methods, is discovery learning in which the aim is to motivate the child to develop understanding on the basis of his own experience, and the emphasis is upon wide experience, the gradual introduction of numerical symbols only after concrete experience with numerical relationships, problem-solving rather than computation and intrinsic motivation. There are other specific methods, such as Dienes Blocks and Cuisenaire rods, for use in the development of certain basic concepts. In Britain, the Nuffield Mathematics Project, following closely the ideas of Piaget, developed techniques of instruction and methods of assessment for a wide range of concepts, for example, transitivity, conservation etc.

However, Biggs[35] hypothesized that the traditional methods of teaching should be more successful with respect to tests of mechanical arithmetic, whereas structural and possibly motivational methods would surpass the traditional methods when conceptual understanding rather than rote learning, was demanded. In fact, he found very little difference in the performance of children, whether mechanical or conceptual who had been trained by traditional abd uni-model, structural methods, although there was tendency for the more intelligent children to benefit from-uni-model (i.e. Dienses' method), as against the less intelligent.

2.3.5 Researches in Concept Learning

On a project carried out by Harris and Harris[43] on concept attainment abilities they found that achievement in language arts and mathematics was related to three abilities - numerical, word fluency and memory. Piland and Lemka[35] studied the effects of ability grouping or concept learning. They investigated the effect of conceptual training and transfer of ability grouping on intelligence, sex and temporal tests. Results indicated that (a) ability grouping has no significant effect on concept learning under any effect of the variables of the experiment and (b) high ability subjects (students) are better able to obtain mathematic concepts than medium ability or low ability subjects. The non-significant effect of ability grouping is seen as an important finding in the light of its present emphasis in our secondary schools.. Most of our secondary schools today group their students into Science, Arts or Commercial

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43 Harris and Harris. Concept Attainment Abilities Project. Journal for Research in Match Education (JMEE) 9(5). 1978, 334 - 336.

classes based on the students performances in form three. This would raise issues whether such grouping has any significant effect on the results of schools in the West African School Certificates Examinations. The results cited in this study found the effect as non-significant in a controlled experimental setting, but one wonders whether an effect that is not significant in a controlled setting will work in the school setting.

Studies have also been carried out on the teaching of concepts in schools. According to Cook[27] students receiving both positive and negative instances (exemplars) in teaching mathematics concepts did significantly better on an algebra concepts tests than those given only positive instances. Studies in the organisation of content elements in instructional materials has long been an important issue in educational planning (Ausubel, Bruner, et. al)[44]. From research findings, an emperically based set of instructional design strategies has been developed to organized content elements in concept teaching (Klausmeier, et. al.)[45].

These design strategies include (a) the relationship

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44. Ausubel, D.P. et. al. Educational Psychology: A Cognitive View, New York: Holt, Rinehort, and Winston, 1968.

45. Klausmeier, H.J. et. al.: Analyses of Concept Learning. New Yrok: Academic Press, 1966.

between examples (b) the relationship between examples and non-examples; (c) the ordering of examples and instructional help, (d) developing a procedure for selecting an appropriate number of examples, and (e) the relationship between co-ordinate concepts. Carroll and Methner[45] regarded concept learning as 'the identification of concept attributes which can be generalized to newly encountered examples and discriminate examples from non-examples.

2.3.6 Facilitating Concept Learning

In the instructional process for concept learning, a definition of the concept should be presented in terms of its critical attributes between the examples and non-examples (Tennyson)[46]. Johnson and Stratton's[45] study demonstrated the effectiveness of definition in concept learning. The results of this study indicated that students who were given a definition performed significantly better on classification of new examples, definition of the concept, sentence completion, and selection of synonyms. Klansmeier and Feldman[45] found that a definition

46 Tennyson, R.D., et. al.: The Teaching of Concepts: A Review of Instructional Design Research Literature. Review of Education Research 50 (1) 55-67. 1980.

provided about the same amount of learning facilitation as one rational set of examples and non-examples. Markle and Tiemann's[46] study showed that a concept definition best facilitates concept attainment when stated in terms of critical attributes of the concept.

For instructional process Tennyson and Park[46] proposed a four-step process for concept teaching:

(1) The taxonomical structure of the content should be determined. The three levels of concept structure - super-ordinate, co-ordinate, and subordinate - should be analysed with identification of critical and variable attributes;

(2) A definition of the concept should be prepared in terms of the critical attributes and a pool of examples should be prepared on the basis of critical and variable attributes;

(3) The examples should be arranged in rational sets by appropriate manipulation of theattributes. Within a rational set, containing one example from each co-ordinate concept, the examples should have similar variable attributes,

(4) The presentation order of the rational sets should be arranged according to the divergency and difficulty level among examples of the concept, the presentation order of the examples within the rational sets should be decided according to update information about the learner's knowledge state (p.65).

Some of the following factors identified by Klansmeier, Ghatala and Frayer[46] could affect concept planning: (1) characteristics of the learner, (2) characteristics of the instructional situation and (3) characteristics of the concept.

Obviously, the learner's age and to some extent, ability will affect concept learning, but Klansmeier and his associates gave reasons for ability being more important. They quoted Wiciott's[46] results that children who scored highly on mathematics tests scored more highly on a test of concept mastery. Klansmeier and Meirke[46] listed six functions of instruction in concept learning (1) to acquaint the subject with the structures material; (2) to acquaint the subject with the response desired; (3) to inform the subject of a strategy or method to apply for the solution of the task; (4) to provide substantive information, (5) to provide a set of relevant information examples) and (6) to change the level of motivation of the subject (pupils).

The extent which teachers use instruction which fulfil these purposes will determine, the success of their pupils in attaining the concepts, that is, the more relevant dimensions there are, the more difficult it is to attain. Similarly, abstract concepts are more difficult to learn than concrete ones (Reed and Dick)[47]. It is necessary to consider these factors as well as objectives, instructional materials and methods of assessment in concept learning.

2.3.7 Attitude Towards Mathematics

In the last few decades educators have become more and more concerned with the affective outcomes of educational programmes. Many teachers believe that a student's attitude towards a school subject will affect that student's achievement in the subject (Michaels, Forsyth)[8]. Teachers generally are interested in pupil's attitudes towards the subject they are teaching, teachers of mathematics are particularly concerned about pupils feeling about their subject because mathematics has a reputation for being unpopular. Zacharias (in Time, 1976) contends that fear of mathematics is widespread among school children.

From the above comments, it would be difficult to overemphasize the importance of attitudes in school learning.

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47. Reed, H.B. and Dick, R.D.: The learning and generalization of abstract and concrete concepts. Journal of Verbal Learning and Verbal Behaviour, 7, 485 - 490, 1968

In the first place, it is so evident to the classroom teacher, that the students attitudes toward his subject-matter, toward cooperating with him as the teacher and his classmates, towards attending school, toward giving attention to the communication presented to him and toward the art of learning itself, are all of great importance in determining how readily the pupil would learn.

According to Gagne'[48] the school aims to inculcate in the pupil some attitudes as a result of teaching-learning experiences. Attitudes of tolerance, honesty, good citizenship are often mentioned as goals of education in the schools. Whatever the particular content of an attitude, it functions to affect "approaching" or "avoiding". In so doing, an attitude influences a large set of specific behaviours of the individual. What therefore is attitude?

Campbell[48] defined attitude as "consistency in response to social objects". According to Allport:" "an attitude is a mental and neutral state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related"(p.56). Since human beings do exhibit attitudes hence attitudes are complex states or predeposition of human beings which affect their behaviour towards people,

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48. Gagne', R.M.: Principles of Instructional Design 2nd Ed. New York: Holt Rinehart and Winston, Pp. 55-79; 1976.

things and events (Gagne' and Briggs)[48]. Many investigators have studied and emphasised in their writings, the conception of an attitude as a system of beliefs (Fishbein)[49], or as a state arising from a conflict or disparity in beliefs (Festinger)[50]. These views serve to point out the cognitive aspects of attitudes. Other investigators deal with the affective components, the feelings given rise to or which accompany them as in liking and disliking.

Attitudes relating to learning outcomes in the 'affective domain' are described by Kruthwohl, Bloom and Masia[51]. Certain attitudes are related to action as a result of invigorated emotion. Hence, what action does the attitude support? An attitude influences a choice of action on the part of individual. According to Gagne' and Briggs[48] attitude is an internal state which affect an individual choice of action toward some object, person or event. Such action has led to attitude crisis. Attitude crisis may exist in mathematics learning among teachers, pupils and in society at large. Burton[52] suggested that crisis of attitude among mathematics teachers is displayed in a number of ways the most common of which is confidence-failure.

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49. Fishbein, M.A. Current studies in social Psy., N.Y.: Holt, Rinehart & Winston, 1965.
50. Festinger, L.A. Theory of cognitive Dissonance: N.Y.: Harper & Low, 1957.
51. Krawthwohl, D.R. et al. Taxonomy of Educ. Obj. Handbook II: Affective Doman, New York: McKay, 1964.
52. In Morris, J. Math Anxiety: Teaching to avoid it. Mathematics Teacher, NCTM, 75(6), 413-417, 1981

Insecurities which can be traced back to their own experience of mathematics in school. The crisis of attitude among children can almost be identified by performance - failure and dislike. The crisis of attitude in society is generally seen in the complaints of, for example, employers, that school leavers are not numerate or students perform badly in external examination or children cannot "add"[52]

2.3 Mathematics Learning and Attitudes

Learning of mathematics cannot be divorced from the way the subject is taught in schools. Many psychologists have considered how children learn mathematics. One school of thought is that of behaviourists. Their premise is, "Provide proper conditioning and you can get human beings to behave in any way you want". This view is represented by B.F. Skinner, Robert Gagne, et. al.[34] However, another school of thought is that of the developmental psychologists as represented by Jean Piaget. They both differ in their approaches on how mathematics should be taught. Those favouring learning by discovery or invention: like Piaget and Bruner[53] advocated maximum opportunity for physical exploration by the student. Hence, solutions for problems and generalizations should result from the student's own action on his environment, and fron his own mental operations.

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53. Bruner, J. et. al.: The Process of Education, Cambridge, Massachusetts; Harvard University Press, 1962.

Those preferring guided learning as Gagne' and Skinner,[48] emphasized the importance of carefully sequenced instructional experiences (information processing) through maximum guidance by the teacher and/or instructional material. Basic "associations" of facts are stressed. Here, association refers to the familiar stimulus-response of S→R machanism. Control the stimulus to obtain the desired response. Gagne' emphasized task analysis-what do you want the learner to be able to do? The capability must be stated specifically and behaviourally. Piaget prefers "assimilation and accommodation" to controlled associations of stimuli to responses.

It should be noted that the logical processes involved in mathematics must be based on the psychological structures available to the pupil. These structures would change as the pupil matures physiologically and neurologically, and as the child has the necessary experiences in the physical world. These experiences must involve actions performed on objects and communication with other people such as the teacher and peer group.

2.3.9 Research in Attitudes

Brassell, Brooks and Petry[54] studied ability grouping in mathematica achievement and pulils' attitudes toward mathematica and they found that self-concept appeared to decrease as placement within the ability groups decreased, with the high-ranked pupils in the high level class having the highest scores. In the same study by Brassell, Brooks and Petry[54] the low-ranked students in the medium-level class appeared to have the lowest self-concepts of all. While anxiety and self-concept do not only inversely correlate to each other, they may be related to the learning context. Finally, the group found that mathematics self-concept and mathematics anxiety

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54. Brassell, Anne, et. al: Ability Grouping, Mathematics Achievement and Pupils Attitude toward mathematics. Journal for research in mathematics education 11(4), 1980, 111-119.

appear to be important correlates of mathematics achievement. Quinn[12] studied the casual relationship between mathematics achievement and attitude in grades 3 to 6 and found some significant correlations between attitude and achievement of elementary school pupils

Schofield[55] on a study of teacher's effect on cognitive and affective of pupils' outcomes in elementary school mathematics found that high achievement and high attitudes of teachers were each significantly related to high achievement in pupils, but related to least favourable pupil's attitudes toward mathematics in grade 6 (elementary school). It would appear that most research findings tend to correlate achievement to attitudes: That pupils with high achievement tend to have positive attitude toward the subject and vice-versa In addition, self-concept and anxiety have significant effect on pupils' mathematics achievement and attitude. This only suggests that teachers must attend to self-concept enhancement and anxiety reduction in mathematics. The correlation between attitude and achievement varies not only with grade level

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55. Schofield, H.L.: Teacher Effects on Cognitive and Affective Pupil Outcomes in Elementary School. Journal of Education Psychology. 73: 462-471, 1981.

but also with the sex of the student and is generally somewhat higher for girls. Thus, girls' mathematics marks are more predictable from their attitude than boys' marks (Behr)[56].

2.3.10 Instructional Design and Attitudes

How can one design instruction to facilitate or elicit attitude change or formation? Certainly the method of instruction to be employed in establishing desired attitudes differ considerable from those applicable to the learning of intellectual skills and verbal information (Gagne')[48]. While McGuire[57] identified the use of persuasive communication, Skinner[18] suggested the idea of arranging contingencies of reinforcements by some preferred or rewarding activity. Teachers of mathematics should use instructional strategies such as incorporating learning resources like calculators which could tend to reduce computational problems and thus limit mathematics anxiety in pupils. The use of calculators has been found to be enjoyable and motivating to pupils in the classroom (Suydam)[22]. Hence, this and other activities perceived to be enjoyable and motivating may be adopted to reduce pupils anxiety.

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56. Behr, A.N., Achievement, aptitude and attitude in Mathematics, Two-Year College Mathematics Journal 4, 72-74, 1978.

57. McGuire, M.J. Handbook of Social Psychology. 2nd Ed. Vol. 3, Reading Mass: Addison-Wesley, 1969.

In addition pupils' attitude toward the teacher may be important in the formation of mathematics attitudes. Teachers should therefore, be aware of the fact that at this critical period of attitude formation in high school the teachers' attitudes toward mathematics and their pupils are important and may be the determinants of pupils' attitudes toward mathematics. It may not be a new phenomenon that a large segment of the population fears mathematics (Gaugh, Kogelman and Warren)[53]. What can be done? The following constructive techniques and strategies can be helpful: (1) creating a positive, supportive classroom atmosphere - for example, a teacher who takes time to listen intently while a pupil asks a question, and responds with a willingness to explain, will create an atmosphere in which students feel at ease asking questions. The math - anxious are especially sensitive to criticism and pupils with a low self-concept are reluctant to take risks (Morris)[58]. Hence they do not ask questions, (2) There is need to stress understanding of the thought process. The process and product aspect of mathematics problem-solving are important. Too much emphasis should not be placed on one to the detriment of the other. Pupils should therefore be encouraged to think; (3) The teacher should dispel the

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58. Morris, J.: Math Anxiety: Teaching to avoid it. Mathematics Teacher, NCTM, 74(6) 413 - 417, 1981.

'mathphobia' in his pupils. If the teacher is not afraid to say he 'does not know' when it is the honest answer the pupils would have confidence in the ability of the teacher. The impression that the teacher knows all the answers should be dispelled because it creates defeatism on the part of the pupils especially the weaker ones. (4) Provide new positive mathematics experiences. (5) Use appropriate instructional materials to teach content. (6) Make sure each concept is understood before continuing to new one. (7) Reduce tension and pressure in mathematics classes. (8) Give positive feedback on written tests, (9) Teachers should not only be sensitive but determined.

Apart from above suggestions, anxiety which is a learned response to a negative experience according to Morris[59] should be prevented. Thus, the above techniques and strategies can be tried by teachers' of mathematics aso as to reduce mathematics failure in our schools. It would be appropriate to subject each of the above suggested strategies or techniques to empirical studies so as to determine the their efficacy or otherwise on concept learning and attitudes in mathematics.

2.4 Calculator and Other Instructional Devices

Researches on instructional techniques and materials

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59. Morris, J.: Math. Anxiety: Teaching to avoid it. Mathematics Teacher, NCTM, 74 (6) 413-417, 1981.

such as programmed text/instruction, individualised instruction, computer-based instruction etc. have been carried out and their effects on the teaching-learning process do produce interesting results. The results of researches on programmed instruction on teaching and learning of mathematics, (for example, Abimbade[60] in a study on relative effectiveness of programmed instruction to traditional method of teaching secondary school mathematics) showed that the programmed instruction group did achieve significantly better results than the traditional group. Kalejaiye[61] carried out a study on the individual difference to programmed material in the new mathematics and found that programmed text was effective in changing the attitudes of pupils towards the new mathematics.

Balogun et. al.[60] Adewakun[60] and Okunrotifa[60] have all reported positive results in favour of programmed instruction, Jurgemeyer[62] also got positive results with programmed instruction vis-a-vis the advent of new directions in media technology such as Video discs, interactive Video and micro-computers.

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60. Abimbade, A.: The relative effectiveness of Programmed Instruction to the traditional teaching of secondary school mathematics. Unpublished M.Ed. Dissertation, University of Ibadan, 1983.

61. Kalejaiye, A.O.: Individual differences to programmed instruction in the new mathematics, West African Journal of Education, 15 (3) Oct. 1971.

62. Jurgemeyer, F.H.: Programmed Instruction: Lessons it can teach us. Educational Technology, 14-49, May, 1982.

Crawford[63] reported more favourable attitudes towards mathematics as a result of computer-assisted instruction with seventh graders. But working with the same group, Johnson[64] found no differential increases to positive attitudes toward mathematics. It would appear that little studies are available comparing the use of calculators and other instructional devices. However, interesting results relating to the use of computer's in mathematics instruction would be discussed so as to identify those areas applicable to calculator-use.

2.4.1 Computer Based Instruction

Computer-based instruction is used here purposely to encompass a broader spectrum of computer applications: computer-assisted instruction (CAI), and computer-managed instruction (CMI). Computer-assisted instruction implies the concept of tutorial instruction, drill and practice, presents instructional material to the learner, aseepts and judges responses from the learner, provides feedback and alters the flow of subsequent instructional material on the basis of the learner's responses whereas the computer-managed instruction relies principally on the record-keeping and summarising power of the computer. However, one's

63. Crawford, A.N. and Johnson, F.E. see Aikan, L.R., In "Update on Attitudes and other Affective variables in learning mathematics" Review of Educational Research 46(2), 293 - 311, 1976.

64. Johnson, R.E.: The effect of activity oriented lesson on the achievement and attitudes of 7th grade students in mathematics. Dissertation Abstracts International 1971, 32, 305A.

emphasis in this review shall be the computer-assisted instruction which is more relevant to the objective of the present study.

2.4.2 Evolution of Computer-Assisted-Instruction (CAI)

Following dwindling interest in programmed learning and with the emergent of new technology, educators have asked: How far has education/instruction been individualised with the new technology like computer? Burns and Bozeman[65] proponents of CAI asserted that computer's support for the instructional process offered the promise of greater student achievement, more efficient use of human and material resources, improved attitudes towards the learning process, and enhancement of quality education in general.

Among the first users of C.A.I. were members of the Computer Industry who, in the late 50's used computer-based instructor to train their own personnel (Suppes and Macken)[66]. Educator's interest focussed on programmed instruction as a means toward individualised instruction. Educationally, C.A.I. was an almost natural combination of emerging computer technology and the programmed instruction movement (Scheen and Hunt)[67]. Among the early C.A.I.

65. Burns, P.K. and Bozeman, W.C.: Computer-Assisted Instruction and Mathematics Achievement: Is there a Relationship? Educational Technology, 1981

66. Suppes, P. et. al. Institution for Mathematical Studies in the Social Sciences, California, Standford University, USA, 1967.

67. Schoen and Hunt: In Burns and Bozeman. Educational Technology, 1981.

models to emerge was the Standford Project*. It began in 1963 and its original aim centred on the achievement of a small tutorial system intended to provide instruction in elementary mathematics and language arts. It went through different phases such as Stanford Drill-and Practice System. There were other projects like The Individual Communication System (INDICOM) launched in 1967 in the Waterford, Michigan School District; then PLATO (Programmed Logic for Automatic Teaching Operations) System which originated in the co-ordinated Science Labrratory at the University of Illinois, U.S.A.

The PLATO Project has also gone through many phases. For example PLATO IV system (1981) which continues to be operational, supports several hundred terminals at dispersed locations. Each terminal site is provided access to a central lesson library. The powerful and relatively facile author Language of PLATO called TUTOR accommodates simultaneous system time sharing by students and teacher as lesson materials. The projects have, at the elementary and secondary school levels been concentrated in the areas of mathematics and language arts. There are many other systems all over the world but it appears that the Nigerian educational systems has not been able to catch up with these new technological approaches to education. This may probably be due to

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* Under Patrick Suppes at the Institute for Mathematical Studies in the Social Sciences at Stanford University, U.S.A.

the cost of computer hardware which is generally very expensive.

2.4.3 <u>Pedagogical effectiveness of CAI</u>

Published studies comparing the effectiveness of CAI to traditional instruction report conflicting and inconclusive results. Most studies, however, generally conclude that an instructional programme supplemented with CAI is at least as effective or more than a programme utilizing only traditional instructional methods (Magidson)[68]. Research in the area of CAI effectiveness has typically investigated one or more of five criterion variables; student achievement, student attitudes toward CAI and towards subject-matter, time-savings relative to unit completion and/or mastery learning, learning retention and cost factors. Results of a review of research literature on CAI effectiveness on the above criteria as compiled by Edwards et al[69] are as follows:

(i) All studies reviewed have shown normal instruction supplemented by CAI to be more effective than the normal instruction alone;

(ii) When CAI was substituted, in whole or in part, for traditional instruction, 45 percent of the studies

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68. Magidson, E.M. Issue overview: Trends in CAI Educational Technology 18(4), 1978, 5-8.

69. Edwards, J. et al. How effective is CAI? Review of the Research. Educational leadership. 5. 1975.

demonstrated greater achievement by CAI students, while 40 percent found little or no difference; 15 percent showed mixed results.

(iii) Based on available results, it cannot be concluded that any given CAI mode is more effective relative to student achievement, than other modes.

(iv) CAI has been shown to be equally effective relative to student achievement, when compared with other non-traditional instructional methods.

(v) All studies showed that it took less time for students to learn through CAI than through other methods.

(vi) There is more evidence that learning retention levels of CAI students may not be as high as those of traditionally taught students.

Most of the researches reviewed in this study came from United States of America which appear to be the only country that has the largest published work in computer-instruction. There are no available records on computer instruction research in this country except the work of Ohuoha on computer's utilization in Nigerian Universities with guidelines for improved utilization (Columbia University, Teacher College, 1981). With the advent of technological approaches to education and instruction in Europe, U.S.S.R.

and America, there was renewed interest in student reactions to instructional techniques. Several studies have reported students' attitudes toward computer-assisted Instruction (CAI) (Brown, Filip and Murphy)[70]

2.4.4 Attitudes and CAI

Attitudes are probably dependent on the kind of experience individuals have with instructional device. Resenberg, Rezuikoff, Stroebel and Ericson[71] reported that nurses attitudes toward computers became favourable after they had actually worked with computer. Wodtke[72] found that those students who performed well when instructed by a computer had more favourable attitudes toward it than those students who performed poorly. He concluded that favourable or unfavourable attitudes of students toward a teaching method could be the result of their experience with the particular method of instruction.

Mathis[73] found that College students generally have positive attitudes towards computers when exposed to CAI. It was also found that the CAI has a major advantage over other teaching machines or

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70. Brown (1967, Filip and Murphy (1967). Communications, Mass without meaning. Educational Technology, April 15, 1967, 4-5.
71. Rosenberg, M.J. et al. Developing effective Instructional manuals and computers. Educational Technology, Jan. 1967.
72. Wodtke, R.C. Computers and Learning strategies. Educational Technology, Dec. 1965, 1-5.
73. Mathis, A. College students attitudes toward CAI, Journal of Educational Psychology, 61(1), 1970.

programmed texts in that students can branch immediately to easier materials if they begin to make many errors (Suppes)[66].

Most of the studies showed favourable attitude toward CAI, but, would the use of calculator generate such favourable attitudes? It would have been possible to infer the result of such investigation but this may not be so until empirical study integrating the use of calculator into instruction is carried out. However, from studies so far carried out there are evidences on the positive note for CAI.

For Hansen et al[75] in "What Teachers think - Every high school graduate should know about Computers" found that teachers supported the idea that students should have some minimal understanding about computers, but the extent of coverage of computer topics was minimal Kleiman, G. and others[76] working on microcomputers and hyperactive children found that children did almost twice as many exercises with the computer as they did with paper and pencil, although no differences were found in proportion to correctness or time at ages 6 - 14 years. De-Blassio[77] studied attitudes toward computers in High School mathematics courses and found

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75 Hansen, T.P. et al. What Teachers Think Every High School Graduate should know about Computers. School Science and Mathematics 81: 467-472; October, 1981.
76 Kleiman, G. et al. Micro-computers and hyperactive children in Creative Computing 7: 93-94; March 1981.
77 De-Blassio, J.K. and Bell, F.H.: Attitudes Toward Computers in High School Mathematics Courses. International Journal of Mathematics Education in Science and Technology. 12, 17-56, Feb. 1981.

positive correlations between students' attitudes toward using a computer and attitudes toward mathematics and instructional setting, plus achievement variables for grades 11 and 12. These results are quite significant because it relates effects of compute on mathematics achievement and attitudes which has a good bearing with the present study. However Casner[78] in a study of attitudes toward mathematica of eighth grade students receiving computer-assisted Instruction and students receiving conventional classroom instruction found no significant differences in attitudes toward mathematics between girls using or not using CAI, but boys using CAI showed less negative attitudes towards mathematics at secondary school. Ray[79] studies the effects of computer assisted test construction on achievement in first year algebra and found that students using the computer assisted test with repeatable testing achieved high score than students taking a traditional course at secondary school level. Not only is the computer used for testing but Sears[80] compared

78. Casner, J.L.: S Study of Attitudes Toward Mathematics of 8th Grade Students receiving CAI and Students receiving conventional classroom instruction Unpublished Ph.D. Thesis, University of Kansas 1977.

79 Ray, K.L. The effects of Computer-Assisted Test Construction on achievement in first year algebra. Unpublished Ph.D. Thesis, University of Southern Calfornia, 1977.

80. Sears, L.O. A problem of the Effects of Teaching a Course in algebra II and Trigonometry via Traditional Method and Other Methods. Unpublished Ph.D. Thesis, University of Houston, Texas, 1977.

some teaching methods in solving algebraic and trigomometrical problems and found that there were no significant differences in achievement between the methods including computer-assisted instruction at the Secondary School. However, Vincent[81] studied the computer's c a p a b i l i t i e s a n d effects of supplementary computer assisted instruction on the mathematics achievement and attitude towards mathematics of high school students. He found that students using CAI drill and practice programme had better achievement and attitudes than those not using CAI at grades 9 - 12.

Essentially, most of the studies reviewed have demonstrated some relationship between computer and mathematics. It would appear from research literature that mathematics instruction can be facilitated with the use of computer. Before any conclusion can be made it would be necessary to establish the basis for computing in mathematics instruction. The process for mathematical computation shall be discussed so as to elucidate on the place of calculators and computer in mathematical computations.

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81. Vincent, A.T.: The effects of supplementary CAI on the mathematics achievement and Attitude in EMR High School. Unpublished Ph.D. Thesis. University of Cincinnati, 1977.

2.4.5 Computers and mathematics

Electronic calculators like computers have speed, internal memory but requires human direction at each step in a computational routine. The electronic calculators have limited facilities in terms of stored program. The stored program characteristically marks the difference between computers and electronic calculators. Computer's stored program usually includes logical tests to determine which of many possible program steps should be taken at important junctures in the program.

Thus, the stored program is not just a sequence of steps to follow in computation of computer programming but typically includes all possible paths that computation might take within the scope of the problem, being programmed. Computers and other calculating machines owed their developments to the works of nineteenth century English mathematician George Boole[82] and his "Algebra of logic" popularly called Boolean Algebra which represents logic in mathematical symbols and provides rules for calculating the truth or falsity of statements. Other works were those of Herman Hollerith on machine purchased-card while Howard Aiker in 1937 designed a machine that could automatically perform a sequence of arithmetic operations.[1] However, the

82. Boole, George: The Laws of thought, 1854.

remarkable work by Charles Babbage in 1812[1] who devised a machine called a "differential machine" which could automatically perform simple computations needed for trigonometric and logarithmic tables. It was his invention of analytic engine which led to todays switching networks and internal storage for data processing.

Electronic calculator like computer is an important technological advance because it extends and expands the capabilities of man. Unaided, man is rather "puny". Variety of computers/calculators have reduced or eliminated druggery connected with extended computations. Calculator or computer cannot perform any operations which cannot also be performed by human being but the calculator or computer can operate at very high speed, store and retrieve data at high speed. However, man can reason heuristically and he is best suited to think, reason and discover; whereas a computer is best adapted to calculate, manipulate and compare at very supersonic speed.

To every mathematical problem there is a solution-process (See Fig. 5). Once a problem has been identified in the real-world, the objectives of a solution-proecess are defined. For solution, some abstraction based on human interpretations would produce information/data that are processable by numerical methods to provide solution. The information may be generated in varioss ways such as mathematical formula or numerical data which would be defined, processed and solved.

The numerical method are applied in the computational phase, which is a decisive portion of the total problem solution. This processing of information with the feedback mechanism is the basis for systems approach to mathematical computation.

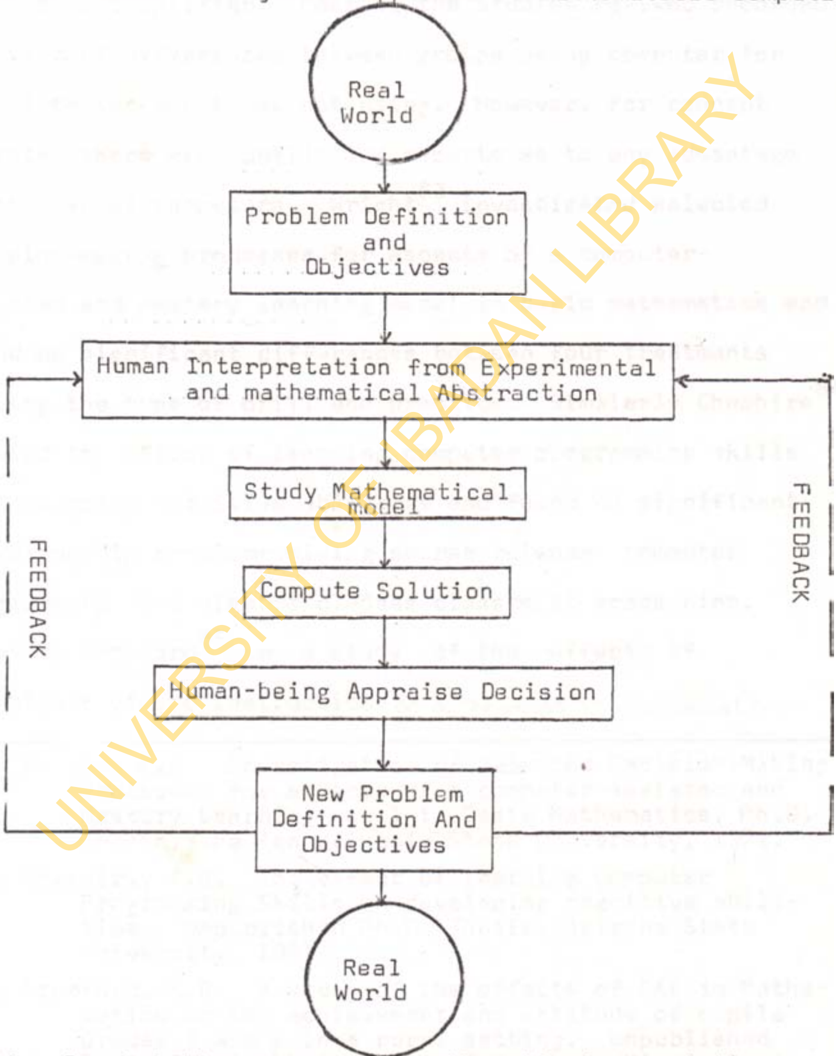

Fig. 5: Solution process in mathematical computation

Source: Modified from Paul, G. A. Introduction to Scientific Computing, New York; Meredith Corp., 1971, pg. 9.

2.4.6 Research in computer-mathematics

Many researches have been reported in computer and mathematics but those ones dealing with concept learning have to be identified. Most of the studies revived recorded significant differences between groups using computer for computatation and those not using. However, for concept learning there are conflicting reports as to any advantage in the use of computers. Wright[83] investigated selected decision-making processes for aspects of a computer-assisted and mastery learning model in basic mathematics and found no significant differences between four treatments varying the type of drill and practice. Similarly Cheshire[84] studied the effect of learning computer programming skills on developing cognitive abilities and found no significant difference in problem-solving scores between computer programming and algebra classes classes at grade nine. However, Cranford[85] in a study of the effects of computer-assisted instruction on achievement in mathematics

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83. Wright, E.B. Investigation of Selected Decision-Making Processes for aspects of a computer-assisted and Mastery Learning model in Basic Mathematics. Ph.D. Thesis, The Pennsylvania State University, 1977.

84. Cheshire, F.O. The effect of learning Computer Programming Skills on developing cognitive abilities. Unpublished Ph.D. Thesis, Arizona State University, 1981.

85. Cranford, H.R. A study of the effects of CAI in Mathematics on the achievemant and attitude of pupils Grades 5 and 6 in a rural setting. Unpublished Ph.D. Thesis, University of Southern Mississippi, 1976.

and attitude of pupils in grades five and six in a rural setting found that the groups which used a computer drill-and-practice program achieved at a faster rate on computation and applications tests. Little difference was, however, found in understanding. Some of these studies have shown no significant differences in learning of concept by computer but some studies where computers have been integrated into the instructions gave positive results.

Deloatch[86] did a comparative study on the use of computer programming activities in an introductory college mathematics course for disadvantaged students and found the computer-augmented instruction to have significant positive effect on the mathematical attitudes of disadvantaged students, but not upon their achievement at College level. Lamb[87] in a study on the co-ordination of graph theory and computer science at the secondary school reported that students with access to computer terminals scored significantly higher in achievement of graph theory content than students without such access.

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86 Deloatch, S.J.: A comparative study of use of Programming abilities in an introductory college mathematics for disadvantage students. Unpublished Ph.D Thesis, Indiana University, 1977.

87 Lamb, R.L.: A study on the coordination of Graph Theory and Computer Science at the Secondary School. Unpublished Ph.D Thesis, Georgia State University, School of Education, 1976.

From studies carried out so far one can gather that the computer could be programmed to serve as a test generator and administrator. Computers have been used in educational settings and for instructional processes, individualising instruction, testing or drilling for competency in basic facts. Computers can be used as teaching-aids that help to achieve the objectives for mathematics learning. When access to computer is available students will be able to use the computer for programming the solutions to problems, for simulating situations in order to test hypotheses, for gaming, as a study of probability and statistics, as well as for testing, practising, drilling and tutoring.

2.4.5 Conclusion

Most of these researches reviewed have been carried out abroad by different researchers functioning in different environments. Their findings may be affected by environments, to apply their conclusions to the Nigerian situations directly may be inappropriate because the Nigerian environment differs from those of pupils in Europe and United States of America who are more exposed to stimulating and sophisticated environments. It would be appreciated that the input of the environment on the individual could play a significant role on the psychological thinking, perception, reasoning and learning of the individual. For pupils in an enriching and stimulating environment, they would be motivated and are likely going to learn better and achieve better in schools than pupils not exposed to such environment. It only means that pupils in under-developed countries of the world will of necessity be at a disadvantage. The advanced and industralised countries have always provided a wider range of experiences. This limitation portends itself in the area of technological based-instruction for example the use of calculators or computers in instruction. Besides, only very few studies on concept learning in mathematics have been carried out here in Nigeria. Falokun[88], Oni[89] and Ogunyemi and Beltie[90] have all investigated concept formation in mathematics using different experimental variables. However, none of them has tried to integrate the use of electronic calculator into the instructional process to find out the effect of such a device on the concept learning and attitudes to mathematics in the secondary school.

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88. Falokun, C.O.: Concept formation in algebraic equations and problem-solving among form V students in Oyo State of Nigeria. Unpublished M.Ph. Thesis, University of Ibadan, 1983.

89. Oni, E.O.: Conceptual difficulties with ionic equations as function of intellectual development among secondary school students. Unpublished M.A. Thesis, University of Ife, Nigeria, 1982.

90. Ogunyemi, F. and Beltie, J.: An investigation of cognitive preferences in mathematics among high and low achievers in the Nigerian Secondary Schools. African Journal of Educational Research, Vol. 1 pp. 97-105, 1974.

CHAPTER THREE

RESEARCH DESIGN AND PILOT STUDY

3.1 Introduction

The research is basically experimental using a 3 x 3 factorial design. The independent variables or main effects are mental ability levels and different modes of instructional presentations, while the dependent variables are achievement and attitude measures.

ACHIEVEMENT MEASURES / ATTITUDE MEASURES			MENTAL ABILITY LEVELS		
			HIGH MENTAL ABILITY C1	AVERAGE MENTAL ABILITY C2	LOW MENTAL ABILITY C3
TREATMENT GROUPS	E1	USE OF CALCULATOR IN INSTRUCTION AND TESTS (UNRESTRICTED GROUPS)	A (12)	B (12)	C (12)
	E2	USE OF CALCULATOR IN TESTS ONLY (RESTRICTED GROUPS)	D (12)	E (12)	F (12)
	E3	NON-USE OF CALCULATOR IN INSTRUCTION AND TESTS	G (12)	H (12)	I (12)

Fig. 6: Paradigm of 3 x 3 factorial design of pilot study.

Number of cells, K = 9.

Number of subjects in each cell, n = 12.

Total Number of subjects, N = 108.

The design is comparable to three-group, before-after design proposed by Solomon[91]. It provided a way to avoid possible interactive effects due to the pretest or pre-attitude and also allowed for both to be used as covariates in the data analysis. The main hypotheses were tested on the effects of calculator use and instruction on concept learning and attitudes towards mathematics and calculator. The experimental and control groups were selected for treatments at random from population of form five pupils in the secondary school.

The structure of this type of research design, according to Kerlinger[92] is where two or more independent variables are juxtaposed in order to study their independent and interactive effects on a dependent variable. In this study there were two independent variables - mental ability levels and modes of presentation and two dependent variables - achievement and attitude measures. The assignment of the subject of the study to treatment groups was randomly based on their mental ability levels. The mental ability levels of the subject were obtained from the results of their Mental Language/Verbal (ML) and Mental numerical (MN) tests.

91. Solomon, R. in Kerlinger, F.N. Foundation of Behavioural Research, 2nd Ed., New York: Holt Rinehart and Winston Inc., 1973, 339 - 375.

92. Kerlinger, F.N. Foundation of Behavioural Research 2nd Ed., New York: Holt, Rinehart and Winston Inc., 197?.

The tests were developed and validated by Australian Council for Educational Research (A.C.E.R.) and they had been used by different researchers in the Faculty of Education, University of Ibadan, Nigeria.

However, Campbell and Stanley[93] have noted the possibility that some errors might result from employing the usual statistics appropriate for the random assignment of individual pupils to treatment groups, such as the ANOVA (Analysis of Variance) for intact classes assigned to treatment groups. In this study therefore, the use of the pre-test and pre-attitude mean scores were used as covariates to serve for adjusting the initial differences within and between groups.

If T_1, T_3 and T_5 represent the pretests, X_1 and X_2 the treatments and T_2, T_4 and T_6 the post-test, the design paradigm can be represented in this format:

Pre-treatment	Treatment	Post-treatment
T_1	X_1	T_2
T_3	X_2	T_4
T_5		T_6

93. Campbell, D. and Stanley, J. Experimental and Quasi Experimental Designs for Research, Stokie; Illinois: Rand McNally, 1963.

Both the pre-and-post treatments incorporated the attitude and achievement measures. Levels of treatments varied depending on the groups. One of the groups received the full treatment: calculator-use in instruction and tests, other experimental group received treatment of calculator-use in tests only and the control group did not receive any treatment on calculator, that is, non-calculator-use.

The aim of this research was to find out how instructional product could facilitate teaching-learning processes, hence the design is an empirical study on the improvement of instruction. The experimental-control group design using equated experimental group subjects and control group subjects through randomization, equal number of subjects in each cell provided an effective comparison in this factorial design. According to Kerlinger[92] research design has two basic purposes:

(1) to provide answers to research questions and

(2) to control variance.

What the research design does is therefore to help the investigator obtain answers to questions of research and also to control the experimental, extraneous, and error variances of the particular research problem under study.

The focus of this study arose as a result of educators' concern on:

(a) possible change in pupil's attitude toward calculator and school mathematics,

(b) possible interference with pupils growth in knowledge of basic mathematical facts and paper-pencil computations,

(c) possible changes in children's scores on standardized achievement tests in mathematics.

(d) potential development of additional mathematics concepts related to calculator;

(e) possible change in computational power of pupils when using calculators and

(f) facilitation of mathematics conceptual learning and problem-solving skills of pupils through the use of calculator.

3.2 Population and sampling procedure

The form five pupils in the secondary school in Oyo State, Nigeria at the time of this study constituted the population, and subjects used were from the sampled population. The subjects were all enrolled in the sampled schools at the time of study. The choice of this category of students was considered appropriate because they already had the requisite knowledge of basic mathematical operations of addition, subtraction, multiplication and division. Their average age was within the piagetian operational range where symbolic abstraction is possible. They were already familiar with mathematics as a school subject, and hence, they were sufficiently predisposed to the learning of suitably prepared structural materials in equations.

The sampling technique adopted for this investigation was the random sampling approach. Kerlinger[92] defined this as the method of drawing a proportion (sample) of a population or universe so that all possible samples of fixed size have same probability of being selected . This approach is regarded by statisticians to be the most practical and free of bias. For instance, Kerlinger also observed that a sample drawn at random is unbiased in the sense that no member of the population has any more chance of being selected than any other member"[96]. However, because of the nature of this research design it was not practicable to randomly select schools throughout the state. Therefore, a multi-stage random sampling selection of the secondary schools in Ibadan city for this study was carried out. The selection of subjects into treatment groups were also carried out through random sampling technique.

96. Fisher, R. The design of Experiments, 6th Ed., New York: Hafner, 1951, pg. 11.

3.2.1 Selection of Schools for the Study

As at the time of this study there were 750 secondary schools in Oyo State and 95 secondary schools in the Ibadan Municipality. Different schools were selected for:

(i) validation of research instruments.

(ii) pilot study.

(iii) main study.

The choice of schools in Ibadan city for this study was because of the accessibility of the researcher to the subjects used in this experimental study.

(i) For the validation of research instruments, United Secondary School, Ijokodo was chosen. The school was established in 1980, and it is made up of boys and girls. The school first presented pupils for West African Examination (WAEC) May/June 1985 General Certificate of Education, Ordinary Level (G.C.E., O/L) Examinations. The school has both Junior Secondary School and Senior Secondary School (JSS/SSS) in line with the New National Policy on Education 6-3-3-4 system. As at the time of this study, the school had a population of about 1500 pupils. The school had five arms of form five and the arms were divided into Arts and Science classes. The research instruments for validation were mathematics achievement test and attitudes towards mathematics and calculator use in mathematics questionnaire. The mathematics pre-test had earlier been validated in previous study[60].

(ii) The multi-stage random technique was used for the selection of the school for the pilot study. Out of the 95 secondary schools in the Ibadan Municipality only 33 of the schools were mixed (boys and girls). Only sixteen of the schools were established more than ten years ago. Most of the 33 schools were established in 1980, and they first presented pupils for West African Examination Council/General Certificate of Education Ordinary level examination in 1985. Most of these schools have relatively large number of pupils averaging about 1000 or more pupils in each school.

Those schools established more than ten years ago have larger number of pupils average about 2000 pupils per school and more equipped than 1980 schools. All the schools have JSS/SSS. Five of the schools were randomly selected out of the 16 schools. On the basis of their West African Examination Council (WAEC) results in General Certificate of Education, ordinary level (G.C.E., O/L) mathematics for the last five years (1980-1984) five of the schools were comparable, (see Table 3). One of the schools Ahmadiyya Grammar School, Eleyele, Ibadan was selected by ballot for the pilot study.

(iii) The procedure for the selection of schools for the main study would be discussed in chapter four of this report. However, the pilot and main study schools were relatively apart. This was to reduce any possible experimental contamination between the subjects in the study.

TABLE 3

WAEC/GCE results of sampled schools in mathematics

SCHOOLS	PERCENTAGE PASSES FOR THE YEAR					% AVE. PASSES
	1980	1981	1982	1983	1984	
ADEKILE GOODWILL GRAM. SCH., APERIN, IBADAN.	37.8	46.3	65.6	53	47.3	50
HOLY TRINITY GRAM. SCH., OLD IFE ROAD, IBADAN	43	24.6	45.3	45.5	85	48
IBADAN CITY ACADEMY, ELETA, IBADAN.	62	55.6	42.4	41	50	50.2
AHMADIYYA GRAM. SCH., ELEYELE, IBADAN.	45	20	36	42	32	45
ISLAMIC HIGH SCH., BASORUN, IBADAN.	59	52	63	37	31	48

3.2.2 Selection of Subjects

The subjects used for the study were mainly secondary school pupils. The pupils were considered as representative of the country's secondary school population because they came from different ethnic, cultural, religious and socio-economic background. The assumption was that the pupils in this group were not different in any way from pupils in other comparable schools in Nigeria. The study was conducted with the form five pupils who were in their first term of their final year in the school. There were 216 pupils (boys and girls) in form five of the pilot study school. The whole of the form five pupils of the school took the A.C.E.R. mental ability tests (ML and MQ).

Out of the 216 pupils who took the tests those pupils who scored between 32 and 51 were within the high mental ability level and 36 of them were randomly selected into the high mental ability (HMA) groups. Those who scored between 27 and 31 were within average mental ability level and 36 of them were randomly selected into the average mental ability (AMA) groups. Similarly, those who scored between 20 and 26 were within the low mental ability level and 36 of them were randomly selected into the low mental ability (LMA) groups.

Twelve pupils (subjects) per group from the HMA were randomly selected into calculator in instruction and tests group (E_1), calculator in tests only group (E_2), and non-calculator group (E_3). The same random selection was done for AMA into E_1, E_2 and E_3 groups. The same procedure was carried out for LMA groups. A total of 108 pupils took part in the pilot study. The same procedure of subjects selection was carried out in the main study except that the 3 treatment groups were in 3 schools. The nature of the research design allowed for the use of boys and girls schools for the pilot and main studies. However, to control for sex variable one would have used girls only and boys only schools. But this design controlled for sex variable by having nearly equal number of boys and girls in each cell/group. Kerlinger[92] observed that both girls and boys are used in an experiment, randomization can be used in order to balance the individual differences that are concomitant to sex. Then the number of girls and boys in each experimental group will be approximately equal". The girls and boys were assigned randomly in nearly equal numbers to the groups in the pilot and main studies.

3.3 Research Instruments:

These are ACER Higher test ML and MQ published by Australian Council for Educational Research (ACER) (See Appendixes 8 & 9) which are standardized tests in verbal and numerical abilities. However, the tests were modified for the Nigerian situation. There were also author-prepared instruments such as:

(1) Attitude measures towards mathematics and calculator.

(2) Mathematics pretest.

(3) Mathematics achievement/post-test.

(4) Instructional Module in Mathematics.

In this study, mathematics achievement test and mathematics post-test meant the same test.

3.3.1 Preparation of Instruments

(1) Attitude Scale

Working from the basis of 20-item scale developed by Aiken and Dreger[97] and using the Likert scaling procedures, the attitude scales were two Likert-type A & B with five response-options. One scale was used to measure attitudes toward mathematics (A) and the other to measure attitudes toward the use of calculator in mathematics by the pupils (B). For scale A, there were 12-items and for Scale B there were 14-items,. Pupils responded to each item by choosing one of five Likert alternatives: strongly agree (5), agree (4), undecided (3), disagree (2) and strongly disagree (1). There were equal number of positive and negative items in each scale. The positive items were scores, 5, 4, 3, 2,1 as shown on scale . The negative items were reversed for purposes of scoring. The same response alternatives were used with all items. The instrument was field-tested, and pupils were interviewed to determine how valid the scales were for reflecting the pupils' attitudes. The pupils' responses were registered in the space adjacent to an item. (See Appendix 10).

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97. Aiken, L. R. Jr. Personality correlates of attitude toward mathematics. Journal of Educational Research, 1963, 56, 576-580.

(2) Mathematics pre-test:

From the learning experiences of the pupils a sample of question-items on linear equations was prepared. The construction of the test items was based on the analysis of the objectives in the cognitive domain, knowledge, comprehension and application. For the task analysis, we have algebraic operations, expressions, identifying euqations, forming equations and solving equations to comply with the following behavioural objectives:

(i) to identify expressions such as:

$$ax + b$$

from linear equations of the form:

$$ax + b = x$$

where a and b are constants.

(ii) to form linear equations with one variable:

$$\frac{3x + 4}{4} - 6 = 0$$

(iii) to solve linear equations of one variable:

$$3x + x + 2 = 10$$

The numbers for each of the behavioural objectives and corresponding topics were worked out. On the whole, 15 question test-item was constructed. The test-items were multiple choice objective questions format, and the pupils were expected to complete the test in 30 minutes. It was field-tested for validity and reliability.

TABLE 4

Mathematics pre-test items construction format for content validity

TOPICS	BEHAVIOURAL OBJECTIVES			TOTAL
	KNOWLEDGE	COMPREHENSION	APPLICATION	
1 Algebraic operations	1	1	-	2
2 Algebraic Expressions	1	1	1	3
3 Identifying Equations	1	1	-	2
4 Forming Equations	1	1	1	3
5 Solving Equations	2	2	1	5
TOTAL	6	6	3	15

(3) Mathematics post-test:

The test-item content was based on equations: simple, simulatenous, and quadratic. The test was applicable to forms four and five pupils of secondary school who had covered these aspects of the seondary school mathematics curriculum. The test-item selection was based on the following objectives:

(i) to provide pupils with basic facts on algebraic concepts.
(ii) to develop pupils' computational skills in mathematics.
(iii) to identify relations in mathematical concepts.
(iv) to solve simple forms of different equations.
(v) to translate word problems to equation and solve them.

The objectives were translated into the test plan relating each objective to the cognitive domain and the appropriate task.

TABLE 5

Mathematics post-test plan for content validity

TOPICS	COGNITIVE DOMAIN				TOTAL
	COMPUTATIONAL ALGORITHMS	CONCEPTS	APPLICATIONS	PROBLEM SOLVING	
Simple Equation	4	4	3	3	15
Simultaneous Equations	3	3	2	2	10
Quadratic Equations	3	1	1	-	5
TOTAL	10	8	6	6	30

The test items were made up of 30 multiple choice objective questions. Each test-item had five options lettered A, B, C, D and E. One of the options was the correct answer. The pupils were required to answer all the questions in 40 minutes. For validity and reliability of the test, a pilot study for the test validation was carried out. The school used to carry out both validity and reliability tests was United Secondary School, Ijokodo, Ibadan.

(4) Instructional module

The module had been prepared in response to the need for appropriate and adequate mode of instructional presentation. From the analysis of some Nigerian textbooks on secondary school mathematics carried out it was observed that they did not meet the need of calculator-use in instruction. It became necessary to prepare both the module and calculator in instruction guide (See Appendix 7).

According to Bell[98], the main difficulty, of course, is that few existing school mathematics textbooks have really interesting problems that exploit the power given by calculators.

Presentation sequence in the teaching of mathematical concepts plays an important role in the learning of the subject. Suppes, like Gagne'[5], subscribes to the idea of the importance of accounting for content structure in the study of learning and sequencing. Suppes, Hyman and Jerman[5] stated that in the cognitive domain mathematics provides one of the clearest examples of complex learning and performance, for the structure of the subject-itself provides numerous constraints on any adequate theory . A substantial amount of Suppes' work reflects the attitude contained in the following statement:

> For anyone interested in the psychological foundations of mathematical concept formation

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98. Bell, Max. S. Calculators in Elementary Schools? Some tentative guidelines and questions based on classroom experience. The Arithmetic Teacher 23(7), No. 1976, pp. 502 - 507.

> it is natural to ask what is the sort of connection that holds between the logical structure of mathematical concepts and the psychological processes of acquisition of the concept.[8] (p.73).

Here the need to determine the hierarchies of learning mathematical concepts which would conform with psychological principles becomes necessary as well as the mediational procedures. To this end, the ideas of Ausubel[99] on Advance Organizers and Gagne's[100] learning hierarchy theory were utilized in the construction of the instructional module used in this study. Since calculators were used as part of treatment in the study the instructional module was developed to tap the intrinsic capabilities of the calculator. Hence, the instructional module was prepared with

99. Ausubel, D. P. The Psychology of Meaningful Verbal Learning. New York, Grune and Stralton, 1963.

100. Gagne', R. M. Learning Hierarchies. Educational Psychologists 6(1), 1968, 3-6.

the following objectives in view:

(i) To introduce the pupils to the concept of equations, simple, simultaneous and quadratic.

(ii) To identify different forms of equations: simple, simultaneous and quadratic.

(iii) To solve simple forms of different equations: simple, simultaneous and quadratic.

(iv) To translate word-problems into equational format: simple and simultaneous.

(v) To solve the word-problem-equations: simple and simultaneous.

The above objectives were related to the cognitive domain in the learning content. Hence, appropriate instructional module on simple, simultaeeous and quadratic equations was developed. (See Appendix 7).

3.3.2 Validation of instruments

(1) Attitude Questionnaire:

The attitude measures-scale for mathematics and calculator, prepared by the author was validated for use at United Secondary School, Ijokodo. The 12-item and 14-item of attitude toward mathematics and attitudes toward calculator were developed in line with Aiken and Dreger[97] using the Likert Scale procedure. The subjects were form five pupils of the school in which two classes were selected randomly (by ballot) as sample for the validation process. Pupils responded to each item by choosing one of five Likart alternatives: strongly agree, agree, undecided, disagree and strongly disagree . The sessions were conducted during the free periods of the sampled classes with their mathematics teacher in attendance. The purpose of the questionnaire was explained, and that it would be followed with an achievement test. The questionnaire was first administered before achievement test so that the test might not interfere with their response set. On the whole 80 pupils responded to the questionnaire. Out of the 80 pupils, 40 pupils were randomly selected for testing the validity and reliability of the scale.

For the internal consistency reliability coefficient of the attitude measure. Pearson product moment used to compute the correlation coefficient between odd and even ($r = 0.98$), using Spearman-Brown coefficient the reliability coefficient was found to be o.99 (for the calculation see Appendix 11). The calculated correlation coefficient of $r = 0.98$ is significant for $N = 20$ at $\alpha = .05$ $r = 0.423$.

While another widely used index of item discriminability was the critical ratio based upon the means and variances of the upper and lower 27% of the sampled distribution. The correlation co-efficients of mathematics-attitude and calculator-attitude were computed (See Appendix 12). The mean significant difference of the mathematical attitude scale and calculator attitude scale was computed (See Appendix 13). Shaw and Wright[101] stated that Aiken and Dreger, in 1964, reported a test-re-test reliability coefficient of 0.94. It would be found that those two results are quite close correlation coefficient between 27% upper score and 27% Lower Score on Attitude Scale (MAS and CAS) obtained using Spearman-Rank Order Correlation coefficient. The correlation between 27% upper score and 27% lower score on attitude scale for mathematics attitude score (MAS) and calculator attitude score (CAS) (See Appendix 12) was found to be $r = 0.98$. It means that there is posit significant relationship between MAS and CAS because calculated correlation coefficient is higher (r for $n = 10$ at $\alpha = .05$ is 0.5337) from table of r.

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101 Shaw and Wright, Scale of the Measurement of Attitudes, N.Y. McGraw-Hill, 1967.

The significant mean difference in mathematics attitude score (MAS) and calculator attitude Score (CAS) for 27% upper score was computed using t-test (See Appendix 13). Mean Age = 16.2 years.

TABLE 6

Significant mean difference in mathematics attitude Score (MAS) and Calculator attitude Score (CAS) for 27% Upper Score

Nx	$\bar{x}$ (MAS)	σx^2	$\bar{y}$ (CAS)	σy^2	Ny	Calculated t-ratio	t-value at α =.05	Sign. level
10	44.5	72.5	48.8	72.43	10	1.16	1.81	ns

ns: Not Significant at $p \leq .05$

The significant mean difference in Mathematica Attitude Score (MAS) and Calculator Attitude Score (CAS) for 27% Lower Score was computed using t-test (See Appendix 14).

Mean Age = 16.6 years.

TABLE 7

Significant mean difference in mathematics attitude score (MAS) and Calculator Attitude Score (CAS) for 27% Lower Score

Nx	$\bar{x}$ (MAS)	σx^2	$\bar{y}$ (CAS)	σy^2	Ny	Calculated t-ratio	t-value at α= .05	Signif. level
10	30.7	236.5	27.7	63.9	10	0.73	1.81	ns

ns : Not significant at $p \leq .05$

(2) Mathematics Pretest

According to Flanagan[102] in the empirical selection of test items, he suggested that the first consideration is the validity or discriminatory power of the test and the second one is item difficulty. The best index of validity is one which provides the extent to which an item will predict the criterion such as the difficulty index and discriminatory power. Using Kelley's approach[103] in computing 27% upper score and 27% lower score the difficulty index was found to be 0.40. Following similar

102 Flanagan, J.C. General consideration in the selection of test items. Journal of Educational Psychology, 30, 1939.

103. Kelley, T.L. The selection of upper and lower groups for the validation of test items. Journal of Educational Psychology, Vol. 30, 1939, 17-24.

approach the discriminatory power of the test was found to be 53.3%. For the reliability coefficient of the test, Kuder-Richardson formula: KR21 was used.

$$R = 1 - \frac{\bar{X}(N - \bar{X})}{N \sigma^2}$$

R	:	Reliability coefficient.
$\bar{X}$	:	Mean of the test scores
σ^2	:	Variance of the test scores.
N	:	Number of test items.

For this study, the reliability co-efficient obtained would be considered adequate considering the levels of difficulty and discrimination of the test-item. Blood and Budd[105] furthered opined that a reliability co-efficient for class-room test should be at least 0.60 (Appendix 6).

3.3.3 Modification of mental ability tests - ACER higher tests ML and MQ

Both A.C.E.R. Higher Test: ML and MQ for verbal and numerical abilities were developed by Australian Council for Educational Research in Australia, which is socially and culturally different from Nigeria. Though the tests have been found to be applicable to Nigerian setting (Egbugara)[106], it would be necessary to make some modifications if they would be used effectively and appropriately in Nigeria.

The A.C.E.R. ML test deals with questions on language and vocabulary of English Language. Both Australia and Nigeria have English Language as their Lingua Franca the test may therefore, not suffer much reliability and validity in terms of structure and lexis. However, some of the test-items contained culturally

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105. Blood, D. I. and Budd, W. C. Educational Measurement and Evaluation, New York: Harper and Row, 1972.

106. Egbugara, U. O. Effects of Three Levels of Advance Organizers on Achievement of Some Nigerian Secondary School Physics Students, Ibadan: Unpublished Ph.D. Thesis, University of Ibadan, Nigeria, 1984.

biased words and expressions e.g. the use of Alastian dog which had to be replaced with a more familiar Nigerian name. Those test-items which showed propensity for Cultural bias were modified by changing them to socially and culturally acceptable words in Nigeria.

Whereas in the A.C.E.R. MQ test of numerical ability most of the test items were appropriate except in cases where units of money had to be changed. The Australian pound and penny had to be changed to Naira and Kobo respectively. These changes did not have structural effect on the test-item or their meaning. The durations of the tests ML and MQ had to be changed. Instead of the 20 minutes allocated for each test it was change to 30 minutes so as to give the pupils enough time to read and answer the questions. Secondly it gave room to correct typographical mistakes or non-clarity.

Nonetheless, the tests can be considered to be valid and reliable for the level of pupils after those modifications had been made. It would be understood that those changes could not possibly have affected the validity or reliability of the tests because nothing structurally in the tests were changed. The validity index and reliability coefficient of the tests were not supplied but from available records the tests had been standardized.

3.4 The Pilot Study

3.4.1 Objectives of the Pilot Study

(i) To validate and modify instruments.

(ii) To simulate experimental conditions.

(iii) Trial run for the entire experimental plan.

(iv) To detect flaws so as to increase the probability of a good research.

3.4.2 Procedure for the Pilot Study

The pilot study began in early October 1985. The Form V mathematics teacher provided adequate support. There were 216 pupils in form V of the Ahmadiyya Grammar School, Eleyele, where the pilot study was conducted. Because of the time-table arrangement of the school, some of the tests were conducted after school hours. The school was organising evening remedial classes for Form V pupils from 2 p.m. to 3.30 p.m. There was 30 minutes session everyday for each group. The sampled pupils were divided into S treatment groups based initially on their mental ability scores on A.C.E.R. Higher Tests ML and MQ, and randomly selected into those groups. The groups were randomly selected into treatment groups by taken cognizance of their relative performances on the tests. The calculator groups were instructed by the author while the mathematics teacher helped to instruct the non-calculator groups. The instructional module was used by all the groups. The pilot study lasted for six weeks. There were breaks in between the days of administration either due to pupils being engaged for a school programme or the author/school mathematics teacher not able to attend. However, records of attendance were kept and dates for the administration of the instruments. By the end of the pilot study only an average of ten pupils per group totalling ninety (90) pupils completed the study.

3.4.3 <u>Administration of research instruments</u>:

The first instrument administered during the pilot study was the A.C.E.R. Higher tests ML and MQ. The mental ability tests were used to divide the pupils into different treatment groups. Most of the pupils in Form V of the school took the tests (185 out of 216). The tests took place after the pupils preparatory classes. The school mathematics teacher and the author administered the tests from 4 p.m. to 5.30 p.m. on 21-10-85. The pupils had been informed of the test by their mathematics teacher. Hence the pupils showed enthusiasm towards the test. They were told the purpose of the test that it was not supposed to grade them but to assist in diagnosing their problems in mathematics. The ML test was first taken and followed by MQ test by all the classes. The time of the day the tests were administered had effects on pupils. Some pupils complained of tiredness. In fairness the pupils had been receiving lessons before the test began. It would appear that the tests could only be taken at that time so as to avoid any contamination, and leakage of test-materials. Hence all the pupils had to take the tests at the same time. Each of the tests had a duration of thirty minutes. The pupils were provided with individual question and answer sheets (Appendices 8 and 9). There were thirty-six question-items on each of the tests. There were anough examples on each of the tests and the pupils were required to respond to all the thirty six test-items.

After the tests had been completed by the pupils he results of the tests of ML and MQ were used to divide the pupils into treatment groups. The test scores (X) of each pupil, were added together to determine his/her relative position. Since the test was meant to divide the pupils into three different ability levels those pupils who scored $32 \leq x \leq 51$ were grouped into High Mental ability level, pupils who scored $27 \leq x \leq 31$ were grouped Average Mental ability level, and those pupils who scored $28 < x <$ were grouper Low Ability level.

The c-fferent mental ability levels were then randomly selected (by ballot) into the three different treatment groups).

Calculator unrestricted group, calculator restricted groups and Non-Calculator-use in instruction/test group. The mathematics pre-test and pre-attitude questionnaire were not administered to all the nine groups before instruction began. There were four instructional sessions of thirty-five minutes per session for each of the group. On the whole, twenty-four instructional sessions were conducted during the pilot study for the six groups by the author. The mathematics teacher had only one group of thirty-six pupils of four sessions because three groups were put into one. He had to do this because there was no need for the use of calculator and the pupils were going to receive the same learning experiences.

Immediately the instructional process was coming to an end, the pupils had to take the mathematics post test and respond to the attitude measures. The unrestricted and restricted calculator-use groups used the calculator on the post test while the remaining three groups of non-calculator-use did not use calculator on the test but they responded to the attitude measures. The post test of thirty-items had a duration of forty minutes. When the mathematics post test had been completed the pupils were supplied with the attitude measures which they freely responded to.

3.4.4 The Scoring of different instruments: ML and MQ mathematics pre-test, post-test, attitudes measures.

Both ML and MQ tests were scored on a scale of 1-35. There were 36 test-items on each of the tests. For the mathematics pre-test it was scored on scale of (1-15). There were 15 test-items on the test. Similarly, the mathematics achievement test was scored on the basis of number of question on the test (1-30). The raw scores on the tests were not converted but were directly used in the various analyses. The tests scores (X) in ML and MQ were added together for each pupil so the possible range of score $1 \leq X \leq 72$ was used to divide the pupils into different ability groupings.

Method of summated ratings was used for attitude scores. Items were worded positively and negatively. For positively worded items they were scored 5, 4, 3, 2, 1 and negatively worded items the scoring was reversed as 1, 2, 3, 4, 5. Items scores were added (i) for both Mathematics Attitude Scale (MAS) and Calculator Attitude Scale (CAS) (ii) for each attitude scales MAS and CAS. The item score was assumed to be the weighted sum of the common factor and a factor specific to the item. The common factor was the general attitude variable that we were trying to measure. For MAS + CAS Scores (X) could range between $26 \leq X \leq 130$, for MAS alone scores (X) range $12 \leq X \leq 60$ and CAS: $14 \leq X \leq 70$.

3.5 Analysis of data of pilot study

Analysis of data comprised mainly the comparison of achievement test mean scores and attitude measures. The computer library programme LIB φ2φP was particularly useful for the one and two way factorial analysis of variance and covariance. This programme enabled the use of the attitude towards mathematics and calculator scores (ATS) to adjust the achievement scores of the groups.

Pupils' scores (X) in the mental ability tests were grouped into different ability range: Low ability (LA: $20 \leq X \leq 26$), Average ability (A.A.: $27 \leq X \leq 31$), and High ability (H.A.: $32 \leq X \leq 51$) respectively. These score categories were used as the selection basis for examining the effects of cognitive, numerical and verbal aptitude levels on the post-test and attitude scores. Also multiple correlation coefficients R, R^2 derived from analysis of covariance were computed to determine the relationships between scores of the attitude measures and post-test. All tests of significance were carried out at the 5% alpha level, and all computations were aided by the University computer. However, the computer results of analyses were given to the nearest significant levels e.g. 0.001 or 0.01 etc.

3.6 Results of Pilot Study

The results were analysed and discussed in relation to the hypotheses earlier stated. That is:

Hypothesis One:

There will be no significant difference in the mean achievement scores of those groups of pupils who use (i) Calculator in tests and instruction - the unrestricted groups (UCU) (ii) Calculators in tests only - the restricted groups (RCU) and (iii) No calculators - use at all (NCU). That is:

$$Ho: M_{E_1} = M_{E_2} \quad M_{E_3} \text{ at } \alpha = .05$$

TABLE 9

Analysis of variance of Post-test Scores of Groups UCU, RCU, and NCU

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F-RATIO	P
Covariates VAR02 - ATS	1	50.349	50.349	4.627	0.032*
Main Effects GRP	2	7.014	3.507	0.322	0.999 ns
Explained	3	57.363	19.121	1.757	0.160 ns
Residual	86	935.785	10.881		
TOTAL	89	993.148	11.159		

* Significant at $p < .05$

ns: Not significant at $p = .05$.

TABLE 10

Multiple Classification of Post-Test Scores By Groups UCU, FCU and NCU

Grand Mean 8.18

Variable Groups	Category	N	Unadjusted Dev'n	BETA	Adjusted for independents Dev'n	Beta
	1	30	-0.28		-0.13	
	2	30	0.39		0.39	
	3	30	-0.11	0.09	-0.26	0.08

MULTIPLE R SQUARED = 0.058
MULTIPLE R = 0.240

TABLE 11

Summary of the Mean, Standard Deviation and Variance of the Groups UCU, RCU, NCU

Variable	N	Mean	Std. Dev.	Variance
VAR 01:- MAT	90	26.6555	7.6190	58.06
VAR 02:- ATS	90	77.4556	12.9114	166.70
VAR 03:- ACT	90	8.1778	3.3405	11.16
VAR 04:- MAS	90	42.6555	8.5554	73.195
VAR 05:- CAS	90	34.6333	11.0933	123.06

From table 9, it showed that there was significant difference when attitude scores were used as covariates to post-test scores. However, it would be inconclusive to say that the post-test scores had significant difference at $\alpha = .05$. It was not sufficient to reject the null hypothesis based on this result. However, it would be necessary to run significant level test for the groups in the main study.

Hypothesis two:

There will be no significant difference in the mean achievement scores of those groups of pupils of high (H.M.A.), average (A.M.A.), and Low (L.M.A.) mental abilities.

That is:

$$Ho: MC_1 = MC_2 = MC_3 \text{ at } = .05.$$

TABLE 12

Analysis of variance of Post-test Scores of HMA, AMA, and LMA Groups

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	P
Main Effects GRP	2	273.489	136.744	16.531	0.001***
Explained	2	273.489	136.744	16.531	0.001
Residual	87	719.659	8.272		
TOTAL	89	993.147	11.159		

*** Highly significant at $p < .001$.

TABLE 13

Multiple Classification Analysis of Post-Test Scores by Groups: HMA, AMA and LMA

Grand Mean = 8.18

Variable + Category Groups	N	Unadjusted Dev'n	Unadjusted BETA	Adjusted for Independents Dev'n	Adjusted for Independents BETA
1	30	1.96		1.96	
2	30	0.32		0.32	
3	30	-2.28		-2.28	
			0.52		0.52

MULTIPLE R SQUARED = 0.275

MULTIPLE R = 0.525

There appeared to be significant difference in the mean scores of the groups of different mental ability levels. This significance difference could only be ascertained when a multiple - range test - post - hoc analysis is performed in the main study.

TABLE 14

Analysis of covariance of Post-Test Scores of groups HMA, AMA and LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	P
Covariates VAR02 - ATS	1	50.348	50.348	6.372	0.015*
Main Effects GRP	2	263.301	131.650	16.662	0.001***
Explained	3	313.649	104.550	13.232	0.001***
Residual	86	679.498	7.901		
TOTAL	89	993.147	11.159		

*** Highly significant at $p < .001$.
* Significant at $p < .05$.

TABLE 15

Multiple Classification Analysis of Post-Test Scores by Groups, HMA, AMA and LMA. ACT - GROUPS - ATS

Grand Mean = 8.18

Variable + Category

Group	N	Unadjusted Dev'n	BETA	Adjusted for Independents & Covariates Dev'n	BETA
1	30	1.96		1.96	
2	30	0.32		0.25	
3	30	-2.28		-2.21	
			0.52		0.52

Multiple R Squared = 0.316
Multiple R = 0.562

On the basis of the sampled data and the analysis carried out the null hypothesis two was rejected. That is: There will be no significant difference in the achievement scores of those groups of pupils in HMA, AMA and LMA at $\alpha = .05$ could be rejected. There would be need to carry out the post-hoc analysis for the treatment effects particularly in the main study.

Hypotheses three:

Ho: There will be no significant difference in the mean attitude towards mathematics and calculator scores of those groups of pupils who use (i) calculators in tests and instruction - unrestricted groups (UCU), (ii) Calculators in tests only - the restricted groups (RCU), and (iii) No Calculators use at all (NCU), i.e.

$$Ho: XE_1 = XE_2 = XE_3 \text{ at } \alpha = .05$$

TABLE 16

Analysis of variance of the Attitude Scores (ATS) of the groups UCU, RCU and NCU

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	P
Main Effects Group	2	385.086	192.543	1.159	.319 ns
Explained	2	385.090	192.545	1.159	.319 ns
Residual	87	14451.105	166.105		
TOTAL	89	14836.195	163.699		

ns - Not significant at $p = .05$

TABLE 17

Multiple classification Analysis of the Attitude Scores for the Groups UCU, RCU and NCU

GRAND MEAN = 77.46

Variable + Category Groups	N	UNADJUSTED Dev'n	UNADJUSTED BETA	ADJUSTED FOR INDEPENDENTS Dev'n	ADJUSTED FOR INDEPENDENTS BETA
1	30	2.54		2.54	
2	30	-0.02		-0.02	
3	30	-2.52		-2.52	
			0.6		0.6

MULTIPLE R SQUARED = 0.026

MULTIPLE R = 0.161

The analysis showed that the result of the attitude scores was not significant. None of F-ratio was significant and the null hypothesis was therefore not rejected. Hence, there was no significant difference in the mean attitude scores of the groups. However, this would also be tested in the main study.

Hypothesis four

There will be no significant difference in attitude towards mathematics and calculator scores of those groups of pupils of HMA, AMA and LMA. That is:

$$Ho: X_{C_1} = X_{C_2} = X_{C_3} \text{ at } \alpha = .05$$

TABLE 18

Analysis of Variance of the Attitude Scores of Groups HMA, AMA and LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	SIGNIFICANT OF F
Main Effects GRP	2	96.355	48.178	0.284	.999 ns
Explained	2	96.355	48.178	0.284	.999 ns
Residual	97	14739.867	169.424		
TOTAL	89	1483.229	166.699		

ns - Not significant p = .05

TABLE 19

Multiple Classification Analysis of the Attitude Scores for groups HMA, AMA and LMA

Grand Mean = 77.46

Variable + Category	N	Unadjusted		Adjusted for Independents	
Group		Dev'	Beta	Dev'n	Beta
1	30	0.04		0.04	
2	30	-1.29		-1.29	
3	30	1.24		1.24	
			0.08		0.08

MULTIPLE R SQUARED = 0.006
MULTIPLE R = 0.081

The analysis of the result of the attitude scores of the groups HMA, AMA, and LMA seemed to suggest that there was no significant difference in the mean scores, and hence, the null hypothesis was accepted.

Hypothesis five:

There will be no significant relationship in pupils' attitudes toward mathematics and their attitudes toward the use of calculators in secondary school mathematics as α = .05

TABLE 20

Summary of the Analysis of Variance of the MAS and CAS Scores of Groups UCU, RCU and NCU

	GROUPS	df	F-ratio	SIGNIF OF F	SIGNIF LEVEL
	UCU	29	0.297	.999	ns
MAS	RCU	29	0.943	.999	ns
	NCU	29	0.131	.999	ns
	UCU	29	1.654	.209	ns
CAS	RCU	29	1.179	.324	ns
	NCU	29	0.26	.999	ns

ns - Not significant at p = .05

It would appear from the analysis of this result that there was no significant difference in the attitude scores of the three groups. There was no difference in the group means of these three groups, for the MAS and CAS, the groups could have the same attitudes to mathematics and calculator. However, this could have been due to some factors or treatment which this pilot study did not envisage there was no pre-attitude treatment for the groups to ascertain groups attitude before treatment.

This would have to be taken care of in the main study.

TABLE 21

Summary of the Analysis of Variance of MAS and CAS Scores of the HMA, AMA and LMA groups

	GROUPS	df	F-RATIO	SIGNIF OF F	SIGNIF LEVEL at α = .05
	HMA	29	0.850	.999	ns
MAS	AMA	29	0.022	.999	ns
	LMA	29	0.339	.999	ns
	HMA	29	2.051	.146	ns
CAS	AMA	29	3.014	.064	ns
	LMA	29	0.538	.999	ns

ns - Not significant at α = .05

The group means were not significant at α = .05, there was no difference at all in the mean scores. It would appear as if there was no difference in the attitudes of pupils of different mental abilities. They seemed to have the same attitudes toward mathematics and calculators.

Finally Pearson correlation was used to test relationship of the groups achievement scores to attitude scores.

r = 0.225, n = 90 at α = .05. This showed that there was no high relationship in the achievement scores and the attitude scores. For the MAS and CAS

$$r = 0.156, \quad N = 90 \quad \alpha = .07$$

The relationship of the mathematics attitude scores and calculator attitude scores was not significant at $\alpha = .05$. This was already evident in the analysis of variance of the variance of the groups.

Nonetheless, this might have arisen out of uncontrolled variance of pre-attitudes and other extraneous factors. Since the ANOVA was not significant in all the groups, tests of significance for the treatment groups were not carried out.

3.7 Discussion on the result of Pilot Study

The number of subjects in the groups could have affected the statistical analysis as related to significance level. For larger number of subjects the result could have possibly been different. The pilot study was able to establish that there was significant difference in post-test scores of the groups UCU, RCU, NCU which led to the rejection of the null hypothesis. Though, no tests of significance for the treatment groups were further carried out, there was not enough evidence of equalisation of the groups through pre-test and pre-attitudes. Hence it would be difficult to ascertain what had contributed to the difference in post scores either it was the treatment or other factors. As regards the groups' attitudes, most of the tests showed no significant difference in the mean attitude scores. This would likely be that the groups had similar attitudes towards mathematics and electronic calculator. Further tests in the main study might reveal more information about these findings.

3.8 Detection of flaws corrected for the main study

The pilot study revealed certain aspects of research procedures which needed to be corrected before the main study: (i) the number of schools (ii) number of subjects in each group (iii) no pre-test and pre-attitude questionnaire were administered. The pilot study began with 12 subjects per groups but ended with 10 subjects per group. Like in most experimental studies that would go on for weeks, arrangement should be made to take care of subject mortality. The number of schools increased to three in the main study which could reduce subject contamination of treatment. In the pilot study instructions and tests were carried out after the school hours - because of the problem of school's time-table. Most of the pupils complained of physical tiredness. The problem of time-table was tackled during the main study when the study took place during the school hours and in the mornings. For the main study, three comparable schools were used, it became necessary to have cooperating teachers from the different schools to assist in the instruction and testing. Efforts were made to brief all the pupils in the study and the cooperating teachers about the purpose of the study and its implications to mathematics education in Nigeria.

Some of the limitations experienced during the pilot study related mostly to incorporating the instructional time into the normal school-hours. Pupils' trepidation as regards the handling of the calculators and pupils' anxiety in the face of calculator during pilot study was somehow remedied for the main study. The pupils could not take the instructional module and calculators home to practise. For this kind of study, the experimental groups could have been much more motivated by allowing them to take the modules and calculators home for practice.

However, the non-calculator groups was discouraged from the use of calculators. In fact, they would not be exposed or advised to use calculator either in class or at home throughout the study. The main study took cognizance of the pilot study results on the use or non-use of calculator and some plausible answers to the introduction or otherwise of technological devices such as calculators, computers etc. into instructional systems.

CHAPTER FOUR

THE MAIN STUDY METHODOLOGY

4.1 Design

The experimental design for the main study was slightly modified from the pilot study design so as to take care of the flaws identified in the pilot study. One of the corrections carried out was to make use of three comparable secondary schools (mixed) in Ibadan instead of one school used for the pilot study. Three groups were used in each of the three randomly selected schools.

SCHOOL		MENTAL ABILITY LEVELS		
		HIGH MENTAL ABILITY H.M.A. (C_1)	AVERAGE MENTAL ABILITY A.M.A. (C_2)	LOW MENTAL ABILITY L.M.A. (C_3)
SCHOOL E_1	Unrestricted Groups (UCU) Calculator in Instruction and tests	A 1 (n=14)	B 2 (n=14	C 3 (n=14
SCHOOL E_2	Restricted Groups (RCU) Calculator in tests only	D 4 (n=14)	E 5 (n=14)	F 6 (n=14)
SCHOOL E_3	No Calculator Use at All Groups (NCU)	G 7 (n=14)	H 8 (n=14)	I 9 (n=14)

Fig. 7: A paradigm of 3 x 3 factorial design for the main study.

N = 126 subjects

K = 9

Variables used in the main study

VAR 01 MAT - Mental ability test scores

VAL 01 PEA - Pre-attitude questionnaire scores

VAR 03 PET - Pre-test scores

VAR 04 POA - Post attitude questionnaire scores

VAR 05 POT - Post test scores

VAR 06 MAS - Mathematics atiitude questionnaire scores

VAR 07 CAS - Calculator attitude questionnaire scores

In the main study, no intact classes were used and therefore, the use of covariates allowed the pre-test mean scores and pre-attitude mean scores to serve in adjusting the initial differences or equalizing factors within and between groups. In addition, the pre-test served as a measure of the level of pupils' prior familiarity with the selected learning material content on which the test was based. The pre-attitude questionnaire administration was to help to establish prior attitude of subjects towards mathematics and calculators, and if, there would be any attitudinal change as a result of the treatment or otherwise.

If T, represents the Pre-test or Pre-attitude, X_1 the treatment one - the use of calculator in tests and instruction, X_2 restricted calculator use in tests only and T_2 the post treatment tests or attitude measure; and R means randomization of treatments to groups.

Then, the design can generally be represented as follows:

R	T_1	X_1	T_2
	T_1	X_2	T_2
	T_1		T_2

4.2 Population of the main study

Secondary schools in Ibadan Municipality constituted the population of the study and the three mixed secondary schools used for the study were selected by the following method. There were ninety-five (95) Junior and Senior Secondary Schools in Ibadan Municipality at the time of the study. A multi-stage stratified random sampling technique[107] was used in selecting the schools.

First stage, schools in Ibadan were stratified on the basis of those that offered students for the West African School Certificate Examinations of WAEC in for the last ten years and those which did not. There were thirty-three schools in this category.

Second stage, all those schools selected in first stage were stratified on the basis of whether they were mixed

107. Chein, I. "An Introduction to Sampling". In C. Selltiz et al. Research Methods in Social relations. New York. Holt, Rinehart and Winston, 1959, pp. 509 - 545.

schools or not (See Appendix 19). There were sixtenn (16) schools in this category.

The third stage, using a random sample (by ballot) five schools from the mixed schools were selected. Out of the five schools only three of the schools satisfied the condition of comparability and were selected. The three (3) schools were:

1. Holy Trinity Grammar School, Old Ife Road, Ibadan.
2. Islamic High School, Basorun, Ibadan.
3. Ibadan City Academy, Eleta, Ibadan.

The three schools were then randomly selected (by ballot) into treatments groups with school 1 as the experimental school E_1 - the unrestricted calculator groups (UCU) (to use calculator in instruction and tests); experimental school E_2 - the restricted calculator groups (RCU) (to use calculator in the tests only) and school 3 the control - the non-calculator groups (NCU) (E_3).

Subjects were then randomly selected into these treatments and control groups.

4.2.1 Subjects of the main study

Form five pupils in their first term of their last year in the secondary school were used as the subjects for the study. In each of the three schools all Form five pupils the mental ability tests (verbal and numerical) so as to be able to divide them into different ability levels. In school (1) eighty four (84) pupils took the tests and forty eight pupils were selected into the different ability levels (see Table 22). In school (2) seventy six (76) pupils took the tests and only forty eight were selected into the different ability levels. In school (3) one hundred and fifty nine (159) pupils took the tests and forty-eight (48) pupils were selected. All selections were done randomly for the different ability levels.

TABLE 22

Summary of Mental Ability Tests Scores for Schools 1, 2, 3 in the Main Study

SCHOOLS	N	MEAN $\bar{X}$	SD	RANGE OF ABILITY LEVELS SCORES HMA	AMA	LMA
1	84	28.64	7.9	37 - 52	30 - 36	25 - 29
2	76	32.78	10.59	41 - 56	33 - 40	25 - 32
3	159	33.025	8.97	41 - 52	34 - 40	25 - 33

An average of sixteen pupils per group started the programme. There were nine (9) groups in all with the total number of subjects that started as one hundred and

and forty four (144). However, by the end of the programme some of the pupils had dropped out which left an average of fourteen subjects per group. Where there were more than 14 subjects per group the extra(s) were randomly dropped on the basis of sex. Like in the pilot study the groups were equalized on sex at all times.

4.3 Comparability of Schools

The study had taken care of sex variable by having equal number of girls and boys in each group. For the comparability of the schools the following conditions were considered:

i. Results of the schools in the West African Examinations Council (WAEC) examinations and mental ability tests.

ii. Age of the schools - this had been taken care of during the selection.

iii. Qualifications of teachers.

iv. Sequencing of topics in the scheme of work.

v. Opinions of teachers and pupils.

vi. Training of teachers for the programme.

The WAEC results of the three schools in mathematics from 1980-1984 were obtained and analysed.

TABLE 23

WAEC Results in Mathematics for Schools 1, 2, 3

Percentage Passes: 1980 - 1984

SCHOOLS	1980	1981	1982	1983	1984	AVERAGE PASSES
HOLY TRINITY GRAM SCHOOL	43	24.6	45.5	45.5	85	48
ISLAMIC HIGH SCHOOL	59	52	63	37	31	48
IBADAN CITY ACADEMY	62	55.6	42.4	41	50	50.2

TABLE 24

Analysis of Variance of Mean Percentage Passes of the Schools 1, 2, 3.

SOURCE	df	SUM SQUARES SS	MEAN SQUARE MS	F RATIO	SIGNIF. LEVEL
BETWEEN GROUPS	2	1233.222	116.611	0.185	NS
WITHIN GROUPS	12	7556.488	629.715		
TOTAL	14	7789.81			

NS: Not Significant at P = .05

This table on the mean percentage passes on the schools showed that there was no significant difference in their mean passes. It could then be inferred that the three schools might have performed relatively equally in the last five years 1980 - 1984. Hence, the three schools were possibly comparable on this basis.

When the results of all the pupils who took the mental ability tests in the three schools were obtained and analysed it helped to determine if the schools were comparable on the mental ability tests scores.

TABLE 25

Analysis of Variance of Mean Mental Ability Test Scores of Schools 1, 2, 3

SOURCE	Df	SUM OF SQUARES SS	MEAN SQUARES MS	F-RATIO	SIGNIF. LEVEL
BETWEEN GROUPS	2	1359.41	679.705	0.873	NS
WITHIN GROUPS	316	246034.30	778.59		
TOTAL	318	2473[illegible]3.71			

NS: Not significant at $p = .05$.

The table showed that there was no significant difference in the mental ability test scores of the three schools. Though the number of pupils who took the tests in the schools were not equal: $N_1 = 84$, $N_2 = 76$ and $N_3 = 159$ it would appear that the groups could be compared on the test scores and being relatively equal statistically.

To obtain information on the other conditions of comparability, a questionnaire was constructed by the researcher (See Appendix 16). The face and content validity of the questionnaire were carried out by this investigator and some lecturers in the Teacher Education Department, University of Ibadan. Teachers of mathematics in the three schools responded to the items on the questionnaire.

Teacher's Variables and Content Coverage

	School 1	School 2	School 3	Average
No. of Mathematics Teachers in Sampled Schools	5	6	5	5.3
Total Years of Experience of the Teachers	59	37	24	40
Syllabus (Covered (Partially (in the year)	0.4	0.33	0.4	0.38
Syllabus (Covered (Fully in (the Year	0.6	0.67	0.6	0.62

The teachers in the three schools indicated that they had taught equations to their pupils at different terms of the year for different classes before the pupils reached first term of Form V.

TABLE 27

Calculator Usage Effectiveness by Teachers

	*Very Effective	Effective	Not Effective	Total No. of Responses
SCHOOL 1	-	2	3	5
SCHOOL 2	-	3	3	6
SCHOOL 3	-	3	2	5

None judged Calculator to be very effective at the secondary school level - this cannot be a conclusive evidence on Calculator effectiveness at secondary school.

TABLE 28

Use of Instructional Materials by Schools

Materials	School 1	School 2	School 3
Four figure Table	+	+	+
Calcularor	+	+	-
Mathematics Set	+	+	+
Slide Rule	-	+	-
Geoboard	-	+	-
Other boards (Graphboard etc.)	+	-	+
Objects (Sticks, Shapes etc.)	+	-	+

\+ Used in the school

\- Not used in the school.

From the available data, it would appear that the three schools were comparable.

4.4 Monitoring the Cooperating Teachers

The design of the study involved conducting tests and having classroom instructions during the school hours. Because of the problems of schools' distances and time-table it became imperative to solicit the assistance and cooperation of mathematics teachers in the sampled schools. Through the Principals, the Form V mathematics teachers in the schools were briefed on the purpose of the study.

Fortunately all the three school teachers agreed to assist in the programme. The teachers were shown the format of the "Teacher - pupil - material Interaction model" developed from Ogunniyi[108] Laboratory Interaction Categories (LIC) - a modified version of Flanders' Interaction Categories. This method was used to bear credence to Flanders' findings that, teaching behaviour is the most potent, single controllable factor that can alter learning opportunities in the classroom[11].

In order to determine the teachers' classroom effectiveness and behavioural characteristics of the pupils the investigator decided to observe Teacher - pupil - material interaction in the three schools. Each of the teachers was observed for thirty minutes three times in a week and the records of observations were then analysed.

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108 Ogunniyi, M.B.: An analysis of laboratory activities in selected Nigerian secondary Schools. European Journal of Science Education. 1983 Vol.5, No. 2, 195 - 201.

Permission was sought and granted from the Principals of sampled schools to observe the cooperating teachers and pupils during their lessons. Thus, arrangement was made to observe the teachers and pupils whenever they had mathematics on their school time-table, and was held with only those pupils in the study.

TABLE 29

A Comparison of Percentage of Teacher/ Classroom Interactions Behaviour

TEACHER'S CATEGORIES	PERCENTAGE RATING SCHOOL 1	SCHOOL 2	SCHOOL 3	MEAN $\bar{X}$	SD
A - Accepts Feeling	0.3	0.19	0.42	0.30	0.13
G - Gives Verbal reward	0.3	0.19	0.22	0.24	0.029
R - Reinforces response	2.02	1.57	2.20	1.93	0.32
Q - Questions	19.35	18.89	13.96	17.066	7.89
L - Lectures	12.55	15.42	14.59	14.19	1.43
D - Directs	15.84	8.33	8.61	10.93	4.25
C - Criticises	4.744	1.55	11.62	5.97	5.10
M - Manipulates Materials	2.61	5.09	0.42	2.7066	4.68*
S - Supervises	2.69	4.3	9.07	5.353	3.32

* The standard deviation calculated for the materials do appear to be high compared with others. Table 29 continues next page with the pupils' categories.

PUPILS' CATEGORIES	PERCENTAGE RATINGS SCHOOL 1	SCHOOL 2	SCHOOL 3	MEAN $\bar{X}$	SD
RQ - Responds to questions	13.95	18.49	12.41	14.95	3.16
IQ - Initiates questions	1.26	1.56	1.04	1.287	0.26
IT - Initiates talk	2.60	3.75	0.82	2.39	1.48
CA - Calculates Using materials	9.83	6.48	6.17	7.49	2.05
RD - Reads, Writes/and/or Draws	11.29	7.21	13.78	10.76	3.32
N - Non-productive activities	1.74	6.91	7.84	5.50	3.28

n = 3 recordings in each school.

N = 14 - 16 (No. of students per group).

Variability in the use of materials as shown by the standard deviation seemed to be high, and this would appear to suggest the difference in the teacher - students interaction.

The interaction pattern, from Table 29 showed that the three teachers were direct teachers, they did not use materials much. Hence the teachers of schools 1 and 2 were advised to use more of the materials - particularly teacher of school (1) who had to use calculator throughout the study.

TABLE 30

Percentage Distribution of Teachers' Questions

CATEGORY OF QUESTIONS	PERCENTAGE RATINGS SCHOOL 1	SCHOOL 2	SCHOOL 3	MEAN $\bar{X}$	SD
FACTUAL	41.76	27.5	41.02	36.76	8.028
RHETORICAL	44.37	57.9	39.88	47.38	9.41
LEADING	7.55	11.8	8.58	9.31	2.22
PROBING	6.36	2.7	5.51	4.86	1.9

TABLE 31

Mean Distribution of Questions/Minute of Teacher/Pupils Interaction

GROUP	TIME IN MINUTES 1 - 10	11 - 20	21 - 30
TEACHER'S OF SCHOOLS 1,2,3 $\bar{X}$	1.2	1.016	1.18
PUPILS OF SCHOOLS 1, 2, 3 $\bar{X}$	1.17	0.7	0.85

Tables 29-31 showed that the teachers had relatively the same pattern of Teacher-Student and material interaction. Thus, it could be inferred that the three teachers were direct teachers. The only variation is in the use of materials where they have been designed to be structurally different as indicated in the research design.

4.5 Administration of Instruments

When the cooperating teachers had been found to be comparable by the Teacher-pupil material interaction model they were advised about how to administer the instruments. The pupils had been separated into different ability levels through the mental ability tests scores, they all had to take the pre-test and respond to the pre-attitude questionnaire. The sessions were held for thirty minutes (7.30 - 8.00 a.m.) on Mondays, Tuesdays and Wednesdays in the three schools. Thursdays and Fridays were used to hold dialogue with the teachers.

The pre-test and pre-attitude responses were collected from the teachers before the treatments started. The teachers were advised to keep record of attendance of pupils. Each of the teacher was supplied with the instructional module. They were advised to follow the instructional format in the module and they were instructed not to use any other text for the study. The calculator groups were supplied with hand-held calculators. Each pupil in the two treatment groups (E_1 and E_2) used calculator on the pre-test. The next treatment was instruction which was carried out by the cooperating teachers. The unrestricted calculator group used calculator throughout the treatment period.

4.5.1 Guidelines on the Use of Calculators

Calculators were used by the experimental groups: E_1 and E_2. E_1: Calculator use in instruction and tests. E_2: Calculator use in tests only.

The subjects in these groups and the cooperating teachers were instructed by the investigator on how to use the calculator. The instruction on how to use the calculator took place two days prior to the commencement of the six-week duration of the study. E_1 groups who were in the same school received the instruction first day and they were followed by E_2 groups the second day. There were three sessions per day, and each of the instructional sessions was held with high, average and low mental ability groups respectively. Each session had a duration of thirty minutes and they were held immediately after the school hours (2 - 3.30 p.m.) in each of the schools.

Fourteen calculators were made available to each group (one per pupil). This allowed the pupils to get familiar with the calculators.

PROCEDURE:

The operational keys of the calculator were shown: addition (+), subtraction (-), multiplication (x), division (÷), square root (√) percentage (%), memory storage M^+,M^- R.C M), (See Fig. 2). When the pupils could identify and operate them, the following example was done with the groups using the calculator:

Simplify the expression:

$$55 \times 10 - 7.22\ (7.22 \div 10.96)$$

SOLUTION:

OPERATIONAL KEYS	DISPLAY ON SCREEN
Punch ON/C	0.
Punch 5 twice	55.
Punch x	55.
Punch 10	10.
Punch =	550.
Punch -	550.
Punch 7 points(.) and 2 twice	7.22
Punch =	542.78
Punch M	542.78
Punch 7,point (.) and 2 twice	7.22^{M}
Punch ÷	7.22^{M}
Punch 1 and 0, point(.) 9 & 6	10.96^{M}
Punch =	0.6587591^{M}
Punch M⁻	0.6587591^{M}
Punch R.CM	542.12125^{M}

Ans. = 542.12125

This answer was checked with the paper-and pencil calculation and comparison was made between the answer from calculator and the paper-and-pencil procedure. The pupils were then asked to practise with more exercises on calculator. The teachers checked the pupils' work and made corrections where necessary.

2. Calculators were used with the instructional module copies of which were supplied to the E_1 (Calculator in instruction and tests) groups only. The teacher of E_1 groups was specifically instructed that the pupils in his group should use only the module and no other textbooks should be used by them. After the operational uses of the calculator had been done on the first day, the investigator advised the groups to continue the next day on the use of calculators with their copies of the instructional module.

The general instruction on the use of calculator with the instructional module can be found at the end of the module (see Appendix 7). The other two cooperating teachers were given the instructional modules to be used as the teaching and learning material. The pupils in their groups were not supplied with the module. These other groups did all the culculations with paper - and - pencil as they were used to in their normal mathematics class lesson.

During the four weeks of instruction the cooperating teachers were closely monitored. Each of the teachers was observed three times a week and records were kept. This was to make sure that they were carrying out the objectives of the programme. Attempts by the teachers to deviate from the expressed objectives were corrected. Throughout the duration of instruction the teacher candidly cooperated.

By the sixth week the post-test and post-attitude questionnaire were administered.

4.6 Data Collection

All data used in this study were collected from the sampledschools. The mental ability test scores of the nine groups were extracted from total scores of those form five pupils who took the ML and MQ tests in the three schools (See Table 22.) The pre and post tests scores, and pre and post attitude questionnaire scores were collated by the investigator. The pre-test scores were 15 points and could have been doubled to equal the post-test scores of 30 points. However, this could have statistically made no difference in results because analyses were done with the means of the scores.

4.7 Data Analysis of the Main Study

Analysis of data comprised the comparison of post-treatment and post-attitude mean scores (POT, POA) with the pre-test and pre-attitude mean scores (PET,PEA) respectively. The computer library programme LIB020P, was used for:

(i) all the analyses of covariance

(ii) Analyses of variance

(iii) the significant mean effects

Comparison of significance of the means the multiple range tests using:

(a) Student - Newman Keuls (SNK at $\alpha = .05$)

(b) Scheffe alpha is .05)
)
(c) LSD alpha is .05) all ONE WAY
) ANOVA
(d) Tukey alpha is .05)

(iv) Pearson correlation coefficients.

(v) Multiple regression analyses

(vi) Frequency distributions.

All tests of significance were carried out at P = .05, and all computations/programming were with the aid of the University Computing Center. except for the t - tests comparision of means which were done with the hand-held calculator.

CHAPTER FIVE

RESULTS OF THE MAIN STUDY

The results of the study were discussed in relation to the null hypothesis earlier stated.

5.10 Hypothesis 1

There will be no significant difference in the achievement mean scores of those groups of pupils who used (i) calculators in tests and instruction - the unrestricted group (UCU) (ii) calculators only in tests - the restricted group (RCU) and (iii) No-calculators at all (NCU). That is:

$$H_0: ME_1 = ME_2 = ME_3 \text{ at } \alpha = .05$$

TABLE 32

Summary of the means, standard deviations and variances of the three Groups (UCU, RCU and NCU)

*Variables	N	Mean	SD	Variances
MAT	126	30.903	7,6779	58.950
PEA	126	81.2937	11.4200	130.4164
PET	126	9.1349	3.3331	11.1095
POA	126	84.0397	13.1954	144.1186
POT	126	14.2381	4.9565	24.5668
MAS	126	47.4683	7.3065	53.3703
CAS	126	36.5873	11.8701	140.8993

Fach of the groups unristricted calculator (UCU) as E_1, restricted calculator (RCU) as E_2 amd non-calculator (NCU) as E_3 was made up of three groups of three mental ability levels: high mental ability (HMA) as C_1, average mental ability (AMA) as C_2 and low mental ability (LMA) as C_3, and this gave the total number of groups to be nine (See fig. 6). For the computer programming and analysis of the data each of the three groups merged into one to give three groups in all for treatments and also three groups for mental ability levels.

That is E_1: (1, 2. 3 = 1) : UCU
E_2: (4, 5, 6 = 2) : RCU
E_3: (7, 8, 9 = 3) : NCU
C_1: (1, 4, 7) = 1) : HMA
C_2: (2, 5, 8)= 2) : AMA
C_3: (3, 6, 9)= 3) : LMA

All tests of significance were carried out at $p = .05$ but the use of computer for the analysis gave the results of the statistical computations to the nearest significant levels. For example there were .001, .01, etc p-levels, and for this study, they are highly significant. Other significant levels different from $p < .05$ or $p > .05$ were used as they were received from the computer-print-out. They did not affect the interpretations of the results.

TABLE 33

Analysis of Covariance of Post Achievement Test Scores of UCU, RCU, and NCU Groups

Source	df	Sum of squares SS	Mean squares MS	F Ratio	P
COVARIATE MAT	1	195.819	195.819	12.341	.001***
MAIN EFFECTS	2	939.265	469.633	29.598	.001***
EXPLAINED	3	1135.084	378.361	23.846	.001***
RESIDUAL	122	1935.758	15.887		
TOTAL	125	3070.842	24.567		

*** Highly Significant at $p < .001$

When the mental ability test scores (MAT) were used as a covariate on the post-test scores there was significant difference at $\alpha = .001$ of the group - means.

TABLE 34

<u>Multiple Classification Analysis of Post-Test Scores By Groups UCU, RCU and NCU with Mental Ability Scores</u>

GRAND MEAN = 14.24				ADJUSTED INDEPENDENTS + COVARIATES	
VARIABLE & CATEGORY GRP	N	UNADJUSTED DEV'N	BETA	DEV'N	BETA
1	42	3.14		4.01	
2	42	-1.10		-1.61	
3	42	-2.05		-2.40	
			0.46		0.58

MULTIPLE R SQUARED = 0.370

MULTIPLE R = 0.608

From R^2 = .37, indicated that only 37% of the variance in the criterion measure of post-test scores was associated with the mental ability test scores whereas the remaining63% of the variance might have been due to treatment or some to error.

TABLE 35

Analysis of Variance of Mental Ability Test Scores

the three Groups (UCU, RCU and NCU)

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F-RATIO	SIGNIF. OF F
MAIN EFFECTS GRP	2	748.619	374.309	5.935	0.004**
EXPLAINED	2	748.621	374.311	5.935	0.004**
RESIDUAL	123	1756.938	63.065		
TOTAL	125	8505.559	68.044		

** Significant at $p < .01$

The mental ability scores were used to divide the pupils into different ability levels. Hence, one would expect a significant difference in the means of the mental scores of the groups. When the mental ability scores of the groups were used as the covariate to post-test scores there were significant differences in the covariate, main effects, and explained variance of the groups. Hence, there was significant difference in the post-test scores of the groups.

Since all the groups took the pre-test which was to serve as an equalizing factor, an analysis of covariance of the post-test was carried out using pre-test as the covariate.

TABLE 36

Analysis of Covariance of Post-Achievement

Test Scores of UCU, RCU and NCU groups

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	SIGNIF. OF F
COVARIATE (PET)	1	33.992	33.992	1.713	0.190^{ns}
MAIN EFFECTS (GRP)	2	615.825	307.912	15.516	0.001***
EXPLAINED	3	649.817	216.606	10.915	0.001***
RESIDUAL	122	2421.025	19.844		
TOTAL	125	3070.842	24.567		
COVARIATE	BETA				
PET	0.007				

*** Highly significant at $p < .001$
ns: Not significant at $p < .05$

TABLE 37

Multiple Classification Analysis of Post-test Scores of Groups UCU, RCU and NCU with Pre-test covariate

GRAND MEAN = 14.24

VARIABLE + CATEGORY		UNADJUSTED		ADJUSTED FOR	
GRP	N	DEV'N	ETA	DEV'N	BETA
1	42	3.14		3.10	
2	42	-1.10		-1.08	
3.	42	-2.05		-2.02	
			0.46		0.45

MULTIPLE R SQUARED = 0.212

MULTIPLE R = 0.460

From R^2 = 0.21, indicated that only 21% of the variance in the criterion measure of post-test scores was associated with the pre-test scores whereas the remaining 79% of the variance might have been due to treatment or some to error.

TABLE 38

Analysis of variance of the Pre-test of the groups UCU, RCU and NCU.

SOURCE	df	SUM OF SQUARES	MEAN SQUARE	F-RATIO	SIGNIF. LEVEL
MAIN EFFECTS					
GRP	2	8515.531	4257.766	0.852	.999 ns
EXPLAINED	2	8515.563	4257.781	0.852	.999 ns
RESIDUAL	123	614953.436	4999.621		
TOTAL	125	623469.000	4987.750		

ns - Not significant at p = .05

The mean Pre-test scores of the groups did not show any significant difference at α = .05. This would suggest that the three groups were equalized by the pre-test. Hence any difference on the post-test scores would likely be du to the treatment. To further test for the contribution of each treatment groups (UCU, RCU) to the significant difference from the control group (NCU) a post-hoc analysis was carried out to determine any significant difference among the groups. If a significant difference did exist, which of the groups was better than the other was determined by multiple range test of one way Scheffe and t-tests. It would be noted that LSD or Scheffe could only be applied if only and if there was significant difference at $\alpha = .05$.

TABLE 39

Multiple Range Test of Post-test scores by One-Way Scheffe Procedure - ANOVA+

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROB	SIGNIF LEVEL
BETWEEN GROUPS	2	641.332	320.660	16.23	0.001	***
WITHIN GROUPS	123	2429.5273	19.7522			
TOTAL	125	3070.8594				

*** Highly significant at $p < .001$

The groups were rearranged into groups of 2 for t-tests as shown in the table of t-test.(Table 40).

+ Oneway LSD, Scheffe, TUKEY-HSD and SNK were carried out, and they showed the same result.

TABLE 40

Summary of t-tests of the Post-test Scores

Groups UCU, RCU and NCU

	GROUPS	N	$\bar{X}$	SD	SD^2	t-ratio	SIGNIF LEVEL
1.	UCU	42	17.38	4.483	20.10	5.354	.001 ***
	NCU	42	12.191	4.40	19.384		
2.	UCU	42	17 38	4.483	20.10		
	RCU	42	13.143	4.44	19.784	4.35	.001 ***
3.	RCU	42	13.43	4.44	19.784		
	NCU	42	12.191	4.40	19.384	0.98	ns

*** Highly significant at $p < .001$
ns Not Significant at $p = .05$

Based on these two analyses one might suggest that there would be significant difference in the mean post-test scores of the groups. Hence hypothesis one was rejected.

Further statistical test (see Table 41) of multiple regression analysis where the dependent variable - post-test scores and independent variables were mental ability scores and pre-test scores of the three groups showed significant difference ($F(2,123) = 7.29$ at $p < .01$).

The results of the multiple regression analysis showed that there was a linear correlation between the dependent variable — post-test scores, and the independent variables (the mental ability and pre-test scores). This correlation meant a significant relationship between the post-test scores and the mental ability and the pre-test scores.

Though, the hypothesis was rejected on the basis of the statistical tests one would want to determine what main effects if any, the treatments had on each group of the treatments and control. Considered for analysis was the unrestricted calculator groups (UCU) - those who used calculator on tests and in instruction that is, (A, B, C).

TABLE 41

Multiple Regression Analysis of Post-test scores with mental ability and Pre-test scores (ABC, DEF, GHI Groups)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	SIGNIF LEVEL
REGRESSION	2	325.33122	162.66561	7.28745	.01**
RESIDUAL	123	2745.52592	22.32135		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR	F-RATIO	SIGNF. LEVEL
VAR 01 - MAT	0.19728	0.32833	0.05461	13.052	.01**
VAR 03 - PET	0.01536	0.21891	0.00638	5.802	.05*
(CONSTANT)	6.75831				

VARIABLE	MULTIPLE R	R^2
VAR 01 - MAT	0.25252	0.06377
VAR 03 - PET	0.32549	0.10594

** Significant at $p < .01$

* Significant at $p < .05$

TABLE 42

Analysis of Covariance of Post-test Scores

of A, B, C, Groups of UCU

(MAT as covariate)

Source	df	Sum of Squares SS	Mean Squares MS	F-ratio	Signif. Level
Covariate MAT	1	180.965	180.965	13.277	0.001 ***
MAIN EFFECTS GRP	2	124.979	62.489	4.585	0.016*
EXPLAINED	3	305.944	101.981	7.485	0.001***
RESIDUAL	38	517.957	13.630		
TOTAL	41	823.900	20.095		

*** Highly significant at $p < .001$

* Significant at $p < .05$

TABLE 43

Analysis of Covariance of Post-test Scores

of A, B, C Groups of UCU

(Pre-test as covariate)

Source	df	Sum of Squares SS	Mean Squares MS	F-ratio	Signif. Level
COVARIATE PRE-TEST	1	3.470	3.470	0.255	o.999 ns
MAIN EFFECTS GRP	2	302.392	151.196	11.091	0.001 ***
EXPLAINED	3	305.862	101.954	7,479	0.001 ***
RESIDUAL	38	518.038	13.633		
TOTAL	41	823.900	20.095		

*** Highly Significant at p < .001

ns: not significant at p = .05

From the above table it appeared that there was no significant difference in the mean scores of the groups.

Since the mean post-test scores were significantly different for the three groups, a One-way Multiple range test using LSD procedure was used to determine the level of significance due to treatment.

TABLE 44

Multiple range test of Post-test Scores of Groups A, B, C. One-Way LSD Procedure - ANOVA

Source	df	Sum of Squares SS	Mean Squares MS	F Ratio	F Prob	Signif. Level
BETWEEN GROUPS	2	302.4727	151.2363	11.312	.001	***
WITHIN GROUPS	39	521.4336	13.3701			
TOTAL	41	823.9063				

***Highly Significant at $p < .001$

The three groups were re-arranged into group of twcs for t-test.

TABLE 45

Summary of t-test of the Post-test Scores of tne Groups A, B, C.

GROUPS	N	$\bar{X}$	SD	SD^2	t-ratio	Signif. Level
A	14	20.7143	4.9835	23.840	4.22	.001***
1. C	14	14.1429	3.0091	9.055		
A	14	20.7143	4.9635	24.840		
2. B	14	17.2857	2.4940	6.220	3.01	.01 **
B	14	17.2857	2.4940	6.220		
3. C	14	14.1429	3.0091	9.055	3.19	.01 **

*** HighlySignificant at $p < .001$
** Significant at $p < .01$

From statistical tests, the post-test mean scores were significantly different for the three groups and hence, hypothesis one was again rejected.

The post-test scores of the restricted calculator groups were considered for analysis. The groups D, E, F who used calculator in tests only.

TABLE 46

Analysis of Covariance of Post-test Scores

cf Groups D, E, F.

Source	df	Sum of Squares	Mean Squares	F Ratio	Signif. of F
COVARIATE					
PRE-TEST	1	317.210	317.210	26.035	.001 -
MAIN EFFECTS					
GRP	2	30.940	15.470	1.270	.292 ns
EXPLAINED	3	348.150	116.050	9.525	.001 ***
RESIDUAL	38	462.990	12.184		
TOTAL	41	811.140	19.784		

ns: Not significant at $p = .05$

***Highly Significant at $p < .001$

Whatever was responsible for the main effect not being significant at $\alpha = .05$ could be explained by the multiple classification analysis. So as to determine the level of significance the multiple range test - LSD procedure was carried out. In addition to further determine the treatment effects the three groups were rearranged into groups of two and t-tests were done.

TABLE 47

Multiple Classification Analysis of Post-test Scores of Groups D, E, F with Pre-test scores

GRAND MEAN = 13.14

VARIABLE + CATEGORY GRP	N	UNADJUSTED DEV'N	ETA	ADJUSTED FOR INDEPENDENTS + COVARIATE DEV'N	BETA
1	14	2.86		1.38	
2	14	0.50		-0.C5	
3	14	-3.36		-0.70	
			0.58		0.22

MULTIPLE R SQUARED = 0.429

MULTIPLE R = 0.655

R^2 = 0.429, indicated that only 42.9% of the variance the criterion measure of Post-test scores was associated with the pre-test scores whereas the remaining 57.1% of the variance might have been due to treatment or some to error.

In order to determine the treatment effect, One-way ANOVA using LSD procedure of the multiple range test was carried out, and the t-tests of the groups.

TABLE 48

Multiple Range Test of Post-Test Scores of Groups D,E,F, by One Way ANOVA LSD Procedure

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROB	SIGNIF. LEVEL
BETWEEN GROUPS	2	275.5703	137.7852	10.033	.001	***
WITHIN GROUPS	39	535.5742	13.7327			
TOTAL	41	811.1445				

TABLE 49

Summary of t-tests of the Post-test of Groups D,E, F.

	GROUPS	N	$\bar{X}$	SD	SD^2	t-ratio	SIGNIF LEVEL
	D	14	16.000	3.4194	11.6922		
1	F	14	9.7857	3.1908	10.1812	4.973	.001 ***
	D	14	16.000	3.4194	11.6922		
2	E	14	13,643	4.3959	19.3239	1.58	ns
	E	14	13.643	4.3959	19.3239		
3	F	14	9.7857	3.1908	10.1812	2.39	.05*

ns: Not Significant at P > .05

*** Highly Significant at P < .001

* Significant at p ≤ .05

For the groups D, E, F the means of the post-test scores could be considered to be significantly different. Hence the hypothesis was again rejected.

The post-test scores of the non-calculator groups were also considered for analysis. The groups G, H and I did not use calculator in tests and instruction and were treated as the control group.

TABLE 50

Analysis of the Covariance of the Post-test Scores of Groups G, H, I

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F-RATIO	SIGNIF OF F
COVARIATE PRE-TEST	1	385.968	385.968	38.819	0.001 ***
MAIN EFFECTS GRP	2	30.679	15.339	1.543	0.226 ns
EXPLAINED	3	416.646	13.882	13.968	0.001 ***
RESIDUAL	38	377.827	9.94		
TOTAL	41	794.473	13.377		

ns : Not Significant at p > .05

***Highly Significant at p < .001

Whatever was responsible for the main effects not to be significant at α = .05 could be explained by the multiple classification analysis.

TABLE 5.

<u>Multiple Classification Analysis of Post-test Scours of Groups G, H, I.</u>

GRAND MEANS = 12.19

VARIABLE + CATEGORY		UNADJUSTED		ADJUSTED FOR INDEPENDENTS + COVARIATE	
GRP	N	DEV'N	ETA	DEV'N	BETA
1	14	o.45		-0.52	
2	14	1.[illegible]1		1.20	
3	14	-2.26		-0.70	
			0.39		0.20

MULTIPLE R SQUARED = 0.524

MULTIPLE R = 0.724

R^2 = 0.524, indicated that 52.4% of the variance in the criterion measure of Post-test scores was associated with the pre-test scores (quite large). Whereas the rest 47.6% of the variance might have been due to treatment or some to error.

In order to determine the level of significant difference, and if this was due to treatment the multiple range test one-way LSD procedure and t-tests of the post-test mean scores of the groups were carried out.

TABLE 52

Multiple Range test of Post-test Scores by One-way ANOVA Procedure of Groups G,H, I

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROP	SIGNF LEVEL
BETWEEN GROUPS	2	120.3320	60.1660	3.481	.04	*
WITHIN GROUPS	39	674.1445	17.2858			
TOTAL	41	794.4766				

* Significant at $p < .05$

TABLE 53

Summary of t-test of Post-test Scores of Groups G,H,I

	GROUPS	N	$\bar{X}$	SD	SD^2	t-ratio	SIGNIF LEVEL
	G	14	12.643	5.0931	25.9397		
1	I	14	9.9286	4.1224	16.994	1.55	ns
	G	14	12.643	5.0931	25.9397		
2	H	14	14.0000	2.9872	8.9234	-0.86	ns
	H	14	14.000	2.9872	8.9234		
3	I	14	9.9286	4.1224	16.994	2.992	.01 **

ns: Not significant at $P = .05$

** Significant at $P < .01$

The effects of the covariate as represented by the pre-test seemed to have affected the level of significance of post-test scores as evident in the high covariates F-ratio value. Though the multiple range test of LSD producedure on the post-test scores showed significance of F, it was not high enough to have obliterated the effects of pre-test scores. In addition, the t-test was significant for H and I alone of the three groups tested.

Since F-ratio was significant as shown in the multiple range test, hypothesis one was again rejected. The results of the analyses carried out using multiple regression analysis, one-way ANOVA, multiple range test and t-tests of post-test scores (Tables 33 - 41) showed that there were significant differences in the mean scores of the groups, hypothesis one was conclusively rejected. It also demonstrated that (i) the unrestricted calculator group (UCU), those pupils who used calculator in tests and instruction were better in performance than restricted group (RCU), those who used calculator only in the tests as indicated by the comparison of the means of post-test scores analysis and t-test, and (ii), the unrestricted calculator groups (UCU) were also significantly better in performance than the non-calculator group (NCU) as indicated in the post-test scores analysis - t-test, and (iii) there was no significant difference in the performance of the restricted calculator groups (RCU) as indicated in the post-test scores analysis (See Tables 46 - 49).

This was further collaborated by the results of each of the groups in UCU, RCU and NCU as indicated on Tables 42 - 53. For UCU, Table 45 indicated that the high mental ability group of this unrestricted calculator group performed significantly better than the low mental ability, as could be expected, and also the same group did better than the average mental ability group, while the average mental ability group did also better than the low mental ability group.

For RCU, the high mental ability group of the restricted calculator group did significantly better than the low mental ability group, There was no significant difference between the performance of high and average groups but there was a difference in the performance of the average and low mental ability groups in favour of average mental ability (Table 49).

For NCU, the control group, that is, non-calculator group there was no difference in the performances of high and low; high and average except average and low mental ability groups (Table 53)

5.20 Hypothesis 2.

There will be no significant difference in the achievement scores of those groups of pupils of high, average and low mental abilities. That is:

$$Ho: MC_1 = MC_2 = MC_3 \text{ at } \alpha = .05.$$

TABLE 54

Analysis of Covariance of Post-test

Scores of the groups HMA, AMA and LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	SIGNIF OF F
COVARIATE MAT	1	195,821	195.821	9.915	0.002 **
MAIN EFFECTS GRP	2	465.539	232.800	11.788	0.001 ***
EXPLAINED	3	661.420	220.473	11.164	0.001 ***
RESIDUAL	122	2409.422	19.749		
TOTAL	125	3070.842	24.567		

** Significant at $p < .01$

*** Highly Significant at p α .001

The mental ability scores could not have had confounding affects on the post-test score since the groups had been randomly selected on the basis of their scores in the mental ability tests. This significant difference in the mental ability mean scores of the groups was expected. This had been corroborated on the ANOVA table of MAT (Table 55).

TABLE 55

Analysis of Variance of Mental Ability Scores
of the Groups HMA, AMA, LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS!	F RATIO	SIGNIF OF F
MAIN EFFECTS GRP	2	5610.996	2805.498	119.215	0.001***
EXPLAINED	2	5610.996	2805.498	119.215	0.001***
RESIDUAL	123	2894.574	23.533		
TOTAL	125	8505.570	68.045		

*** Highly Significant at $p < .001$

There was high significant difference on the mental ability scores since the groups were not equalized o, th s basis, However, the effects of the pre-test on the treatment w a s able to demonstrate if actually the significance difference in the post-test scores was due to experimental treatment or other factors.

TABLE 56

Analysis of Covariance of Post-test Scores of the Groups HMA, AMA, LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES SS	F RATIO	SIGNIF F
COVARIATE (PRE-TEST)	1	33.992	33.992	1.689	0.193 ns
MAIN EFFECTS GRP	2	581.739	290.869	14.454	0.001 ***
EXPLAINED	3	615.731	205.244	10.199	0.001 ***
RESIDUAL	122	2455.111	20.124		
TOTAL	125	3070.842	24.567		

*** Highly Significant at $p < .001$
ns Not Significant at $p = .05$

Whatever could have accounted for the covariates not to be significant at $\alpha = .05$ might have been due to the equalizing factor of the pre-test on the groups, as it could be detected on the ANOVA table of Pre-test.

TABLE 57

Analysis of Variance of the Pre-test Scores

of the Groups HMA, AMA and LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	SIGNIF OF F
MAIN EFFECTS GROP	2	11415.445	5707.723	1.147	0.321 ns
EXPLAINED	2	11415.500	5757.750	1.147	0.321 ns
RESIDUAL	123	612054.375	4976.051		
TOTAL	125	623469.875	4987.758		

ns : Not Significant at P = .05

The mean pre-test scores of the groups did not show any significant difference at α = .05. This would suggest that the three groups were equalized on the basis of the pre-test scores. Hence any difference on the post-test scores would likely be due to the treatment given to the groups. To further test for the level of significance so as to ascertain which was due to treatment or other factors, a post hoc analysis was carried out.

If a significant difference did exist which of the groups was better than the other. To do this, multiple range test one-way Scheffe procedure and t-tests were carried out.

TABLE 58

Multiple Range Test of Post-test scores One-Way Scheffe Procedure (ANOVA) of Groups HMA, AMA, and LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROB
SOURCE GROUPS	2	594.8946	297.4473	14.776	0.001***
WITHIN GROUPS	123	2475.9648	20.1298		
TOTAL	125	3070.8594			

***Highly Significant at $p < .001$

Similarly a multiple regression analysis of Post-test scores, table 59, showed significant difference: ($F_{(2,123)} = 28.398$ at $p < .001$)

TABLE 59

Multiple Regression Analysis of Post-test scores with Mental ability and Pre-test scores (ADG, BEH, CFI Groups)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	SIGNIF. LEVEL
REGRESSION	2	720.12596	360.06298	28.398	.001***
RESIDUAL	123	1559.53277	12.67913		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR	F-RATIO	SIGNIF LEVEL
VAR 01 - MAT	0.12145	0.21836	0.0467	6.746	.01**
VAR 03 - PET	0.54684	0.42681	0.10772	25.773	.001**
(CONSTANT)	3.41246				

VARIABLE	MULTIPLE R	R^2
VAR 01 - MAT	0.41538	0.17254
VAR 03 - PET	0.56204	0.31589

*** Highly significant at $p < .001$

** Significant at $p < .01$

TABLE 60

Summary of t-test of the Post-test Scores

Scores of Groups HMA, AMA, LMA

	GROUPS	N	$\bar{X}$	SD	SD^2	t RATIO	SIGNIF LEVEL
	HMA	42	16.4524	5.5709	31.0349	4.9	0.001***
1	LMA	42	11.2857	3.9589	15.6729		
	HMA	42	16.4524	5.5709	31.0349		
2	AMA	42	14.9762	3.6990	13.6826	1.43	ns
	AMA	42	14.9762	3.6990	13.6826		
3	LMA	42	11.2857	3.9589	15.6729	4.4	0.001 ***

NS : Not Significant at $p = .05$

*** Highly Significant at $p \leq .001$

Tables 54 - 60 showed that the ability groups differed significantly from each other. The analysis of covariance of Post-test mean scores showed significant difference at $p \leq .001$. The treatment effect too was significant as shown by the multiple range test using One-way Scheffe Procedure. Based on the significance difference of the mean scores of the high, average and low mental ability groups the hypothesis that there would be no significant difference in their mean post-test scores was rejected. Since the groups were significantly different in their post-test mean scores, the three groups were compared using t-test, (Table 60). It was found that high mental ability groups pupils performed better than the low mental ability group. The average mental ability group pupils also did significantly better than the low mental ability groups. However, there seemed to be no difference in the performances of high and average mental ability groups.

Though hypothesis two was rejected on the basis of the above statistical tests, one would want to determine what main effects, if any, the treatments had on each group of different mental abilities.

The post-test scores of high mental ability groups (HMA) from each of the treatment groups UCU, RCU, and control groups NCU were tested for signifitant difference.

TABLE 61

Analysis of Variance of Post-test Scores

of Groups (HMA) One-way Scheffe Procedure

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROB
BETWEEN GROUPS	2	460.3359	230.1680	11.054	0.001***
WITHIN GROUPS	39	812.0742	20.8224		
TOTAL	41	1272.4102			

*** Highly Significant at $p < .001$

Table 61 of Multiple range test showed that there was significant difference in the mean post-test scores of the groups. Further test would show the relative performance of each group.

TABLE 62

Summary of t-tests of Post-test scores of groups (HMA) (A, D, G)

	GROUPS	N	$\bar{X}$	SD	SD^2	T-RATIO	SIGNIF LEVEL
	A	14	20.7143	4.9835	24.8353		
1	G	14	12.6429	4.0931	25.9387	4.24	0.001***
	A	14	20.7143	4.9835	24.8353		
2	D	14	16.000	3.4194	11.6923	2.92	0.01 **
	D	14	16.000	3.4194	11.6923		
3	G	14	12.0429	5.0931	25.9387	2.05	0.05 *

***Highly Significant at $P < .001$
** Significant at $p < .01$
* Significant at $p < .05$

The above t-test table shows that high mental ability group of unrestricted calculator groups (A) performed significantly better than the high mental ability groups of restricted calculator groups (D) and non-calculator groups (G). Similarly the high mental ability group of restricted groups performed better than the control groups - the non-calculator groups in the Post-test. This would suggest that the treatment was effective on the groups and confirmed the rejection of hypothesis two.

The post test scores of Average mental ability groups (AMA) from each of the treatment groups UCU, RCU and control group NCU were tested for significant difference.

TABLE 63

Analysis of variance of Post-test Scores of Groups AMA - One-way Scheffe Procedure

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROP
BETWEEN GROUPS	2	112.9063	56.4531	4.914	o.oll*
WITHIN GROUPS	39	448.0742	11.4891		
TOTAL	41	560.9805			

* Significant at $p < .05$.

Table 63 of Multiple range test showed that there was significant difference in the mean post-test scores, at $p < .01$. Further test would show the relative performance of each group.

TABLE 64

Summary of t-tests of Post of Post-test

Scores of groups AMA (B, E, H)

GROUPS		N	$\bar{X}$	SD	SD^2	t-ratio	SIGNIF LEVEL
	B	14	17.2857	2.494	6.220		
1	H	14	14.000	2.9872	8.9234	3.16	0.01**
	B	14	17.2857	2.494	6.220		
2	E	14	13.642[illegible]	4.3959	19.3240	2.7	0.05*
	E	14	13.6429	4.3959	19.3240		
3	H	14	14.0000	2.9872	8.9234	-0.25	ns

** Significant at $p < .01$

* Significant at $p < .05$

ns Not Significant at $p = .05$

The above t-tests table showed that average mental ability group of unrestricted calculator groups (B) - G performed significantly better than the average mental ability groups of restricted calculated group(E) and the Non-calculator group (H). However, there seemed to be no significant difference in the mean post-test scores of average mental ability groups (E) and (H).

. In other words ,the restricted calculator - average mental ability group did not perform better than the non-calculator - average mental ability group. The result showed that the treatment was effective on the experimental groups and confirmed the rejection hypothesis two.

The post-test scores of low mental ability groups (LMA) from each of the treatment groups UCU, RCU and control group NCU were tested for significant difference.

TABLE 65

Analysis of Variance of Post-test Scores of Groups (LMA) - One-way Scheffe Procedure

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROP
BETWEEN GROUPS	2	171.5703	85.7852	7.103	.002**
WITHIN GROUPS	39	471.0039	12.0770		
TOTAL	41	642.5742			

** Significant at $p < .01$

Table 65 of multiple range test showed that there was significant difference in the mean post-test scores at $p <$ .01. Further t-tests would show the relative performance of each group.

TABLE 66

Summary of t-tests of Post-test Scores of Groups (LMA) C, F. I.

GROUPS		N	$\bar{X}$	SD	SD^2	t-ratio	SIGNIF LEVEL
	C	14	14.1429	3.0091	9.0547	.	
1	I	14	99.9286	4.1224	16.9942	3.1	0.01**
	C	14	14.1429	3.0091	9.0547		
2	F	14	9.7857	3.1908	10.1812	3.72	0.001***
	F	14	9.7857	3.1308	10.1812		
3	I	14	9.9266	4.1224	16.9942	[illegible].10	ns

***Highly Significant at $p < .001$

** Significant at $p \leq .01$

ns Not Significant at $p = .05$

The above t-tests table showed that Low mental ability group of unrestricted calculator groups ' - C performed significantly better than (i) Low mental ability group from Non-Calculator - Control group I and (ii) Restricted calculator group F. However, there was no significant difference in the mean scores of the low mental ability groups from RCU and NCU. It would therefore, appear that there was no difference in the performance of these two groups. Though the result showed that the treatment was relatively effective.

Again hypothesis two was rejected.

5.30 Hypothesis 3.

There will significant difference in the mean attitude scores of those groups of pupils who use (i) Calculators in tests and instruction (unrestricted Groups) (UCU), (ii) Calculators in tests only (restricted groups) (RCU), and (iii) Non-calculators at all-control groups (NCU). That is :

$$H_0 : \dot{X}_{E_1} = X_{E_2} = X_{E_3} \text{ at } \alpha = .05$$

TABLE 67

Analysis of Covariance of the Post-Attitude

Scores of Groups UCU, RCU, NCU

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARE MS	F-RATIO	SIGNIF LEVEL
COVARIATE					
PRE-ATTITUDE	1	2502.728	2502.728	17.064	0.011 ***
MAIN EFFECTS					
GRP	2	1367.972	683.986	4.663	0.011**
EXPLAINED	3	3870.703	1290.234	8.797	0.001***
RESIDUAL	122	17893.831	14.671		
TOTAL	125	21764.594	174.11		

***Highly Significant at p <. .001

* Significant at p.< .05

TABLE 68

Multiple Classification Analysis of Post-Attitude Scores of Groups UCU, RCU and NCU with Pre-Attitude Covariate

GRAND MEAN = 84.04

VARIABLE + CATEGORY		UNADJUSTED		ADJUSTED FOR INDEPENDENTS + COVARIATES	
GRP	N	DEV'N	ETA	DEV'N	BETA
1	42	3.53		4.72	
2	42	-2.94		-2.54	
3	42	-0.59		-2.10	
			0.20		0.25

MULTIPLE R SQUARED = 0.178
MULTIPLE R = 0.422

R^2 = 0.178 - indicated that 17.8% of the variance in the criterion measure of Post-attitude scores was associated with the Pre-attitude scores whereas the rest 82.2% of the variance might have been due to treatment or to some error.

TABLE 69

Analysis of Variance of Pre-attitude Scores

of Groups UCU, RCU and UCU

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	SIGNIF OF F
MAIN EFFECTS					
GRP	2	831.048	415.524	0.424	0.999 ns
EXPLAINED	2	831.063	514.531	0.424	0.999 ns
RESIDUAL	123	120682.063	981.155		
TOTAL	125	121513.125	972.105		

ns : Not Significant at $\alpha = .05$

Table 69 showed that there was no significant difference in pre-attitude scores of the three groups. This would mean that the groups were equalized on their attitudes before the treatment. Any other variance that would have accounted for the difference, if any, in the post-attitude scores of the groups might have been due to the treatment.

Since the covariate, main effects, and explained were significant (See Table 67) it would be necessary to determine (i) the level of significance of the means of the post-attitudes scores and (ii) the level of significance of the attitudinal change between Pre-attitudes and Post-attitudes mean scores.

The one-way multiple range test using student - Newman Keuls (SNK) procedure was used to determine the level of significance due to treatment or otherwise while multiple regression analysis was used to determine the level of significance of the attitudinal change.

TABLE 70

Multiple range Test of Post-attitude Scores of Groups UCU, RCU, NCU by Student - Newman - Keuls Procedure (SNK) ONE-WAY ANOVA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F-RATIO	F-PROB
BETWEEN GROUPS	2	471.3750	235.6875	1.217	0.299 ns
WITHIN GROUPS	123	2381[illegible].000	193.5935		
TOTAL	125	2428[illegible].3750			

NS = Not Significant at $p = .05$

The table showed that the means of the groups were not significantly different at $p = .05$. This would mean that there was no difference in the mean attitude scores of the

TABLE 71

Multiple Regression Analysis of Post-attitude scores with Pre-attitude scores (ABC, DEF, GH I Groups)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	SIGNIF. LEVEL
REGRESSION	1	2502.77415	2502.77415	16.11170	.001***
RESIDUAL	124	19262.02744	155.33893		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR	F-RATIO	SIGNIF. LEVEL
VAR 02 - PEA	0.39182	0.33910	0.09752	16.112	.001***
(CONSTANT)	52.18706				

VARIABLE	MULTIPLE R	R^2
VAR 02 - PEA	0.33910	0.11499

*** Highly significant at $p < .001$

groups. Whatever could have accounted for the significant differences on Table 67 might have due to other variance(s) or error. To determine if a difference did exist between the Pre and post attitude scores a multiple regression analysis of the post-attitude scores as dependent variable and pre-attitude scores as independent variable was carried out ("See Table 71)):

($F (1,124) = 10.1117, p < .001$). While the adjusted R^2 value was 0.11, that is, 11% of the variance was due to the Pre-attitude whereas 89% would have been due to the treatment on the groups giving rise to the significant difference in post-attitude scores, or any other error. The F-value of this regression analysis showed that there was significant difference in the means of the pre and post attitude scores. This attitudinal change could be attributed to the treatments.

Though there had been change in attitudes as a result of the treatments this was not sifficient enough to have brought a difference in the post-attitudes of the groups. Hence, hypotheses three was accepted.

There was no significant difference in the mean post-attitude score of the groups despite the change in attitudes of the groups.

The change in attitudes of the groups could have been attributed to some treatments on tha groups. To determine which of the groups showed a significant difference in their attitudes toward mathematics and calculator, t-tests were carried out.

TABLE 72

Summary of t-tests of Post-attitude Scores of Groups UCU, RCU and NCU

	GROUPS	N	$\bar{X}$	SD	SD^2	t-ratio	SIGNIF LEVEL
	UCU	42	87.571	15.5964	243.250		
1	NCU	42	83.4524	12.6707	160.5466	1.33	ns
	UCU	42	87.571	15.5964	243.250		
2	RCU	42	80.0952	10.6790	114.041	2.22	0.05*
	RCU	42	80.0952	10.6790	114.041		
3	NCU	42	83.4524	12.6707	160.5466	-0.972	ns

* Significant at $p < .05$

ns = Not Significant at $p = .05$

Table 72 showed that there was no difference in the post-attitude scores of those who use calculators and those that did not use calculators. However, there was some significant difference in the post-attitude scores of unrestricted calculator group and restricted calculator group.

The overall picture showed that there was no significant difference in the post-attitude scores of the groups, and so hypothesis three was not rejected. The groups had the same attitudes toward mathematics and calculators.

TABLE 73

Summary of t-tests of Post-attitude Scores of the groups UCU : A, B and C

	GROUP	N	$\bar{X}$	SD	SD^2	T-RATIO	SIGNIF LEVEL
	A	14	89.857	16.9971	288.90		
1	C	14	82.071	11.6452	135.610	1.4	ns
	A	14	89.857	16.9971	288.90		
2	B	14	90.786	16.2773	264.950	-0.15	ns
	B	14	90.7816	16.2773	264.950		
3	C	14	82.071	11.6452	135.610	1.63	ns

ns : Not Significant at P = .05

The table of t-tests showed that there was no significant difference in the post-attitude mean scores of the high, average and low mental ability groups of the unrestricted calculator groups. The groups received the same treatment.

TABLE 74

Summary of t-tests of Post-attitude Scores of the groups RCU: D, E, and F.

GROUP	N	$\bar{X}$	SD	SD^2	T-RATIO	SIGNIF LEVEL
D	14	81.214	6.670	44.489		
F	14	81.000	13.576	184.308	0.053	ns
D	14	81.214	6.670	44.489		
E	14	80.857	11.367	129.209	0.10	ns
E	14	80.857	11.367	129.20		
F	14	81.000	13.576	184.308	-0.03	ns

ns : Not significant at P = .05

The results of the t-tests showed that there was no significant difference in the post-attitude scores of the high, average and low mental ability groups of the restricted calculator groups.

TABLE 75

Summary of the t-tests of Post-attitude mean

Scores of the groups G, H and I

GROUP	N	$\bar{X}$	SD	SD^2	T-RATIO	SIGNIF LEVEL
G	14	88.071	10.658	113.61		
I	14	78.786	14.5453	211.566	1.93	ns
G	14	88.071	10.658	113.61		
H	14	83.857	11.60	134.593	1.001	ns
H	14	83.857	11.60	134.593		
I	14	78.786	14.5453	211.566	1.02	ns

ns : Not significant at $p = .05$

The results of the t-tests showed that there was no significant difference in the Post-attitude mean scores of the high, average and low mental ability groups of the Non-calculator groups. Groups G and I had significant difference at $p = .05$ for one-tailed test.

Though the analysis of covariance of Table 67 had shown that there was significant difference in the mean scores. The multiple range test showed that :

(F (2,123) = 1.217) was not significant at p = .05.

This result was further confirmed by the t-tests which showed that there were no significant differences in the post-attitude scores of the groups. However, there were significant differences in the Pre-attitude and Post-attitude scores of the groups. This would mean that there was some relationship between pre and post attitude scores of the groups.

5.4 Hypothesis 4

There will be no significant difference in the mean of post-attitude towards mathematics and calculator scores of those groups of pupils of high, average and low mental abilities.

That is:

$$Ho: \quad X_{C_1} = X_{C_2} = X_{C_3}, \text{ at } \alpha = .05$$

TABLE 76

Analysis of Covariance of Post-Attitude

Scores of groups HMA, AMA, LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	SIGNIF LEVEL
COVARIATES PRE-ATTITUDE	1	2502.748	2502.748	16.810	0.001***
MAIN EFFECTS (GRP)	2	1098.208	549.104	3.688	0.027*
EXPLAINED	3	3600.[illegible]57	1200.319	8.062	0.001***
RESIDUAL	122	18163.621	148.682		
TOTAL	125	21764.578	174.117		

***Highly Significant at $p < .001$

* Significant at $p \leq .05$

TABLE 77

Multiple Classification Analysis of the Post-Attitude Scores of Groups HMA, AMA and LMA

GRAND MEAN = 84.04

variable + CATEGORY		UNADJUSTED		ADJUSTED FOR INDEPENDENTS + COVARIATES	
GRP	N	DEV'N	BETA	DEV'N	BETA
1	42	2.17		2.91	
2	42	1.41		1.16	
3	42	-3.59		-4.07	
			0.19		0.23

MULTIPLE R SQUARED = 0.165

MULTIPLE R = 0.407

R^2 = 0.165 i n d i c a t e d that 16.5% of the variance in the criterion measure : post-attitude measure was associated with the pre-attitude measure. The remaining 83.5% might have been due to treatment or some to error. So as to determine how much was due to treatment it was necessary to find out if there was any difference in the pre-attitude scores of the groups. Would this difference had effect(s) on the post-attitudes scores?

Otherwise, what was the significance of the main effects?

TABLE 78

Analysis of Variance of Pre-Attitude Scores of HMA, AMA and LMA

SOURCE	DF	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	SIGNIF LEVEL
MAIN EFFECTS	2	2323.857	1161.928	1.199	0.305 ns
EXPLAINED	2	2323.875	1161.938	1.199	0.305 ns
RESIDUAL	123	119190.313	969.027		
TOTAL	125	121514.188	972.113		

ns : Not Significant at p = .05

The table showed that there was no significant difference in the Pre-attitude scores of the groups. The mean significant difference of the post-attitudes scores must have occurred as a result of some treatment. In order to determine which group(s) contributed to the treatment and the significant difference, a multiple range test using one-way ANOVA LSD procedure was carried out.

TABLE 79

Multiple range Test of Post-attitude Scores

ONE-WAY ANOVE LSD Procedure on Groups

HMA, AMA, and LMA

SOURCE	df	SUM OF SQUARES SS	MEAN SQUARES MS	F RATIO	F PROB
BETWEEN GROUPS	2	822.9375	411.4688	2.417	0.091 ns
WITHIN GROUPS	123	20942.00[illegible]	170.2602		
TOTAL	125	21764.9375			

ns : Not Significant at p = .05

The table showed that the mean of the post-test scores of the groups was not significantly different at P = .05. This would suggest that other variance(s) or error could have contributed to the significant difference on Table 76 However, to determine, if this was caused by other variances, multiple regression analyses of the post attitude as dependent variable with pre-attitude as the independent variable were carried out. (see Tables 80 - 82).

For groups HMA and LMA the table showed that (F(1.82) = 7.2626, p < .01), there was significant difference in the mean post attitude scores of high mental ability and low mental ability groups. For groups HMA and AMA the table showed that (F (1,82) = 11.6847, p < .001), Hence it was found that there was significant difference in the mean post attitude scores of high mental ability and average mental ability groups. Also for groups AMA and LMA the table showed that (F (1,82) = 15.4464, p < .001), there was significant difference in the mean post attitude scores of average mental ability and low mental ability groups. From table 79 the mean post attitude scores of the groups had been found not to be significantly different for the groups. Hypothesis four was not rejected. That is, there was no significant difference in the post-attitude scores of the groups. Pupils of different mental ability levels would have the same attitudes toward mathematics and calculators. However, the multiple regression analysis showed that there was attitudinal change within the groups because there was significant difference in the pre-attitude and post-attitude scores of the groups. Table 79 only showed that the means of

TABLE 80

Multiple Regression Analysis of Post-attitude scores with Pre-attitude scores of groups ADG and CFI (High and low mental abilities)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	SIGNIF. LEVEL
REGRESSION	1	1142.86034	1142.86034	7.26255	.01**
RESIDUAL	82	12903.80633	157.36349		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR	F-RATIO	SIGNIF. LEVEL
VAR 02 - PEA	0.32118	0.28524	0.11918	7.263	.01**
CONSTANT	57.32169				

VARIABLE	MULTIPLE R	R^2
VAR 02 - PEA	0.28524	0.08136

** Significant at $p < .01$

TABLE 81

Multiple Regression Analysis for Post-attitude scores with Pre-attitude scores of groups ANG and BEH (High and average mental abilities)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	SIGNIF. LEVEL
REGRESSION	1	1752.57912	1752.57912	11.685	.001***
RESIDUAL	82	12299.08755	149.98887		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR	F-RATIO	SIGNIF. LEVEL
VAR 02 - PEA	0.39669	0.35316	0.11605	11.685	.001***
(CONSTANT)	53.61473				

VARIABLE	MULTIPLE R	R^2
VAR 02 - PEA	0.35316	0.1 2472

*** Highly significant at $p < .001$

TABLE 82

Multiple Regression Analysis of Post-attitude scores of groups EEH and CFI (i.e. Average and low mental abilities)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	SIGNIF LEVEL
REGRESSION	1	2380.00963	2380.00963	15.44635	.001***
RESIDUAL	82	12638.99990	154.13415		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD. ERROR	F-RATIO	SIGNIF LEVEL
VAR 02-PEA	0.48110	0.39813	0.12241	15.46	.001***
(CONSTANT)	43.41655				

VARIABLE	MULTIPLE R	R^2
VAR 02-PEA	0.39813	0.15851

*** Highly Significant at $p < .001$

the groups were equal while Tables 80 - 82 showed that there had been attitudinal change. To determine the level of significance of this attitudinal change t-tests were carried out.

TABLE 83

Summary of t-tests of Post-attitudes Scores of Groups HMA, AMA and LMA

GROUPS		N	$\bar{X}$	SD	SD^2	T-RATIO	SIGNIF LEVEL
	HMA	42	86.214	12.540	157.245		
1	LMA	42	80.452	12.975	168.351	2.07	0.05*
	HMA	42	86.214	12.540	157.245		
2	AMA	42	85.452	13.608	185.180	0.26	ns
	AMA	42	85.452	13.608	185.180		
3	LMA	42	80.452	12.975	168.351	1.72	ns

* Significant at $p < .05$
ns Not Significant at $P = .05$

The table showed that the high mental ability groups had better attitudes toward mathematics and calculator than low-mental ability groups while there were no differences in the attitudes of high mental ability and average mental ability groups, and the average mental ability and the low mental ability groups. Using one-tailed test at P = .05 there was significant difference between the mean attitudes scores of average mental ability and low mental ability groups. From here, the results showed that pupils of high mental ability would have better attitudes toward mathematics and calculators than those pupils of low mental ability. To determine what the differences would be within groups, t-tests of groups A, D and G were carried out.

TABLE 84

Summary of the t-tests of Post-attitude Scores of Groups HMA, A, D and G.

	GROUP	N	$\bar{X}$	SD	SD^2	T-RATIO	SIGNIF LEVEL
	A	14	89.857	16.997	288.901		
1	G	14	88.071	10.6588	113.61	0.33	ns
	A	14	89.857	16.997	288.901		
2	D	14	81.214	6.670	44.489	1.7[illegible]	ns
	D	14	81.214	6.670	44.489		
3	G	14	88.071	10.6588	113.61	1.99	ns

ns : Not Significant at p = .05

The above table showed that no significant difference was found among the high mental ability groups of the unrestricted calculator, restricted for two tailed test. Though the groups A and D, D and G were not significant at P = .05 two-tailed test, both groups were found to be significantly different at P = .05 for one tailed test. In the high mental ability level the unrestricted calculator group had better attitudes than restricted calculator, and the restricted calculator group also had poorer attitude than the no-calculator group. In the analysis of the attitude scores of calculator and non-calculator groups it was found that there was significant difference in the pre - and post-attitude scores when F-test was used. While such a difference was not significant by t-tests. Though some researchers have observed such difference in the use of t-tests and F-test (Spence)[109].

Spence, J. T. et al: Elementary Statistics: London: Prentice-Hall Int. Inc., 1976, pp 162 - 216.

TABLE 85

Summary of the t-tests of Post-attitude Scores of groups AMA: B, E, and H

GROUPS	N	$\bar{X}$	SD	SD^2	t RATIO	SIGNIF LEVEL
B	14	90.786	16.2773	264.950		
H	14	83.857	11.60	134.593	1.3	ns
B	14	80.786	16.2773	264.90		
E	14	80.857	11.367	129.209	2.33	.05*
E	14	80.857	11.367	129.209		
H	14	83.857	11.60	134.593	0.69	ns

* Significant at p < .05
ns Not significant at p = .05

The table of t-test of post-attitude scores of (AMA), A, D and G groups showed that there was significant difference between average mental ability of unrestricted group and restricted groups while other groups were not significant.

TABLE 86

Summary of T-Tests of Post-Attitude Scores

of Groups LMA: C, F and I

GROUPS	N	$\bar{X}$	SD	SD^2	T-RATIO	SIGNIF LEVEL
C	14	82.071	11.6452	135.61		
I	14	78.786	14.5453	211.566	0.66	ns
C	14	82.071	11.6452	135.61		
F	14	81.000	13.576	184.308	0.22	ns
F	14	81.000	13.576	184.308		
I	14	78.786	14.5453	211.566	0.42	ns

ns : Not Significant at $p = .05$

The results of the t-tests showed that there were no significant differences in the post-attitude mean scores of unrestricted, restricted and no calculator groups in the low mental ability level.

The analysis of covariance of Table 79 showed that there was significant difference in the mean scores. But the multiple range test showed that($F(2,123) = 2.417$ which was not significant at $p = .05$). This result was further comfirmed by the t-tests which showed that there were no differences in the post-attitude scores of the groups except the unrestricted and restricted calculator groups of average mental ability groups. However, there were significant differences in the pre-attitude and post-attitude scores of the groups, which actually showed that some relationship between the pre- and post-attitudes scores of the groups.

5.5 Hypothesis 5

There will be no significant relationship in pupil's attitudes toward mathematics and their attitudes toward the use of calculators in secondary school mathematics at $\alpha = .05$.

t-tests were used to determine the significance differences in the mean mathematics attitude scores (MAS) and mean calculator attitude scores (CAS) which were derivable from post-attitude scores of each of the groups.

TABLE 87

Summary of t-test of MAS and CAS

of the Groups

GROUPS	MAS				CAS					
	N	$\bar{X}$	SD	SD^2	N	$\bar{X}$	SD	SD^2	T RATIO	SIGNIF LEVEL
UCU	42	47.167	7.946	63.167	42	40.452	13.895	193.083	2.72	.01**
RCU	42	49.262	6.161	37.945	42	31.833	8.881	78.874	10.45	.001**
NCU	42	45.976	7.478	55.926	42	37.476	10.879	118.353	4.17	.001***
HMA	42	49.238	5.686	32.332	42	37.024	12.719	161.780	5.68	.001***
AMA	42	48.452	5.790	33.522	42	37.000	11.288	127.415	5.84	.001***
LMA	42	44.714	9.214	84.892	42	35.738	11.801	139.271	3.89	.01**

** Significant at $p < .01$

***Highly Significant at $p < .001$

The table of t-tests showed that there were significant differences in the means scores of MAS and CAS for all the groups which indicated that there was relationship between the MAS and CAS scores of each group. This relations might be negative or positive depending on the correlation coefficients.

Though, all the mean scores were all significantly different at $p < .01$ or $p < .001$, it was necessary to determine the significant level of the relationship by Pearson correlation coefficients approach.

TABLE 88

Summary of Pearson correlation coefficients of the Groups. (MAS & CAS)

GROUPS	N	r	SIGNIF. LEVEL
UCU	42	-0.091	ns
RCU	42	-0.026	ns
NCU	42	-0.084	ns
HMA	42	-0.24	ns
AMA	42	0.19	ns
LMA	42	-0.26	ns

ns : Not Significant at $p = .05$

The table 88 showed that none of the correlation coefficients was significant at $p = .05$.

The groups showed overall significant differences in their mean attitude scores, and yet, from available data in this study it would appear that most of the groups had nearly zero correlation and specifically low negative correlation.

TABLE 89

Multiple Regression Analysis
of Mathematics attitude scores with Calculator
attitude scores (MAS WITH CAS) for all the groups

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	SIGNIF LEVEL
REGRESSION		83.35525	83.35525	1.569	ns
RESIDUAL	124	6588.01777	83.12918		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD. ERROR	F-RATIO	SIGNIF LEVEL
VAR 07-CAS	-0.06879	-0.11178	0.05492	1.569	ns
(CONSTANT)	49.98527				

VARIABLE	MULTIPLE R	R^2
VAR 07-CAS	0.11178	0.01249

ns - Not Significant at p = .05

It showed t h a t . pupils with high attitudes toward mathematics have low attitudes toward calculators.

To determine the l e v e l of relationship, a multiple regression analysis of the MAS and CAS scores on the groups were carried out (see Table 89)

The multiple regression analysis table showed that there was no significant difference in tha mathematics attitude scores and calculator attitude scores. Hypothesis 5 was accepted: ($F(1,124) = 1.57$, $p > .05$). Since F-value was not significant, it implied that the means of MAS and CAS were not different significantly. Hence, thera would not be any relationship between the MAS and CAS. From t-tests table, it w a s. possible to ascertain the effects of the treatment on the groups. The t-tests of the groups were all significantly different which would imply that individual groups would have different attitudes to mathematics and to calculators. That is, for the groups there w a s some relationship between the MAS and CAS.

5.6 : <u>Hypothesis</u> 6.

There will be no significant relationship in pupils' achievement and attitudes toward mathematics and calculators at $\alpha = .05$.

TABLE 90

Correlation Coefficients of Post-tests

with POA, MAS and CAS

		POA		MAS		CAS	
GROUPS	N	R	SIGNIF LEVEL	r	SIGNIF LEVEL	r	SIGNIF LEVEL
UCU	42	0.174	ns	0.419	0.01**	-0.14	ns
RCU	42	0.05	ns	0.17	ns	-0.06	ns
NCU	42	0.26	ns	0.38	0.05	0.05	ns
HMA	42	0.14	ns	0.21	ns	-0.01	ns
AMA	42	0.28	ns	0.24	ns	0.21	ns
LMA	42	0.04	ns	0.195	ns	-0.11	ns

** Significant at $p \leq .01$

* Significant at $p < .05$

ns Not Significant at $p \geq .05$

The table 91 showed the intercorrelation coefficients of the seven variables: (n = 126, r = 0.308, $p <$ 0.001 for POT/MAS), (N = 126, r = -0.05 not significant at p = .05. for POT/CAS), (N = 126, r = 0.194 significant at $p < .05$ for POT/POA).

TABLE 91

Correlation Coefficients of the variables for all the groups (N = 126)

	MAT VAR 01	PEA VAR 02	PET VAR 03	POA VAR 04	POT VAR 05	MAS VAR 06	CAS VAR 07
VAR 01	-	-0.06684	0.46162	0.12407	0.41538	0.26162	-0.[illegible]2098
VAR 02	-	-	-0.05212	0.33910	-0.06909	0.22119	0.24045
VAR 03	-	-	-	0.14685	0.52761	0.37356	-0.06875
VAR 04	-	-	-	-	0.12756	0.45267	0.83539
VAR 05	-	-	-	-	-	0.30747	-0.04551
VAR 06	-	-	-	-	-	-	-0.11178
VAR 07	-	-	-	-	-	-	-

The two tables showed that most of the groups did not have any significant relationship between achievement scores and attitude scores at $p < .05$. Though correlations did exist in some group (MAS) especially UCU and NCU, t h i s would not be adequate to generalize the relationship. However, the general pattern was that low negative correlation or very nearly zero correlation occurred in calculator attitude and achievement.

The table of correlation coefficients showed that there were significant relationships between the groups'

(i) Pre-test and Post-test

(ii) Pre-attitudes and Post-attitudes

(i) N = 126 POT: $r = 0.528$, $p \leq 0.001$

(ii) N = 126 POA: $r = 0.339$, $p < 0.001$

Any differences that would have occured in the Post-attitude and Post-test scores could have been due to treatment. The main effects of Post-attitude and Post-test scores have been found to be significantly different (see Tables 29, 54, 67 and 76). Since both were significantly different, they would appear to have some relationship.

To determine the level of significance of the relationship between post-test scores and post-attitude

TABLE 92

Multiple Regression Analysis of Post-attitude scores with Post-test scores for all the groups (PDA with POT

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	SIGNIF. LEVEL
REGRESSION	1	911.65634	911.65634	4.03[illegible]86	.05*
RESIDUAL	124	233[illegible]1.04525	188.48101		

VARIABLES IN THE EQUATION

VARIABLES	B	BETA	STD ERROR	F-RATIO	SIGNIF. LEVEL
VAR 05 - POT	0.54486	0.19376	0.24774	4.037	.05*
(CONSTANT)	75.70253				

VARIABLE	MULTIPLE R	R^2
VAR 05 - POT	0.19376	0.03754

* Significant at $p < .05$

TABLE 93

Multiple Regression Analysis of Post-test scores with calculator attitude scores and mathematics attitude scores for all the groups

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	SIGNIF. LEVEL
REGRESSION	2	275.10200	137.55100	6.05159	.01**
RESIDUAL	123	2795.75514	22.72972		

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR	F-RATIO	SIGNIF. LEVEL
VAR 07 - CAS	0.03025	0.07246	0.03615	6.700	.01**
VAR 06 - MAS	0.20260	0.29862	0.05874	11.897	.001***
(CONSTANT)	3.01416				

VARIABLE	MULTIPLE R	R^2
VAR 07 - CAS	0.03908	0.00153
VAR 06 - MAS	0.29931	0.08958

*** Highly significant at $p < .001$

** Significant at $p < .01$

scores of the groups, a multiple regression analysis of Post-attitudes as dependent variable and post-test as independent variable was done. The table showed that there was significant difference in the post-attitude and post test scores of the groups (See Table 92) ($F(1,124) = 4.84$, $P < .05$).

In order to ascertain that this significant difference was not due to chance or error, a multiple regression analysis of Post-test scores as dependent variable, and calculator attitude scores and mathematics attitude scores as independent variables were carried out. (Table 93) showed that there was a significant difference in the Post-test scores, and CAS and MAS; $F(2.123) = 6.052$, $P < .001$).

The two regression analyses showed that there was significant relationship between Post-test scores and post attitude scores of all the groups. On the basis of the analysis, the hypothesis was rejected. That is, there was a significant relationship between the post-test scores and the post-attitude scores. In addition, it was found that there was a linear correlation between post-test scores and mathematics attitude scores and calculator attitude scores.

CHAPTER SIX

DISCUSSION

6.1 Relationship of Results to hypotheses and Previous Empirical Studies

The results of this study would be discussed in relation to the hypotheses tested. The purpose of this study was to investigate the effects of the use of hand held electronic calculators on outcomes in mathematics instruction. The learning outcomes investigated were primarily achievement and attitudes. The criterion measures of achievement were pre- post-tests scores, and for attitudes were pre- post-attitude scores.

6.2 Performance Treatments and achievement:

The hypotheses which dealt with achievement were one and two:

I. Hypothesis one: There will be no significant difference in the mean achievement scores of pupils who use (i) calculators in instruction and tests (UCU)
(ii) calcuators in test only (restricted groups -(RCU) and (iii) no calculators at all - control groups,(NCU.

This hypothesis was rejected because significant difference was found in the mean post-test scores of the groups $(F(2,123) = 16.234, p < .001)$. Also the groups that used calculators throughout (UCU) were significantly better than no calculator group (NCU) ($t(82) = 5.35$, $P < .001$) and also UCU groups were significantly better than the calculator on the test only groups (RCU). ($t(82) = 4.35$, $P < .001$).

However, no significant difference was found between the groups RCU and NCU, ($t(82) = 0.98$, $P > .05$) which showed that neither of these two groups was better. Hence, $E_1 > E_2 = E_3$.

Similar findings had been obtained by Gaslin[8] who compared the achievement and attitudes of high school pupils. Pupils in treatment groups E_1 and E_2 were allowed to use calculators on post-tests and retention tests and no calculator or C control group. Significant treatment effects were found on both post-test achievement measures with $E_2 > E_1 > C$ and the retention test with $E_2 > E_1 = C$; however, no significant differences on attitudes were found. These findings were also collaborated by Fineman[8].. However, Quinn[13] and Hutton[8] did not find any significant differences between calculator and non calculator groups on the achievement variable. Other studies which support the findings of this study are those of Andersen[8] who was interested in the effects of restricted versus unrestricted use of calculators in mathematics achievement and attitudes E_1 - the unrestricted groups, E_2 - the restricted groups and C no calculators groups. The pupils were pre-post-tested, using ANCOVA as the principal analysis procedure it was found that $E_1 = E_2 > C$ on achievement and attitudes. Recent studies by Hedren[110] found classes (in Sweden) using calculators, whenever they could be of use, were as competent as control classes on mental arthemetic and calculations with simple algorithms, and had better understadding of numbers and problem-solving (ages 10-12). This was further supported by Mellon[111] and Kelly[112] whose studies found calculators to be effective. Kelly[112] found that calculator enhanced the use of deductive reasoning, ability to explain strategies in retropect, in retropect and implementation of strategies to increase understanding of problems. He also found that the specific processes to promote effective solution and ability to evaluate were aided by the use of calculators.

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110 Hedren, Rolf: The Hand-held Calculator at the Intermediate Level. Educational Studies in Mathematics Vol. 16, 11. 163-179, May 1985

111 Mellon, Joam: Calculator Based Units in Demands and percents for 7th Grade Students. Unpublished Ph.D. Thesis: Columbia University Teachers College: DAI 46A, Sept. 1985.

112 Kelly, M.G. The effect of the use of the Hand-held calculator on the development of problem-solving strategies: Utah State University, 1984: DAI, 45A 3571, June. 1985.

Padberg[113], using calculators to discover simple theorem in an example from number theory, concluded that "calculator enables one to generate a sufficient number of examples that one can easily get through to conjectures or theorems". All these pointed out that calculators are not only used as computational device but can also be used in concept formation a problem-solving techniques.

In his work, Cheung[114] described how a scientific calculator can be used to introduce the method of successive substitutions in generating approximate solutions to a number of equations that can be expressed in the form $y = f(x)$ including trigonometric equations such as $y = \sin(\cos(\tan x))$.

So far, the empirical studies reviewed and the results of this study on achievement showed that most calculator groups performed better than or equalised other groups; and in no case was the use of calculator had debilitating effect at secondary school level.

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113. Padberg, F.F.: Using calculators to Discover simple Theorems - An examples from number Theory Arithemetic Teacher, NCTM, Vol. 28, No. 8, 1981, pp

114 Cheung, Y.L.: Using scientific calculators to demonstrate the method of successive substitution. Mathematics Teacher. Vol.79 No. 1, Jan. 1986. pg. 15-17.

The results of the groups (UCU) unrestricted calculator groups showed that there was significant difference in the mean post-test scores of A, B and C groups:

($F(2,39) = 11.312$, $p < .001$). The t-tests showed that high mental ability group performed significantly better than average and low mental ability groups (Table 45) This showed that high mental ability pupils that used calculator performed better than other calculator groups of the average or low mental ability groups. Here, the use of calculator is an added advantage in the instructional process and tests.

The results of groups RCU - the restricted calculator groups showed that there was significant difference in the mean post-test scores of D, E, and F groups. ($F(2,39) = 10.033$, $p < .001$). The t-tests also showed that the high mental ability group of the RCU group that used calculators on the tests only performed significantly better than others in the group. Though there was no significant difference in mean scores of high and average mental ability groups, yet the average mental ability group performed better than low mental ability group (Table 40). Since the main effects was not significant (Table 46 and 50), it would appear that the effect of using the calculator on the tests alone would not be as effective as incorporating the use of calculators in the instructional process and tests. The non-significant difference of the main effects could be attributed to either the treatment or error and the $R^2 = 0.429$ indicated that 42.9% of the variance in the post-test scores was associated with the pre-test scores. This might have been quite high to have provided some effects on the post-test scores. The comparison of the mean post-test scores showed significant difference, the means were significantly differnt as a result of the treatment. This was confirmed by the t-tests (see table 49).

The results of non-calculator NCU groups showed significant difference in the mean post-test scores (see table 50). Also the main effect was not significant. *The multiple classification table showed that $R^2 = 0.524$,* indicating that 52.4% of the variance in the criterion measure of post-test scores was associated with pre-test scores. This is quite large, whereas the rest 47.6% of the variance might have been due to treatment or some to error. The treatment might have not nullified the effects of the pre-test as to make the main effects to be non-significant.

The means of the post-test scores were then compared by multiple range test so as to determine their significance: (F(2,39) = 3.48, P < .05). The means were found to be significantly different. For the control group, there was no difference in means of the high and low mental ability groups, high and average mental ability groups except for the average and low mental ability groups (See Table 53). This finding is supported by those of Hembree and Dessart[115] that the use of calculators in testing produces much higher achievement scores than paper and pencil efforts, both in working exercises and in problem-solving. They went further to show that this applied to all grade and ability levels. In particular, it applies to low and high ability pupils in problem solving. The better problem-solving performance is a result of improved computation and process selection. However, some other results were contrary especially the findings of the United States National Assessment of Educational progress (NAEP) which have discovered some area of mathematics where pupils who did not use calculators

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115. Hembree, Ray and Dessart, D.J. Effects of Hand-Held Calculators in Pre-College Mathematics Education: A mental-analysis. "Journal for Research in Mathematics Education, 17, March, 1986: 83-99.

fared better that pupils equipped with calculators (Driscoll)[116]. Indeed, when pupils lacked the understanding of a concept, the use of calculators offered no advantage (Driscoll)[117]. The t-tests (Table 40) showed that no significant difference was found between restricted calculator groups and non-calculator groups which implied that the use of calculators only on tests would not result in higher achievement in mathematics. Many researchers in the calculator field have advanced reasons that such pupils might not have confidence in the results displayed on the calculator screen due to non-continuous practice with calculator (Carpenter et. al.)[30,31]. Other related studies that supported the findings on achievement are those of Murphy[118] who found that students with unrestricted use of calculator achieved higher problem-solving scores than students not using calculators for instruction

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116. Driscoll, M.J. Research within Reach: Elementary School Mathematics, Raston, Va: National Council of Teachers of Mathematics, 1981. pp

117. ______ Research within Reach: Secondary School Mathematics. Reston Va: National Council of Teachers of Mathematics, 1982, ppp

118 Murphy, N.K., The effects of a Calculator Treatment on Achievement and attitude Towards Problem-solving in 7th Grade Mathematics. (Doctoral Dissertation, University of Denver, 1981) DAI 42A, 2008-2009, 1981.

or tests. However, Rule[119] found no significant difference between groups which used or did not use calculators for a unit on functions. While his findings on computational benefit of calculators was in conformity with the findings of this study since all the groups had equal time to complete instructions and tests.

The time was not incorporated as a criterion measure in this study, but other studies have found that using calculators during instruction and tests produced a significant improvement in less time than without calculators (Stewart)[119] Hence, further studies in Nigeria might incorporate time variable as a criterion measure.

II. Hypothesis Two:

There will be no significant difference in the mean post-test scores of high, average and low mental ability groups. This hypothesis was rejected because there was significant difference in the mean post-test scores of the groups: (F (2,123) = 14.776, $p < .001$). The ability groups differed significantly on their post-test scores as the high mental ability groups (HMA) performed

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119 Stewart, J.T. See Suydam, M.N. In Research in Mathematics Reported in 1981, JRME, 1981.

significantly better lower mental ability groups: (t (82) = 4.9, P < .001), and the average mental ability groups also did bettwe than the low ability groups: (t (82) = 4.4, P < .001). However, it appeared there was no significant difference in the performance of high and average mental ability groups (t (82) = 0.98, P > .05). The findings are consistent with other similar studies. Zepp[8] examined whether there was an interaction between the use of calculator and different ability levels high, medium and low in secondary school pupils' solutions to proportion problems and found no differences. This was collaborated by Bolesky[8], whereas, Fischman[8] and Laursen[8] found significant differences in achievement scores of students in different ability groups. Brassell, et. al.[120] found positive correlation between mathematics achievement and ability groups.

The result of the high mental ability groups showed that there was significant difference in the mean post-test scores of groups A, D and G. (F(2.39) = 11.054, p < .001).

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120. Brassell, et. al. Ability Grouping , Mathematics Achievement and Pupils Attitudes toward Mathematics. JRME, Vol.11, No.1. Jan. 1980.

Table 62 - 66 showed that the high mental ability group that used calculators on instruction and test performed significantly better than high mental ability group that used calculators in tests only and that restricted calculator groups high mental ability performed significantly better than the high mental ability group of non-calculator group. The pattern also showed that the unrestricted calculator groups in A, B and C performed better than groups in D, E and F and G, H, and I. This pattern of performances was irrespective of whether the groups were high, average or low mental ability levels (HMA > AMA > LMA). However, there were few deviations in the pattern. For example, with the AMA groups (B,E,H) there was no significant difference between E (the restricted group) and H (Non-calculator group) performance on their post-test scores: (t (26) = -0.25, P > .05). Nichols[22] found among students using calculators in College basic mathematics that those having higher aptitudes in mathematics showed significantly higher attitude scores than students having lower aptitudes. This supports the finding of this study.

Similarly in the low mental ability groups (C,F.I.) there was no significant difference in theperformance of the restricted calculator group (F) and the non-calculator group (I) ($t(26) = -0.10$, $P > .05$). Based on these results, one is inclined to say that the unrestricted calculator groups whether in the high mental ability levels (HMA), the average mental ability level (AMA) or the low mental ability level (LMA) seemed to have performed better than other treatment groups irrespective of mental ability levels. That is:

A performed better than D or G

B performed better than E or H

C performed better than C or I

The finding of this study is supported by Lenhard[121]. In a variety of analyses using t-tests and ANOVA he found that the higher ability pupils made fewer concept and computation errors than the lower ability pupils. In addition the higher ability pupils performed significantly better than the low mental ability pupils in mathematics achievement tests.

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121. Lenhard, R.W. Hand-held Calculators in the Mathematics Classroom as Stuart Public School, Stuart Nebraska (Doctoral Dissertation, Montana State University, 1976). Dissertation Abstract International, 1977, 37A, 5661.

On the contrary Kasnic [122] using a 2-factor ANOVA with pre-test ability as a blocking variable found that there were no differences between calculator groups andcontrol groups, nor were any differences found for the different ability levels between calculator groups and the control groups. However, Miller[123] who examined whether calculators would be effective instructional aids in developing the concept and skill of long-division obtained similar results. When separate ANOVA analyses for low and high ability groups were done, the results showed that the performances of calculator groups of low mental ability groups were significantly better than the Non-calculator groups of low mental ability. The high mental ability of restricted and unrestricted calculator groups performed equally as the high mental ability of the control groups on achievement and attitudes. The finding in this study was also supported by that of Lawson[124] who found

122. Kasnic, M.J.: The effect of using hand-held calculators on Mathematical Problem-solving ability among six grade students. (Doctoral Dissertation, Oklahoma State University, 1977) DAI, 1978, 38A, 5311.

123. Miller, D.F. Effectiveness of Using Minicalculators as an Instructional Aid in Developing the Concept and Skill of Long Division... (Doctoral Dissertation, Florida State University 1977), DAI, 1977, 37A, 6327.

124. Lawson, K.W. Use of Calculators in High School General Mathematics... (Doctoral Dissertation, Brigham Young University, 1978) DAI, 39A.

that the use of calculators did not affect performance in estimation but students of lowest ability made the most errors with the calculators compared with other ability levels: higher or average. This finding in collaboration with the ones in this study implied that ability levels of the students is an important factor as far as mathematics achievement by calculator is concerned.

6.3 Performance Treatments and Attitudes

Hypothesis Three

There will be no significant difference in the mean attitude towards mathematics and calculator scores of those groups of pupils who use

(i) calculators in tests and instruction - the Unrestricted groups (UCU),

(ii) Calculators in tests only - restricted groups - RCU, and

(iii) and Non-calculator - control groups NCU.

The table of analysis of covariance of the post - attitude scores with pre-attitude scores as covariate showed that the groups' covariates were significant: ($F(1,24)$ = 17.064, $P < .001$).

Similarly the main effect was also significant: ($F(2,123)$ = 4.663, $P < .01$) and the explained variance was also significant: ($F(3,122)$ = 8.797, $P < .001$). But the comparison of the means of the post-attitudes scores using multiple range test, (SNK) student that is, student Newman

Keul test showed the means were not significantly different:

$F(2,123) = 1.217 \quad p = 0.299$, i.e. $P > .05$)

This was also confirmed by the statistical test of straight analysis of variance of the post-attitude scores (See Appendix 20). But the pre- and post-attitude scores of the groups were found to be significantly different as was shown by multiple regression analysis. (Table 71). The t-tests revealed that the hypothesis was not rejected for groups UCU and NCU-, RCU and NCU; but significant difference did exist between UCU and RCU. Hence the hypothesis was rejected for the two groups. This would imply that there was a significant difference in the means of the post attitude scores of the unrestricted calculator groups and the restricted calculator groups. Over-all, there was attitudinal change among the groups as revealed by the regression table. Conclusively, hypothesis three cannot be rejected in its entirety.

This hypothesis was not rejected though significant difference was found in the mean pre- and post-attitudes scores of the groups by regression analysis:

$(F(1,124) = 16.1117, \quad p < .001)$

The significant difference obtained in the pre- and post-attitude scores implied that there was attitudinal change among the groups. Generally the groups had a change of attitude towards mathematics and calculator. However, there was no significant difference in the mean post-attitude scores of the groups as shown by the multiple range test of the treatment groups and control group: $(F(2,123) = 1.217, P > .05)$.

The non-significance of the attitude scores at this level might have been caused by treatment effects or variances due to other extraneous variables or error. However, to determine the level of treatment effects, the results of t-tests were discussed. It was found that there was no significant difference in the post-attitude scores of the unrestricted calculator groups and non-calculator group $(E_1 = E_3)$:$(t(82) = 1.33, P > .05)$ and $(t(82) = 0.97, P > .05)$: $(E_2 = E_3)$ (restricted calculator group and control group). However, significant difference did exist between the post-attitude scores of unrestricted calculator and restricted calculator groups: $(t(82) = 2.22, P < .05)$ $(E_1 > E_2)$.

The findings on attitudes is in conformity with other related studies Hutton[8], Boling[8], Whitaker[12] and Bolesky[8] where no differences were found between calculator groups and non-calculator groups. Similarly (Gaslin and Vaughn)[8] found E = C. (experimental = control), and this was contrary to findings by Fischman, Zepp and Andersen[8].

Koop[125] and Mellon[111] found significant differences between calculator and non-calculator groups. In Bulletin No. 9 of the Calculator Information Center[26], of the seven findings reported on attitudes toward mathematics in calculator studies, six of the findings produced non-significant differences, (which agreed with the results of this study) whereas one group did produce a significant difference in favour of calculator based instruction. In this study, the results indicated that calculator instructed pupils did at least as well as, if not better than the non-calculator instructed pupils on attitudes. In addition, both the cooperating teacher and the investigator found that teaching with calculators was much less onerous than teaching without calculators.

The results on Table 72 showed that there was no significant difference in the mean attitude scores of those pupils who used calculator throughout - the unrestricted groups despite differences in mental ability levels. Similarly there was no significant difference in the mean attitude scores of the restricted calculator groups despite differences in their mental ability levels.

For the groups G, H and I of the non-calculator groups, there were no significant differences between G and I, G and I was found to be significantly different at p = .05 by one-tailed test.

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125 Koop, J.B. Calculator use in the Community College arithmetic course, JRME, 13(1) 1982, 50 - 60.

t(26) = 1.93 for one-tailed test, t-ratio is significant. This finding is supported by Gaslin[8], Hutton[8] who found no differences on attitudes of the groups. Contrary to this finding is that of Lenhard[8], Zepp[8], Fisch an[8] who found differences on the attitudes of the different groups. Recent studies by Hembree and Dessart[115] found that pupils using calculators had better attitude towards mathematics than pupils not using calculator and their findings applied across all grades and ability levels.

Some other studies involving younger populations according to Koop[125] have reported a more positive attitude towards mathematics when students were allowed to use calculator. However, Dyce and Gooden[8] found no significant changes in student attitudes. Most of the studies reviewed did not discuss the relationship between the pre- and post-attitudes they only reported differences or none in the post-attitude scores of groups. However, what is most important is to recognize from the findings of various studies whether there are differences in attitudes scores or not when calculator was used. The studies of Anderson[8] and Ayers[25] actually pin-pointed these difference where calculator groups were described as having higher attitude scores then non-calculator groups.

Hypothesis Four

There will be no significant difference in the mean post attitude towards mathematics and calculator scores of those groups of pupils of low, average and high mental abilities.

The table of analysis of covariance of the post-attitude scores with pre-attitude scores as covariate showed that the groups' covariates were significant: $(F(1,124) = 16.810, p < .001)$. Similarly the main effects was also significant: $(F(2,123) = 3.688, p < .05)$ and the explained variance was also significant $(F(3,122) = 8.062, p < .001)$. But the comparison of the means of the post-attitudes scores using multiple-range test-SNK (student Newman Keul test) showed that the groups means were not significantly different: $(F(2,123) = 2,417, p = .091, ns)$. This was also confirmed by the statistical test of straight analysis of variance of the post-attitude scores (see Appendix 20).

The pre- and post-attitude scores of the groups were found to be significantly different as was shown by multiple regression analysis. (Table 71). This would imply that there had been attitudinal change among the groups as revealed by the regression table. The t-tests also revealed that the null hypothesis was rejected among HMA and LMA because significant difference did exist between the means of the post-attitude scores of the groups. However, the null hypothesis was not rejected between HMA and AMA; AMA and LMA because no significant differences were found in the means of the post-attitude scores of the groups. Consequently hypothesis four cannot be rejected in its entirety.

This hypothesis was not rejected though significant difference was found in the means of the post-attitude scores of the groups (Tables 76). It was also found that the high mental ability groups had better attitudes than low mental ability groups: ($t(82) = 2.07$, $P < .05$). No significant differences were found between

(i) HMA and AMA: ($t(82) = 0.29$, $P > .05$) and

(ii) AMA and LMA: ($t(82) = 1.72$, $P > .05$).

Since the groups HMA and LMA showed some significant differences in their post-attitude scores, the high mental ability groups seemed to have better attitude towards mathematics and calculators. Attitude toward mathematics has been found directly related to aspired school grades and ability levels (Spickerman)[126].

Considering the t-tests for the within groups of high mental ability, A, D and G; none of the post-attitude scores was significant except for D and G which was $t(26) = -1.99$ significant at $P = .05$ (one tailed test). The high mental ability group of the non-calculator group had better attitude than the high mental ability group of the restricted calculator group.

In the average mental ability groups of the unrestricted calculator group had better attitudes than the restricted calculator group. There were no significant differences in the mean attitude scores of the other groups. For the low ability groups there were no significant differences in the mean attitude scores of the treatment groups and control group. However, the results did indicate that those groups of unrestricted calculator had better attitudes in respect of ability levels.

This finding is supported by those of Ayers[25] and Andersen[8] who found that

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126 Spickerman, W.R.A.: A study of the relationships between attitudes toward mathematics and some selected pupil characteristics in a Kentucky High School (Doctoral dissertation, University of Kentucky, (1965) DAI, 1970, 30, 2733A.

attitudes improved when calculators were used without restrictions. But other findings like those of Elliot[8], found no significant difference between groups using calculators or paper and pencil on problem-solving. Connor[29] found that there was attitudinal difference between calculator and non-calculator groups. Futherman[127] findings on attitudes support those of this study which found ability to have played an important causal role in the attitudinal process . Other studies not necessarily in the use of calculator but media studies have found similar results. The results of these research works would be discussed later in this report.

Hypothesis five

There will be no significant relationship in the groups attitudes toward mathematics (MAS) and attitudes toward calculator (CAS).

The t-tests (Table 87) showed that there were significant differences between mathematics attitude scores and calculator attitudes scores in all the groups. This would imply that some relationship did exist between the MAS

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127 Futherman, Robert: A causal analysis of expectancies and values concerning mathematics (the University of Michigan, 1980), DAI, 341B, 3628, 1981.

and CAS. When this relationship was determined using Pearson correlations approach, it was found that r, correlation coefficients were not significant at $p = .05$ for all the groups and the F-value: ($F(1,124) = 1.57$ also was not significant at $p = .05$). This hypothesis was not rejected, that is, there was no significant relationship between the MAS and CAS. If any relationship did exist it could be said that it was not significant at $p = .05$. Hence any change in attitude possibly towards mathematics might not necessarily mean change of attitude towards calculator. Calculator was used for six weeks by the treatment groups and some of the pupils had not been exposed to instruction where calculators were used. Robert[8] found evidence of calculators influencing immediate and specific attitudinal perceptions, but evidence supporting more general and lasting changes of attitudes was not available.

VI Hypothesis 6.

There will be no significant relationship in pupils' achievement and attitudes towards mathematics and calculator.

The results showed that: ($N = 126$, $r = 0.308$, $p < .001$) for post-test scores against mathematics attitude scores, N = 126, r = 0.05. Not significant at P = .05 for post-test scores against mathematics scores and N = 126, r = 0.194, P < .05 for post-test scores against post-attitudes.

There was a significant relationship between post tests scores and post-attitude scores. When multiple regression analysis of post-test as dependent variable and post-attitudes as independent variable was done, the following result was obtained: (F(1,124) = 4.84, P < .05).

Similarly with post-test scores as dependent variable, and MAS and CAS as independent variables the result of the multiple regression analysis also showed: (F(2,123) = 6.052, P < .001).

Both results showed some significant differences hence some correlations existed and hypothesis 6 was rejected. That is, there was significant relationship between post-test scores and post-attitudes scores. This finding is supported by Quinn's[13] study who investigated the causal relationship between mathematics achievement and attitudes, and found some significant correlations between mathematics attitudes and achievement at grades 3 and 5. Similarly Gordon[128]

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128 Gordon, B.W. A profile of High and Low Achievers in Mathematics (Doctoral dissertation, Duke University 1971) DAI, 4639 - 4640, Feb. 1978.

on a profile of high and low achievers in mathematics found that attitudes to mathematics to be related to students' level of achievement. This was not corroborated by Shumway et al[21] who found that children's attitudes towards calculators were more positive than their attitudes toward mathematics. Other contrary findings were those of Corey[129] and Wolf and Blixt[130] who suggested that attitudes toward mathematics are causally predominant over mathematics achievement for their common variance. The findings in this study are comparable with those of other media when used in mathematics instruction.

6. Relating findings to other media

Calculators as an electronic medium could be compared, in capability for mathematics instruction with any other media. UNESCO, according to Balogun[131] in "New methods and Techniques in Education" listed the following media:

(1) Radio and Television

(2) Electronic Computers and

(3) Programmed learning and application.

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129 Corey, J.F.O. The relationship between attitude ... and academic achievement, (Doctoral dissertation, The University of Rochester, 1978), DAI, 39A, 2824 - 2825, Nov. 1978.

130 Wolf, F.M. and Blixt S.L. A cross-sectional and cross-lagged panel analysis of mathematics achievement and attitudes. Educational and Psychological Measurement, 41: 1981, 829 - 834.

131 Balogun, T.A. Programmed Learning and the teaching of Science, West African Journal of Education (WAJE) 15 (2), 1971, 109-116.

Relatively, most of the listed media had been studied with limited results in Nigeria especially radio, television, programmed learning (print), but the investigator had not found any reported studies on electronic computers or calculators in classroom instruction in Nigeria.

DeBlassio[77] found positive correlations between students' attitudes toward using a computer and attitudes toward mathematics and instructional settings plus achievement variables. However, Earle[131] on student attitude toward geometry using computer assisted instruction found that there were no significant differences between treatment groups in attitudes towards mathematics. Some findings of the study by Backens[132] in mathematics by Television and Wilson s[133] study by audio tutorial course in mathematics compared with the ones in this study where favourable attitudes were found towards mathematics. But Wilkinson[134] who studied the effect of supplementary materials upon

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132 Earle, H.F. Student attitudes toward geometry. (Doctoral dissertation, University of Maryland, 1972) DAI, 1972, 34, 1059A.

133 Backens, V.W. The effects of teaching beginning mathematics by Television (Doctoral dissertation, North Texas State University, 1970), DAI, 1970, 31, 5143A.

134 Wilson, P.M. Do students learn from and like an audio-tutorial course in Freshman mathematics? Two year College Mathematics Journal, 1972, 3(2), 32 - 41.

135 Wilkinson, G.G. The effect of Supplementary materials upon academic achievement and attitudes toward mathematics... (Doctoral dissertation, North Texas State University, 1971 DAI, 1971, 32, 1994A.

academic achievement in and attitudes towards mathematics showed that there were no significant differences in improvement in attitudes towards mathematics. Similarly Kolmos[135] studied the effects of instructional media in teaching and learning beginning statistics, and found that 'Carrel' groups did not significantly differ in their attitudes toward mathematics.

Despite some favourable and few conflicting findings on the use of media in mathematics instruction it would remain how much of those favourable findings have been disseminated to the users in the schools and other learning environments.

6.5 Educational Implications of the Study and Recommendations

The results of this study have shown that the use of calculators by teachers would be an advantage in the teaching and learning of mathematics in the secondary schools. However, what prospects and problems await the use of calculators in mathematics education? There would probably be problems in the calculators entering mathematics classrooms in Nigeria if the experience of the United States of America's school systems is anything to go by.

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135 Kolmos, A.S. Effects of Instructional Media in Teaching Beginning statistics (Doctoral dissertation, University of Illunous, 1970) DAI, 1970, 31, 4600A.

Hembree[115] observed that in December 1974, the National Council of Teachers of Mathematics (NCTM) issued a far-reaching statement that urged the use of hand-held calculators in schools (NCTM, 1974). The council found that the core of mathematics instruction in the elementary school grades was computation, pleasantly coinciding with the calculator's first purpose, and a host of other intentions of its use were envisioned (Suydam)[3] such as: to aid algorithmic instruction, facilitate concept attainment, reduce the need for memorization, enlarge the scope of problem-solving, motivate students and encourage discovery, exploration and creativity. With the reduced cost of calculators it appeared accessible to the school systems.

However, more than a decade later, not only has the calculator failed to redirect the curriculum, it has even failed to enter most U.S. mathematics classroom. (Hembree)[115]

Fewer than 20 percent of elementary school teachers and fewer than 36 percent of secondary school teachers have employed the calculator during instruction (Suydam)[136]

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136 Suydam, N. M. The use of calculators in Pre-College Education: Fifth Annual State of the Art Review, Columbus, Ohio: Calculator Information Center, 1982 (ERIC Document Reproduction Service No. ED22018).

Some have suggested that the use of calculators in school might not produce entirely positive effects, even computers, so far, have not changed the system of teaching of mathematics in any fundamental way (Bell)[137].

What must have been the cause(s) of such development in an advanced technological society such as U.S.A? Perhaps several causes have inhibited the services of calculators in schools. First, not all teachers and educators applauded the NCTM's poisition: indeed its statement on calculators provoked a barrage of skeptical comments, warning that such devices would replace skills with paper and pencil. It was this kind of reaction that led to "one of the largest bodies of research on any topic or material in mathematics education" (Suydam)[136].

The questions that have often been raised are

(i) Do calculators threaten basic skills?

(ii) What benefits would be derived from calculator usage not already offered in the use of pencil and paper?.

The answer to the first question had consistently seemed to be no particularly at the secondary school level where

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137 Bell, F.H. Can Computers Really Improve School Mathematics? <u>Mathematics Teacher</u> Vol. 71, No. 5, 1978.

basic skills would have been developed with manipulative materials, paper and pencil (Suydam)[139]. To the second question, the benefits of calculators have remained somewhat in doubt, since many studies presented ambiguous findings (Hembree)[115]. While some studies recorded no harmful effects of calculators' use in upper grades of elementary schools and in high schools some failed to show significant differences in either students' achievement or their attitudes towards mathematics. Teachers and educators may then ask, why bother with calculators? In addition most of the studies available are in published dissertations where most of the findings have not yet been popularized in the education system. Hence, teachers and researchers need to reassess the calculator in what Begle[140] called its "crucial implications for mathematics education". Nonetheless, the findings of this study and others like that of Hembree and Dessart[115] have shown that

(a) Calculators greatly benefit student achievement especially for low, average and high ability pupils.

(b) Positive attitudes about calculators might help to reduce students dread to tedious calculations and word problems.

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139 Suydam, N.M. The use of calculators in Pre-College Education: A state of the art review. Columbus, Ohio: Calculator Information Centre, 1979.

140 Begle, G.G. Critical Variables in Mathematics Education, Washington D.C: Mathematical Association of America and NCTM, 1979.

Driscoll[116] has affirmed teachers enthusiasm towards the calculator-use and positive attempts at the incorporation of calculators into the California State Board of Education mathematics programmes have been reported Yet, the question of how the device could best be used for effective instruction in the classroom demanded research attention (Suydam)[136], (Hembree and Dessart)[115] and by the U.S. National Science Foundation report[142]

It is apparent that with the availability of calculators, it will be impossible for schools to ignore them. Teachers now use them, and some pupils do have wrist-watches equipped with digital calculators. In higher education little restrictions (if any) are being placed on the use of calculators. In the secondary school, at least calculators may sooner or later replace slide-rules and books of tables in the service of existing curricula. The following opinions may be advanced while others may be mere speculations as to the use of calculators in and out of school, for it could be said:

141 California State Board of Education Mathematics Framework for California Public Schools, Kindergaten through Grade Twelve. Prel. Ed. Sacraments: "California State Department of Public Instruction, 1985.

142 National Science Foundation: Programme Solicitation: Materials fof elementary School Mathematics Instruction (NSF 55 60). Washington D.C.: National Science Foundation 1986.

(a) that calculators represent the kind of phenomenal change in technology that can substantially change the society;

(b) one aspect of the change in society is that people outside of school are already using calculators to accomplish what we now make the principal component of years of schooling; and

(c) for schools to ignore this challenge poses great risks to the proper mathematics education of the youngsters, and

(d) in fact, that calculators have already had a considerable impact on education in and out of school.

Recommendation:

This study has revealed that the use of calculators has no harmful effects on the secondary school mathematics, it is therefore, recommended that:

1. School authorities should allow the use of calculators to supplement teachers and pupils instructional aids in the teaching and learning of mathematics. The versatility of hand-held calculators cannot be in doubt. Carr[143] observed how calculators could be useful in the teaching

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143. Carr. Jane, M. Get away from the Table: Make Interest more Interesting. Mathematics Teacher. Vol. 79, No. 9, Dec., 1986.

and learning of a mathematics course for business majors. He opined that several instructors who had to teach the course agreed that hand-held calculators could be used to solve most problems by choosing the appropriate formula and the solving for many variables. This has been found to be useful particularly in this study for the solution of quadratic equations by general formula (say: $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ where a, b and c are constants). Similarly calculators can easily be used to create a series of iterations to approximate value to some desired degree of accuracy (e.g. $\frac{1}{2m}$ where m = 0,1,2,3,...) and in other areas of concept learning in mathematics.

2. That examining bodies for secondary education should allow the use of calculators in tests. From this results calculators can easily replace the use of Tables or Slide-rules in schools because one gains not only greater speed and accuracy but also the advantage of computing values that are very large. By using the method of successive substitution, Cheung[111] observed that secondary school pupils would have little difficulty in understanding equations and their solutions.

3. Where possible, books should be written to incorporate exercises that would involve drills in mathematics,

and thereby encourage pupils' effective participation in algorithmic computations and problem-solving.

4. Calculators may be purchased at great expense, it would be advisable for schools to operate a pool of calculators so that each class can contribute and benefit from such an arrangement. One advantage about calculators is that it is not as fragile as most other media. Most, if not all can operate on battery. Operations of calculators are easily learnt, even by elementary school pupils and its durability and versatility are some advantages.

6.6 Suggestions on further Research

As mentioned in the previous sections, this study has raised a number of pertinent and philosophical questions which were probably outside the scope of this investigation. Hence, they could not be answered by the present study in any great depth. Indeed some of the questions raised would constitute an extension of this undertaking and answers to them would serve to uncover unresolved issues associated with this investigation. The following suggestions for further research studies on the Nigerian educational scene are predicated on these unresolved issues. Specifically there is need to inquire into the following areas of possible calculator-use:

1. Primary School level: In primary school at what class can the calculator be integrated into mathematics primary school curriculum in Nigeria so as not to have harmful effects on the pupils' basic computational skills:

2. Secondary School level: The findings of this study like most others have shown that calculators can effectively be used to enhance higher achievement and positi· attitudes in mathematics. It would be appropriate if this study can be replicated with a larger population, longer duration, more criterion measures in attitudes and achievement, and possible sex differential in relation to calculater usage It would also be appropriate to have further research studies to look at:

(a) the effectiveness and efficiency of calculator-use compared with other media in instruction e.g. programmed text on print or disc, computers etc.

(b) the development of mathematical concepts, problem-solving capabilities with calculators,

(c) teachers, parents, educators and school administrators attitude towards calculator-use in mathematics instruction and

(d) the calculator cost-effectiveness in relation to other media.

3. On higher education: Since the use of calculators in higher education is allowed, it will be appropriate to have research studies that would investigate what effects calculator use may have on:(i) concept development, problem-solving and attitudes toward remedial mathematics in higher education in Nigeria, (ii) the teaching and learning of the physical sciences.

4. The possible impact of the use of hand-held calculator on other school subjects particularly the physical sciences and statistics.

6.7 Summary and Conclusion

The purpose of the study was to determine the effects of the use of electronic calculator on the learning outcomes of mathematics instruction. The criterion measures of the learning outcomes of the study were achievement in mathematics and attitudes toward mathematics and calculator. The study was limited to secondary school mathematics and the achievement measure was in terms of computational, conceptual and problem-solving aspects of linear equations while the attitude was limited to attitudes toward mathematics and calculator use in mathematics instruction. The study did not investigate other personality variables of attitudes such as self-concept, anxiety etc.

Most of the literature and empirical researches consulted dealt with the studies that were carried out in the United States of America or reported there. The pilot and main study used a 3 x 3 factorial design with three levels of ability, high, average and low and with two treatment groups and control group. It was a pre-test - post-test control group design. The treatments were calculator in instruction and tests, and calculator in tests only. For the pilot study, all the nine groups were in the same school. However, for the main study, three comparable schools were used. Each school was randomly assigned to treatment groups and control groups. There were three groups of different mental abilities in each school.

For the pilot study, 90 subjects completed the study and for the main study 126 subjects completed the study with an average of 14 subjects per group. There were equal number of boys and girls per group. The three schools were selected by multi-stage sampling from the population of mixed secondary schools established more than 10 years ago in the Ibadan Municipality. The instruments used for the study were:

(i) Pre-test items in mathematics

(ii) Post-test items in mathematics

(iii) Modified ACER ML and MQ (verbal and numerical) tests.

(iv) Attitude questionnaire

(v) Mathematics teachers attitude and school inventory.

(vi) Instructional module

(vii) Modified Flanders classroom interaction model.

The duration of the study was for six weeks.

Six hypotheses were stated and the results of the study were presented and discussed based on these hypotheses tested in the study. The major findings were on the hypotheses tested while the subsidiary findings were derived from them.

Major findings:

1. The mean post-test scores of those groups who used calculators on instruction and tests (the unrestricted groups), was higher than calculators in tests only (the restricted groups) and the non-calculator groups precisely, the calculator groups have higher achievement than non-calculator groups in mathematics.
2. The mean post-test scores of those groups of high, mental ability was higher than those of average and low mental ability groups.

This would mean that pupils of high mental ability would have higher achievement in mathematics than pupils of other ability levels.

3. There was no significant difference in the mean post-attitude scores of pupils in the unrestricted calculator, restricted calculator and non-calculator groups. Since their means were not significantly different, their attitudes was not different towards mathematics and calculator-use But significant difference did exist between the mea of the post-attitude scores of unrestricted calculator and restricted calculator groups. Hence this had an inconclusive results.

4. There was no significant difference in the mean post-attitude scores of pupils of high, average, and low mental ability levels. Since their means were not significantly different their attitudes was not different towards mathematics and calculator use. For the high mental ability and low mental ability groups, there was significant difference in the means of their post-attitude scores. For the other groups there was no significant difference. This implied that high mental ability group pupils had better attitudes towards mathematics and calculator than low mental ability pupils.

5. There was no significant relationship between the pupils attitudes towards mathematics and attitudes towards calculator. Hence, attitudes towards mathematics was not related to attitudes towards calculator-usage in mathematics.

6. There was significant relationship in the post-attitude scores of pupils and their post-test scores. Achievement was found to be significantly related to positive attitudes towards mathematics and calculator usage.

Subsidiary findings:

(i) The restricted groups showed no significant advantage over the non-calculator groups in the mathematics achievement scores.

(ii) The high mental ability pupils have better attitude towards mathematics than other ability groups.

(iii) The post-test scores of the pupils were more positively correlated to mathematics attitudes than calculator attitudes.

(iv) Although, there were no significant differences in the means of the post-attitude scores of the groups yet, there were attitudinal changes among the groups.

The findings on achievement measure seemed to be conclusive in this study while those findings relating to attitude measure seemed inconclusive. Despite the positive correlation between achievement and attitudes of the groups further research studies should be carried out on attitude variables as regards to calculator usage. This study of electronic calculator in mathematics instruction presents opportunities for further research on the influence(s) of different electronic media: computers, videotapes, television etc. in mathematics instruction on such outcomes as conceptual development, problem-solving, creativity and attitudinal variables.

On the whole, others in Nigeria or elsewhere may replicate this study with larger population and longer duration. To utilize the findings on the use of calculators like many other media in instruction would demand appropriate techniques in disseminating related research results to learners, teachers, educators and school administrators.

Many issues raised in this study may not be resolved effectively by experimental research alone but rather in conjunction with survey, philosophical and clinical researches.

So far, experimental research study in the use of calculators in instruction in Nigeria like most media studies, would entail a lot of expenses in terms of procurements of calculators. Handling and operations of such calculators demand care by pupils and teachers. Unlike some other tools and instructional aids the calculator is rather easily controllable by the learner and may obviously become the successor to slide-rule, book of tables for pupils in the school systems. It would appear that there is the social acceptability of electronic calculator in the business world as a tool but the reluctance of the school systems (primary and secondary) to accept the device as a teaching and learning aid remain an issue to be resolved.

However, the design and possible implementation of the findings of this study can help to provide insight into the integration of calculators into the classroom instruction and mathematics curriculum. The result of the investigation would obviously be of interest not only to classroom teachers, but also to parents, educators, school administrators and examining bodies.

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APPENDIX 1

Mathematics Pre-test

INSTRUCTIONS: TIME: 30 Minutes

1) Answer all the questions

2) All questions carry equal marks

3. Each question is followed by five options lettered A – E find out the correct option to each question and write the correct answer on your answer sheet.

Example: If $\frac{2}{3} - 3x - 2(1 - x)$, which of the following is true for x ?

$A = \frac{4}{3}$, $B = \frac{3}{4}$, $C = -\frac{4}{3}$, $D = -\frac{3}{4}$, $E = \frac{2}{3}$

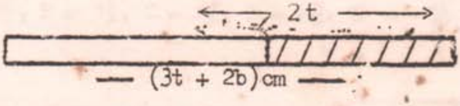
Answer: $C = -\frac{4}{3}$

ANSWER THE FOLLOWING QUESTIONS:

1. Simplify: $\frac{1}{2}(2\frac{1}{4} + 6\frac{1}{2}) \div 3\frac{3}{4}$. (Simplify: $\frac{1}{2}(2\frac{1}{4} + 6\frac{1}{2}) \div 3\frac{3}{4}$)
   $A = \frac{9}{5}$, $B = \frac{4}{7}$, $C = \frac{7}{6}$, $D = 3\frac{1}{2}$, $E = 2$

2. Ademola is x years old. Write an expression to represent his age two years ago.
   A = x years, B = (x – 2)yrs., C = (x+2) yrs, D = 2yrs,
   $E = \frac{x}{2}$ yrs.

3. Given rod below:



From the rod (3t + 2b) centimetres long, a part 2tcm is cut off. What is the length of the reminder ?

A = (5t + 2b)cm, B = (3t + 2b)cm, C = (t +2b)cm
D = 2t cm, E = (5t – 2b)cm.

4. If $2p = m - 4n^2$. Find P when m = 20, n = 2.
   A = 4, B = 6, C = 3, D = 2, E = 1.

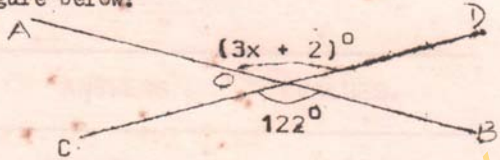
5. Express P Nairas q Kobos in Kobos
   A = 10pq, B = 100P + Q, C = 100 pq

6. Find the value of p if 2(P–4) = 2: A = 3, B = 4, C = 5, D = 6, E = 8

7. Given that $x = -2$ and $y = \frac{1}{2}$, find $xy^2 - x^2y$,

A $= -2\frac{1}{2}$, B $= -10$, C $= 2\frac{1}{2}$, D $= 6$, E $= 8$.

8. Given the figure below:



If $3x + 2 = 122^\circ$, find x:

A $= 40^\circ$, B $= -40^\circ$, C $= 122^\circ$, D $= -122^\circ$, E $= 41^\circ$.

9. Simplify: $2x(3x - 4) - 2x(2x - 4)$.

A $= 6x^2$, B $= 2x^2 - 16x$, C $= 2x^2 + 16x$, D $= 2x^2$, E $= 16x$

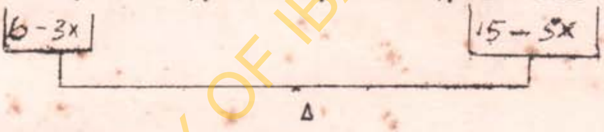
10. If ☐ − 8 − 2(☐ − 3), What the value of ☐

A $= 5$, B $= -5$, C $= 2$, D $= -2$, E $= 6$.

11. If $\frac{1}{7} + \frac{3}{7} = \frac{1 + \Delta}{7}$, What is the value of Δ ? ?

A $= 1$, B $= 7$, C $= 3$, D $= 4$, E − None of the above.

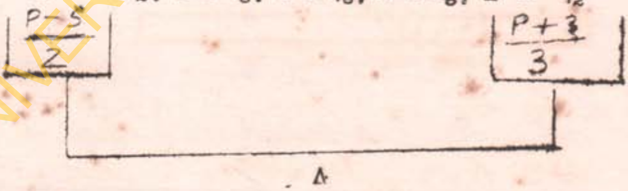
12.



The above is a balance, what is the value of x ?

A $= 10\frac{1}{2}$, B $= 1\frac{1}{8}$, C $= 4\frac{7}{8}$, D $= 2\frac{5}{8}$, E $= 4\frac{1}{2}$

13.



The ab e is a balance, what is the value of P ?

A $= -13$, B $= 21$, C $= 9$, D $= 7$, E $= -21$.

14. If $3b + b - 2b - b = -6 + 6$, What is b ?

A $= 12$, B $= 0$, C $= -12$, D $= 1$, E $= -1$.

15. If 15 subtracted from 10 times x, the result is 55, find the value of x. A $= 10x$, B $= 55$, C $= 10x - 15$, D $= 7$, E $= 4$.

APPENDIX 2

Mathematics Pre-test Answers

NOS	ANSWERS	VALUES
1	C	7/6
2	B	x-zy
3	C	t + 2b
4	D	2
5	B	100p + q
6	C	5
7	A	-2.5
8	A	40°
9	D	$2\ x^2$
10.	D	-2
11	C	3
12	E	4.5
13	B	21
14	B	0
15	D	7

APPENDIX 3

Difficulty Index and Discriminatory Power (p) of the Mathematics Pre-test

TEST-ITEM	DIFFICULTY INDICES	DISCRIMINATORY POWER %
1	0.45	55
2	0.25	75
3	0.25	75
4	0.25	75
5	0.50	50
6	0.60	40
7	0.75	25
8	0.25	25
9	0.40	50
10	0.40	60
11	0.20	80
12	0.15	25
13	0.45	55
14	0.50	50
15	0.25	75

AVERAGE DIFFICULTY INDEX OF PRE-TEST = ·0.40

From R/T x 100 = DIFFICULTY INDEX R..... No. Right,

T ..... Total Test Items.

AVERAGE DISCRIMINATORY POWER OF PRE-TEST = 63.3%

From DISCRININATORY POWER $P = \frac{RU - RL}{\frac{1}{2}T}$

RU ... No. of Pupils in the Upper 27% of the group who got the item right.

R_L ... No. of Pupils in the Lower 27% of the group who got the item right.

APPENDIX 4

Mathematics Achievement test

NAME: ....

AGE: .... SEX: ....

SCHOOL: .... DATE OF TEST ....

This booklet contains an example and 30 multiple-choice objective questions.

<u>INSTRUCTIONS</u>: Please answer all the 30 multiple-choice objective questions. You should write out only the correct letter.
IMPORTANT: You have <u>45 minutes</u> to complete the test. Some questions are easier than others. If you find any question is too hard, leave it out and come back to it later if you have time. Do not spend too much time on any question.

Example: Find x in the equation

$$x = \frac{-ab - ay}{b} \quad \text{if } a = 4,\ b = 1 \text{ and } y = -2$$

A = -4, B = 4, C = 8, D = 12, E = 12. The correct answer is B.
You should write only B.

Now Answer the following questions:

I. Find the value of x if $y = 5b - x$ when $y = -2.2$ and $b = 1.5$
A = -9.70, B = 5.50, C = 9.70, D = -5.50, E = -5.30

2. If $\frac{2}{3} - 3x = 2(1-x)$, which of the following is true for x
A = 1.33, B = 0.75 C = -0.75, D = -1.33, E = 0.67

21. A lorry carrying concrete blocks weighs 864 kg when loaded. The blocks weigh three time as much as the empty lorry. Find the weight of the lorry. Hint, Weight of lorry = Lorry + Concrete - weight of concrete.
A = 2880kg, B 25920kg, C = 34560kg, D = 2160kg, E = 960kg.

22. Dairo is buying books for her friends one of the books they want costs ₦2.00 more than the other. She buys 5 of the more expensive book and 3 of the cheaper book. Hint, Let x = expensive book,y= cheaper book, Form Simul taneous equations and find the cost of the cheaper book.
A= ₦2.75, B = ₦3.50, C = ₦2.00, D = ₦1.50, E = ₦3.00.

23. If John earned ₦48 for 16 hours work, what was his average wage per hour?
A = ₦3.00, B =₦4.00, C = ₦2.00, D = ₦5.00, E = ₦6.00

24. Akin and Ayo were given 90k to share. Akin is younger than Ayo,so he has to get 20k less than Ayo. How much did Ayo get?
Let Akin's share be x and Ayo's share be y form simultaneous equation.
A = 45kobo, B = 55kobo, C = 35kobo, D = 70kobo, E = 20 kobo.

25. From question 24, how much did Akin get?
A = 45kobo, B = 55kobo C = 35kobo, D = 70kobo, E = 20kobo.

26. The sum of three consecutive numbers is 123. Find one of the numbers(Hint e.g. consecutive numbers are 85,86,87)
A = 21, B = 30, C =41, D= 52, E = 66.

27. A bookshelf holds x books each 1200mm thick. The same booksh elf can hold (x+3) books each 900mm thick. What is the length of the shelf?
A = 10800mm, B = 14600mm, C = 15000mm D = 16800mm, E = 19200mm.

28. S + 0.5s +S + 3000 = 18, 000, Find S.
A = 15, 000, B = 6000, C = 9000, D = 7500, E = 5000.

29. If $X = \frac{2 \pm \sqrt{4+16}}{2}$ Find X.

A = 1.236, B= -3.236, C= -1.632, D= 3.236, E = 1.632.

30. If $b^2 - 4ac = 0$ when a = -0.675 C =-75.00 Find b.
A = +142.3, B= -142.3, C =-14.23, D = 202.5, E =14.23.

3 Given that x = 2.0 and y = 0.5, find the value of $xy^2 - x^2y$.

A = 2.50, B = - I0, C = 2.50, D = 6, E = 8., A= - 2.50

4 Given the simultaneous equations 2x - 3y + 2 = 0 and 3x + 2y = 23, calculate the value of (x - y).

A = 21, B = 5, C = 4.2, D = $2\frac{I}{3}$, E = I.0

5 Two quantities, y and x are connected by a linear relation of the form y = kx + c where k and c are constajts. If x = 60 when y =I0 and x = 240 when y = I00, find the equation connecting y and x.

A: y = $\frac{1}{2}$x + 20, B: y = $\frac{1}{2}$x - 20, C: y = k+c D: y = 2k - II0, E: y = 2k - I30.

6. If x = - I, y = 2 and Z = 3, evaluate $x^2 + y^2 + Z^2 - 3xyz$

A = -32, B = -4, C = 4, D = I4, E = 32.

7. Evaluate $y = 3x^2 - 4x - 5$, if x = 2.I2.

A = 0.0032, B = -0.4832, C =-0.0032, D = I3.4832 E = -I3.4832.

8

Find x from the figure.

A = - 40°, B = 40°, C = I22°, D = -I22° E = 4I°

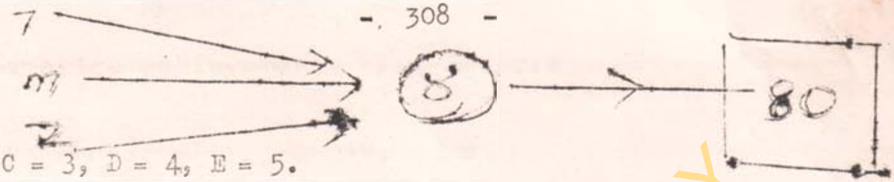
9. If x = 2, evaluate x - (3-(x -(2-x))+4)

A = -5, B =-3, C = 2, D - 5, E = 6

The above figure is a balance, what is the value of x?

A = -5, B = I.25, C = 5, D = -I.25, E = II

II. Find M.



A = I, B = 2, C = 3, D = 4, E = 5.

I2. Find the value of 4x - y if x + y = 8 and 2x - y = 7.

A = 3, B = 7, C = 8, D = I3, E = I7.

I3 If m = 4a - pq find q when m = 5, p = 2 and a = - 4.5

A = II.5, B = - 6.5, C = 6.5, D = -II.5, E = II.0

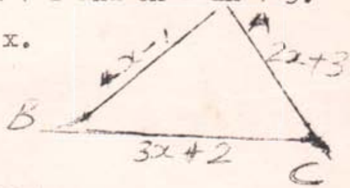
I4. Given that x + 2y = 4 and 3x + 4y = 6, find the value of (x + y)

A = 5, B = 3.5, C = I.0 D = 2.5, E = -I.0

I5. If E = $\frac{1}{2}$m $(v^2 - u^2)$ find m, when E = 270, V = I0 and u = 8

A = I64, B = 36, C = I5, D = 7.5, E = 0.I3

I6. Given triangle ABC where AB = 4x - I BC = 3x + 2 and CA = 2x + 3.
If the perimeter of this triangle is I48cm, find x.



AB + BC + CA = I48

A. = $\frac{4}{9}$ B = I6, C = I5$\frac{4}{9}$, D = I6$\frac{5}{9}$, E = $\frac{5}{9}$.

I7 If [illegible] - 8 =2([illegible] - 3), what is the value of [illegible]?

A = -2, B = 2, C = 5, D = -5, E = 6

I8. The formula F = 9c + 32 is a temperature relationship of Fahreheit (F) and Centigrate (C). Find the temperature when F = C.

A = 40, B = II. 4, C = 8, D = -II4, E = - 40.

I9. Given that 3x + 2y = I8, and 5x - 2y = I4, Find the value of x.

A = 0.5, B = I, C = 2, D = 3, E = 4

20 If 80(Z -I) = 60z, Find z

A = -$\frac{4}{7}$, B = -4.0, C = $\frac{4}{7}$, D = 7.0, E = 4.0

APPENDIX 5

Mathematics achievements test answers

1.	C	16.	B
2.	D	17.	B
3.	A	18.	A
4.	E	19.	E
5.	B	20.	E
6.	E	21.	D
7.	A	22.	D
8.	B	23.	A
9.	B	24.	B
10.	C	25.	C
11.	A	26.	C
12.	E	27.	A
13.	D	28.	B
14.	C	29.	D
15.	C	30.	E

APPENDIX 6

Difficulty Index and Discriminatory Power (P) of the Mathematics Achievement Test

TEST ITEMS	DIFFICULTY INDICES	DISCRIMINATORY POWER (P) %	TEST ITEMS	DIFFICULTY INDICES	DISCRIMINATORY POWER %
1	0.69	50	16	0.53	17
2	0.40	42	17	0.31	17
3	0.51	42	18	0.22	17
4	0.40	50	19	0.78	42
5	0.51	40	20	0.56	58
6	0.51	58	21	0.04	08
7	0.40	58	22	0.42	42
8	0.73	25	23	0.73	42
9	0.16	33	24	0.49	33
10	0.56	58	25	0.49	33
11	0.58	17	26	0.60	33
12	0.62	50	27	0.47	08
13	0.33	42	28	0.40	42
14	0.20	17	29	0.22	33
15	0.17	58	30	0.20	00

AVERAGE DIFFICULTY INDEX = 0.46

AVERAGE DISCRIMINATORY POWER P = 42%

USING $r = \frac{N\sigma^2 - \bar{X}(N-\bar{X})}{\sigma^2(N-1)}$

r = reliability coefficient of the whole test = 0.54

σ = standard deviation of the test scores = 3.95

σ^2 = 15.61

$\bar{X}$ = the mean of the test scores = 13.87

APPENDIX 7

Instructional Module on Equations

TOPICS:

(i) Simple equation.

(ii) Simultaneous equations.

(iii) Quadratic equation.

DIRECTED TO FORM FIVE PUPILS SECONDARY SCHOOL, NIGERIA

This module takes cognizance of the fact that pupils are already familiar with some aspects of equations. It has been prepared to be used with calculator. The general instruction on the use of calculator with this module is at the end. Computational algorithms have been incorporated in all aspects of the exercises in the module.

OBJECTIVES OF THE LEARNING CONTENT:

(i) To introduce the pupils to the concept of equations simple. simultaneous and quadratic.

(ii) To identify different forms of equations: simple, simultaneous and quadratic.

(iii) To solve different equations - simple, simultaneous and quadratic.

(iv) To translate word-problems into equational format - simple and simultaneous equations.

(v) To solve the word-problem equations simple and simultaneous.

PREAMBLE:

The module is divided into FOUR parts. Each part constitutesan instructional content relating to each objective. The instructional content shall cover a period of 40 minutes. It is made up of examples on the concept to be developed and graded.

exercises. The pupils shall be allowed to work at their own pace. Each instructional content shall be followed with exercises which the pupils shall respond to. The pupils shall be made to use only this module for the project.

PART I

INTRODUCTION

Two types of linear equations shall be considered in detail, while quadratics id discussed with examples.

1. Linear simple equation in one variable:

This is an equation having one as the power of its variable. It has a single solution.

Consider this linear equation:

$$\frac{3x + 5}{4} - 8 = 0$$

$x = 9$ is the solution.

Please note that x is the unknown variable and the solution of $x = 9$ will satisfy that equation. Give other examples.

2. Simultaneous Linear equations in two variables called the unknowns. These equations consist of two linear equations in two unknown variables. The equations are solved by eliminating one of the two unkown variables and thereby reduce the equations to one linear equation in one unknown variable; which is then solved as simple linear equation. The solution to the other variable is obtained by substituting the solution already obtained into one of the two given equations and then solve the resulting linear equation.

Consider the equations:

$$x + y = 20$$

$$x - y = 6$$

Please note that x and y are the two unknown variables in these equations:

Solving these equations:

$$\left.\begin{aligned} X &= 13 \\ y &= 7 \end{aligned}\right\} \text{ the two unknowns}$$

These values of x and y shall satisfy the two equations

$13 + 7 = \underline{\underline{20}}$ $13 - 7 = \underline{\underline{6}}$ Other examples shall be given.

3. The third form of equation, quadratics is an equation in one variable, having 2 as the highest power of its variable. It has at most 2 solutions. A general quadratic equation is of the form

$$ax^2 + bx + c = 0$$ where a, b, and c are constants

To solve the quadratic equation $ax^2 + bk + c = 0$, the factor method is used when the expression $ax^2 + bx + c$ can be factorised. However, if it cannot be factorised, the formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$ is used to

solve for x which is the unknown variable and will have two values. To give examples e.g. $x^2 - 3x + 2 = 0$

PART II
SIMPLE EQUATIONS

An equation is an open sentence with an equality sign. For example, $4 + x = x + 2x$ is a statement which expresses a true statement if 2 is substituted for x. That is when $x = 2$ what is on the left hand side (L.H - S :- $(4 + x)$) must be equal to the righthand side (R.H. S :- $(x + 2x)$. The expression $4 + x$ is equal to 6 when $x = 2$ and $x + 2x$ also is equal to 6.

Any of the four basic operations of elementary mathematics (addition, subtraction, multiplication and division) can be performed on both sides of an equation; though the expression will be altered yet the equation will still be true. Examples: $-3x = $ [illegible]; $4x-2 = 5$; $3x + 4 = 7$ etc.

<u>Worked Examples</u>

i) Consider the equation $22 = 7x - 6$

<u>Solution:</u> Add 6 to both sides $22 + 6 = 7x - 6 + 6$

$$28 = 7x$$

Divide both sides by 7: $\frac{28}{7} = \frac{7x}{7}$

$$4 = x$$

The solution is $x = 4$

It may also be necessary for us to check if our solution is correct or not:

Thus if $x = 4$ then $22 = 7(4) - 6$

$$= 28 - 8$$

L.H.S. = R.H.S. : $22 = 2$

The solution is correct.

ii) Consider the equation $x + \frac{x}{22.5} = 3.5$

<u>SOLUTION</u>

Multiply through by 22.5 (the L.C.M.)

Thus $22.5x + x = 3.5 \times 22.5$

$$23.5x = 78.75$$

Divide both sides by 23.5

$$\frac{23.5x}{23.5} = \frac{78.75}{23.5}$$

$$x = 3.35$$

Check $3.35 + \frac{3.35}{22.5} = 3.50$

$3.35 + 0.15 = 3.50$

The solution is correct.

iii) Consider the equation $\frac{x}{2.2} + \frac{x}{3.3} + \frac{x}{4.4} = 1$

SOLUTION

Multiply through by 31.944 (the LCM)

$14.52\,x + 9.68x + 7.26bx = 31.94$

$14.52x + 9.68x + 7.26x = 31.944$

$31.46x = 31.944$

$\frac{31.46x}{31.46} = \frac{31.944}{31.46}$

Divide both sides by $x = 1.015$

Check $\frac{1.015}{2.2} + \frac{1.015}{3.3} + \frac{1.015}{4.4} = 1.0$

$0.46 + 0.31 + 0.23 = 1.0$

The solution is $x = 1.015$.

iv) Solve the equation $\frac{x}{2.5} - 3.5 = \frac{x}{3.5} + 1.5$

SOLUTION:

Multiply both sides of the equation by 8.75, the LCM

$\therefore\ 3.5x - 30.625 = 2.5x + 13.125$

Add: 30.625 to both sides

$3.5x = 2.5x + 43.75$

Subtract 2.5x from both sides

$3.5x - 2.5x = 2.5x + 43.75 - 2.5x$

$x = 43.75$

Check: $\frac{43.75}{2.5} - 3.5 = \frac{43.75}{3.5} + 1.5$

$17.5 - 3.5 = 12.5 + 1.5$

$14.0 = 14.0$

The correct solution is $x = 43.75$.

v) Solve the equation:

$$\frac{x - 20}{3} - \frac{3x - 40}{4} = 100$$

Multiply both sides of the equation by 12 (the LCM)

$$4(x - 20) - 3(3x - 40) = 1200$$

Remove brackets:

$$4x - 80 - 9x + 120 = 1200$$

Collect like terms:

$$4x - 9x = 1200 + 80 - 120$$

$$-5x = 1160$$

Divide both sides by -5

$$\frac{-5x}{-5} = \frac{1160}{-5}$$

$$x = -232$$

Check $\frac{-232 - 20}{3} - \frac{3(-232) - 40}{4} = 100$

$$-\frac{252}{3} - \frac{-696 - 40}{4} = 100$$

$$\frac{-252}{3} + \frac{736}{4} = 100$$

$$-84 + 184 = 100$$

The correct solution is $x = -232$

PUPILS IN CLASS

<u>Practise Exercise:</u> Solve the following equations:

i) $\frac{P + 1.2}{5} - \frac{3(P - 1.5)}{10} = 22.5$

ii) $\frac{t + 1}{t - 1} = 0.75$

iii) $3x - 2(x + 3) = 7 - x$

iv) $x + \frac{1}{3}x = 12$

v) $\frac{1}{7}(y - 4) = \frac{3}{7}y.$

SOLUTION

i) $$\frac{P + 1.2}{5} - \frac{3(P-1.5)}{10} = 22.5$$

Multiply both sides of the equation by 10 (the L.C.M.)

$$2(P + 1.2) - 3(P-1.5) = 225$$

Remove brackets:

$$2P + 2.4 - 3P + 4.5 = 225$$

Collect the like terms:

$$2P - 3P = 225 - 2.4 - 4.5$$

$$-P = 225 - 6.9$$

$$-P = 218.1$$

$$-P = -218.1$$

Check $$\frac{-218.1 + 1.2}{5} - \frac{3(-218.1 - 1.5)}{10} = 22.5$$

$$-43.38 + 65.88 = 22.5$$

$$22.5 = 22.5$$

The correct solution is $P = -218.1$

ii) $$\frac{t + 1}{t - 1} = 0.75$$

Multiply both sides by $(t - 1)$

$t + 1 = 0.75t - 0.75.$ Remove bracket.

Collect the like terms:

$$t - 0.75t = -0.75 - 1$$

$$0.25t = -0.25$$

Divide both sides by 0.25

$$\frac{0.25t}{0.25} = \frac{1.75}{0.25} = \frac{-1.75}{0.25}$$

$$t = -7$$

Check $$\frac{-7 + 1}{-7 - 1} = 0.75$$

$$\frac{-6}{-8} = 0.75$$

$$\frac{3}{4} = 0.75$$

$$0.75 = 0.75$$

The correct solution is t = 7

iii) $3x - 2\ (x + 3) = 7 - x$

$3x - 2x - b = 7 - x$ Remove bracket

$3x - 2x - x = 7 + 6$ Collect the like terms

$x + x = 13$ Divide both sides by 2.

$2x = 13$

$$\frac{2x}{2} = \frac{13}{2}$$

$x = 6.5$

Check: $3x\ 6.5 - 2\ (6.5 + 3) = 7 - 6.5$

$19.5 - 2(9.5) = 0.5$

$19.5 - 19 = 0.5$

$0.5 = 0.5$

The correct solution is 0.5.

iv) $x + \frac{1}{3}x = 12$

Multiply both sides of the equation by 3:

$3x + x = 36$

$4X = 36$

Divide both sides by 4:

$$\frac{4x}{4} = \frac{36}{4}$$

$x = 9$

Check: $9 + \frac{1}{3}(9) = 12$

$9 + 3 = 12$

$12 = 12$

The correct solution is x = 9.

v) $\frac{1}{7}(y - 4) = \frac{3}{7}y$

Multiply both sides of the equation by 7

$$y - 4 = 3y$$

Collect the like terms

$$y - 3y = 4$$

$$-2y = 4$$

Divide both sides of the equation by

-2 $$\frac{-2y}{-2} = \frac{4}{-2}$$

$$y = -2$$

Check $\frac{1}{7}(-2 - 4) = \frac{3}{7}(-2)$

$$\frac{1}{7}(-6) = \frac{-6}{7}$$

$$\frac{-6}{7} = \frac{-6}{7}$$

The correct solution is $y = -2$.

WORD PROBLEMS LEADING TO SIMPLE EQUATIONS

Statements which bear relationships with one another are often considered equations. For example: If I double a number and add 2 ot it, the result is 8. What is the number ? By trial and error with different number combinations one may get the answer as 3, but this waste time.

However, the question could easily be solved if put in an algebraic form.

Suppose the number is x. 2x is the same as 'twice x'.

So : $2x + 2 = 8$ which is an equation

SOLUTION: $2x = 8-2$

$$2x = 6$$

$$x = 3$$

Check : $2 \times 3 + 2 = 8$

$6 + 2 = 8$

$8 = 8$

The correct solution is $x = \underline{3}$ which is the number.

WORKED EXAMPLES: Consider the following:

i) The sum of three consecutive odd numbers is 93. What are the numbers ?

SOLUTION:

Let x = the first odd number

Then $x + 2$ = the next consecutive odd number

And $x + 4$ = the third consecutive odd number

First number + second number + third number = 93

$$x + (x + 2) + (x + 4) = 93$$

$$x + x + 2 + x + 4 = 93$$

$$3x + 6 = 93$$

$$3x + 6 + (-6) = 93 + c - 6)$$

$$3x = 87$$

$$\frac{3x}{3} = \frac{87}{3}$$

$x = 29$ first number

$x + 2 = 31$ second number

$x + 4 = 33$ third number.

ii) A father is now six times as old as his son. In twenty-two and half years from now, the father will be three times as old as his son will then be. How old is each of them now ?

SOLUTION:

Let x years be the Son's present age.

Then 6x years is the father's present age.

Also, (x + 22.5) years is the son's age 22.5 years from now.

And (6x + 22.5) years is the father's age 22.5 years from now.

The father's age be three times the son's age (x + 22.5) years.

$$6x + 22.5 = 3(x + 22.5)$$

$$6x + 22.5 = 3x + 67.5$$

$$6x - 3x = 67.5 - 22.5$$

$$3x = 45$$

$x = 15$, the son's age now

$6x = 90$, the father's age now.

iii) A man drives from Ibadan to Oyo, a distance of 55 km., in 45 minutes. Where the surface is good, he drives at 90km/hr.; where it is bad, at 60km/hr. Find the number of km of good surface.

SOLUTION:

Suppose there are x km of good surface. Then there are (55 - x) km of bad surface. Over the good surface, he drives at 90km/hr.

Therefore, he drives xkm at 90km/hr.

The time taken is x/90 hours.

Over the bad surface, he drives at 60km/hr. Therefore he drives (55-x)km at 60km/hr. The time taken is $\left(\frac{55-x}{60}\right)$ hrs.

The total time taken is 45 minutes or $\frac{3}{4}$ hour.

$$\therefore \quad \frac{x}{90} + \frac{55 - x}{60} = \frac{3}{4}$$

Multiply both sides of the equation by 360.

(the L.C.M.)

$$4x + 6(55 - x) = 270$$

$$4x + 330 - 6x = 270$$ Remove brackets

$$4x - 6x = 270 - 330$$ Collect the like terms

$$-2x = -60$$

$$\frac{-2x}{-2} = \frac{-60}{-2}$$ Divide both sides by -2

$$x = 30$$

There are 30km of good surface and

25km of bad surface

Check: He drives 30km at 90 km/hr, Time taken = $\frac{25}{60}$ hr.

= 25 minutes.

Total Time taken = (20 + 25)

= 45 minutes.

PUPILS' IN-CLASS PRACTISE EXERCISES

i) A rectangle has its length four times as long as its width. Its perimeter is 720 cm, find the dimension of the width and length.

ii) A boy is paid 50 kobo for each day he works and is fined 25 kobo for each day he fails to work. After 20 days, he is paid ₦7.00. For how many days has he worked ?

iii) A girl is 10 years older than her brother. In 5 year's time, she will be twice as old as the boy. How old is the boy ? How old is the sister ?

SOLUTION:

Let the width of the rectangle be w

Length of the rectangle = 4w

Perimeter = 2 (l + b) l = length, b = width

$720 = 2\ (4w + w)$

$720 = 2(5w)$

$720 = 10w$

Divide both sides of the equation by 10:

$\frac{720}{10} = \frac{10w}{10}$, $w = 72$

The width is 72cm and

length is 288 cm.

Check: $720 = 2\ (7 + b)$

$720 = 2\ (72 + 288)$

$720 = 2\ (360)$

$720 = 720.$

Dimensions 72cm 72cm and 288 cm.

ii) Let y represent the number of days he worked.

Number of days he did not work $(20 - y)$

Amount paid for days he worked = 50y kobo

Amount fined for days he did not work = $(20 - y)(25)$ Kobo

Total amount paid for working = 700 kobo

$50y - (20 - y)\ (25) = 700$

$50y - 500 + 25y = 700$

$75y = 700 + 500$

$75y = 1200$

Divide both sides by 75

$\frac{75y}{75} = \frac{1200}{75}$

$y = 16$

He has worked for 16 days he did not work for 4 days.

Check: $16 \times 50 - 4 \times 25 = 700$

$800 - 100 = 700$

$700 = 700$

iii) Let the age of the boy now be x years.

The age of the girl now is (x + 10) years.

In five years times the age of the boy will be (x + 5) years.

Age of the girl in five years time is

$2(x + 5)$ years

$$(x + 10) + 5 = 2(x + 5)$$

$$x + 15 = 2x + 10$$

$$15 - 10 = 2x - x$$

$$5 = X$$

Age of the boy is 5 years

Age of the sister is 15 years.

PART III

SIMULTANEOUS EQUATIONS

So far, the equations that have been solved involved only one unknown each, but if we need to find two unknowns, we require two equations to involve the unknowns. Consider these equations:

$$\left.\begin{aligned} 3x - y &= -13 \\ 2x + y &= 17 \end{aligned}\right\} \text{called simultaneous equations.}$$

The equations are solved by calculation either by substitution method or elimination method. It can also be solved graphically. However, for this module, one shall concentrate on the two methods:

Method of Substitution:

This is by solving one of the equations for one of the variables in terms of the other. One has to select the one variable to be solved more easily by inspection.

For equations: $3x - y = -13$ i)

$2x + y = 17$ ii)

From equation (i) $y = 3x + 13$

One will now substitute value of y in the second equation and get the resulting equation in terms of x alone.

$$2x + (3x + 13) = 17$$
$$2x + 3x = 17 - 13$$
$$5x = 4$$
$$x = \frac{4}{5}$$

One now substitutes $x = \frac{4}{5}$ in the first or second equation as it may be appropriate from equation (i)

$$y = 3x + 13$$
$$y = 3x \frac{4}{5} + 13$$
$$y = \frac{12}{5} + 13$$
$$y = 2\frac{2}{5} + 13$$
$$y = 15\frac{2}{5}$$

Check: From equation (i)

$$3(\tfrac{4}{5}) - 15\tfrac{2}{5} = -13$$
$$\tfrac{12}{5} - 15\tfrac{2}{5} = -13$$
$$3\tfrac{2}{5} - 15\tfrac{2}{5} = -13$$
$$-13 = -13$$

This method is used for cases in which one of the coefficients of x and y in one of the two equations is 1.

Method of Elimination:

The method of elimination by addition or subtraction is very effective where the coefficients of x and y are than 1.

Consider the equations:

$$3x - y = -13 \quad ---- \quad (i)$$

$$2x + 3y = 17 \quad ---- \quad (ii)$$

Multiply equation (i) by 3 and then add to (ii): That is:

$$9x - 3y = -39$$

$$\underline{2x + 3y = -17}$$

Adding: $$11x = -22$$

$$x = -2$$

Substitute $x = -2$ in either equation (i) or (ii)

Now in equation (i) $3(-2) - y = -13$

$$-6 + 13 = y$$

$$7 = y$$

The values $x = -2$ and $y = 7$ give the solution of the two equations:

Check In equation (ii) $2x + 3y = 17$

$$2(-2) + 3(7) = 17$$

$$-4 + 21 = 17$$

$$17 = 17$$

<u>PUPILS' IN CLASS PRACTISE EXERCISES:</u>

Solve the equations (i) $\frac{1}{2}x + \frac{1}{3}y = 4$

$$\frac{1}{4}y - \frac{1}{3}x = \frac{1}{6}$$

(ii) $16t + 3v = 14$

$$V - 10 = -4t$$

SOLUTION:

(i) $\frac{1}{2}x + \frac{1}{3}y = 4$ - - - (i)

$\frac{1}{4}y - \frac{1}{3}x = \frac{1}{6}$ - - - (ii)

(i) x 6 gives $3x + 2y = 24$ - (iii)

(ii) x 12 gives $3y - 4x = 2$ - - (iv)

Multiply (iii) by 3 and (iv) by 2

$9x + 6y = 72$ — (v)

$-8x + 6y = 4$ — (vi)

Subtract (vi) from (v) $17x = 68$

$x = 4$

Substitute for x = 4 in equation (i)

$\frac{1}{2}(4) + \frac{1}{3}y = 4$

$2 + \frac{1}{3}y = 4$

$\frac{1}{3}y = 2$

$y = 6$

$x = 4, y = 6$ are the solutions to the equations.

Check In equation (ii)

$\frac{1}{4}(6) - \frac{1}{3}(4) = \frac{1}{6}$

$\frac{6}{4} - \frac{4}{3} = \frac{1}{6}$

$\frac{18 - 16}{12} = \frac{1}{3}$

$\frac{2}{12} = \frac{1}{6}$

$\frac{1}{6} = \frac{1}{6}$

(ii) $16t + 3v = 14$ - - - - (i)

$v - 10 = -4t$: $v + 4t = 10$ (ii)

$3v + 16t = 14$ - - - - (i)

$$V + 4t = 10 \quad ---- \quad \text{(ii)}$$

(ii) x 3 gives $3v + 12t = 30$ (iii)

Subtract (ii) from (iii)

$$16t - 12t = 14 - 30$$

$$4t = -16$$

$$t = -4$$

Substitute $t = -4$ in equation (i)

$$V = -4t + 10$$

$$V = -4 \times -4 + 10$$

$$V = 16 + 10 = 26$$

$$V = 26$$

Check In equation (i) $16t + 3v = 14$

$$16 \times (-4) + 3(26) = 14$$

$$-64 + 78 = 14$$

$$14 = 14$$

$t = -4$, $V = 26$ are the solutions of the equations.

WORD-PROBLEMS LEADING TO SIMULTANEOUS EQUATIONS

Consider the following statements:

The sum of two numbers is 25 and their difference is 15.

What are the two numbers ?

SOLUTION:

Let the numbers be x and y

$x + y = 25$ Sum

$x - y = 15$ difference

The statements lead to two equations with the unknown numbers as x and y solving the equations:

$$x + y = 25 \qquad (i)$$

$$x - y = 15 \qquad (ii)$$

Adding (i) and (ii) $2x = 40$

$x = 20$

Substitute $x = 20$ in either equations (i) ar (ii)

In equation (i) $20 + y = 25$

$y = 25 - 20$

$y = 5$

Check: In equation (ii) $x - y = 15$

$20 - 5 = 15$

$15 = 15$

The numbers are 20 and 5.

PUPILS': IN-CLASS PRACTISE EXERCISES:

i) 20 spoons and 200 forks cost ₦10; 6 spoons and 100 forks cost ₦4. Find the cost of spoon and fork.

ii) A number of two digits is increased by 54 when the digits are reversed. The sum of the digit is 12. Find the number.

SOLUTION:

i) Let the cost of spoon and fork be x and y Kobo respectively.

20 spoons and 100 forks would cost $20x + 200y = 1000$ -- (i)

6 spoons and 200 forks would cost $20x + 200y = 400$ -- (ii)

The equations (i) and (ii) can be solved, they are simultaneous equations:

$$20x + 200y = 1000 \quad ---- \quad (i)$$

$$6x + 100y = 400 \times 2$$

$$12x + 200y = 800 \quad --- \quad (ii)$$

Add equations (i) and (ii)

$$2x = 18$$

Divide through by 2: $x = 9$

Substitute for $x = 9$ in equation (ii)

$$9 + y = 12$$

$$y = 12 - 9$$

$$y = 3$$

The digits are 9 and 3 and number is 93

Check: From equation (ii) $x + y = 12$

$$9 + 3 = 12$$

$$12 = 12$$

The solution $x = 9, y = 3$ is correct.

PART IV

QUADRATIC EQUATIONS

When the product of two expressions is equal to Zero, then one or other of those expressions must be Zero. Such quadratic expressions lead to an equation in one variable, having 2 as the highest power of its variable. It has at most 2 solutions. A general quadratic equation is of the form $ax^2 + bx + c = 0$ where a, b, c are constants. Quadratic equation can be solved either by factorising the expression or using a general formula:

$$x = \frac{b \pm \sqrt{b^2 - 4ac}}{2a}$$

Consider the following quadratic equations:

i) Solve the equation: $x^2 - 3x + 2 = 0$

SOLUTION: $x^2 - 3x + 2 = 0$, the expression $x^2 - 3x + 2$ can be factorised. Hence factorising:

Subtract (iii) from (i)

$8x + \quad = 200$

$\frac{8x}{8} = \frac{200}{8}$ Divide by both sides by 8

$x = \underline{25 \text{ Kobo}}$

Substitute x = 25 in equation (ii)

$6 \times 25 + 100y = 400$

$150 + 100y = 400$

$100y = 250$

Divide both sides by 100 $\frac{100y}{100} = \frac{250}{100}$

$y = \underline{2.5 \text{ Kobo}}$

Check: In equation (i) Substitute

$x = 25$ any $y = 2.5$

$6 \times 25 + 100 \times 2.5 = 400$

$150 + 250 = 400$

$400 = 400$

The solution of the equation is x = 25 Kobo, y= 2.5 Kobo.

(ii) Let the digits be x and y.

Since the number is made up of two digits then, there would be unit and tenth digits: $10x + y$

Digits reversed $10y + x$

Hence: $10x + y = 10y + x + 54$ --- (i)

Sum of the digits: $= 12$ ------ (ii)

$9x - 9y = 54$

Divide through by 9

$x - y = 6$ ------ (i)

$x + y = 12$ ------ (ii)

$x^2 - 2x - x + 2 = 0$

$x (x - 2) - 1 (x - 2) = 0$

$(x - 1)(x - 2 = 0$

Either $x - 1 = 0$ or $x - 2 = 0$

$x = 1$ or 2.

Check: When $x = 1$: $1^2 - 3(1) + 2 = 0$

$1 - 3 + 2 = 0$

$2 - 2 = 0$

When $x = 2$: $2^2 - 3(2) + 2 = 0$

$4 - 6 + 2 = 0$

$6 - 6 = 0$

The solution of the equation is $\underline{x = 1 \text{ or } 2}$

ii) Solve the quadratic equation: $2x^2 - 7x + 3 = 0$

Using the formula $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Where $a = 2$, $b = -7$, $c = 3$

$\therefore x = \dfrac{-(-7) \pm \sqrt{(-7)^2 - 4 \times 2 \times 3}}{2 \times 2}$

$x = \dfrac{7 \pm \sqrt{49 - 24}}{4}$

$x = \dfrac{7 \pm \sqrt{25}}{4}$

$x = \dfrac{7 \pm 5}{4}$, $\dfrac{12}{4}$ or $\dfrac{2}{4}$ i.e. $\left.\begin{matrix} 7 + 5 = 12 \\ 7 - 5 = 2 \end{matrix}\right)$

$x = 3$ or 0.5

Check when $x = 3$, $2(3)^2 - 7(3) + 3 = 0$

$18 - 21 + 3 = 0$

$21 - 21 = 0$

When $x = \frac{1}{2}$, $2(\frac{1}{2})^2 - 7(\frac{1}{2}) + 3 = 0$

$$2 \times \frac{1}{4} - \frac{7}{2} + 3 = 0$$

$$\frac{1}{2} - \frac{7}{2} + 3 = 0$$

$$3\tfrac{1}{2} - 3\tfrac{1}{2} + 3 = 0$$

The solution of the equation is $x = 3$ or $\frac{1}{2}$.

IN-CLASS PUPILS PRACTISE EXERCISES

Solve the equations (i) $2x^2 - 5x + 2 = 0$

(ii) $2y^2 - 3y - 21 = 0$

(iii) $\frac{3}{x-1} = 5x.$

SOLUTION:

i) $2x^2 - 5x + 2 = 0.$ Check for factorisation:

$2 \times 2 = 4$, factors of 4 are -4 -1 to give -5.

Hence: $2x^2 - 4x - x + 2 = 0$

$$2x(x - 2) - 1(x - 2) = 0$$

$$2x - 1 = 0 \quad \text{or} \quad x - 2 = 0$$

$$x = \tfrac{1}{2} \quad \text{or} \quad 2$$

Check: When $x = \frac{1}{2}$, $2(\frac{1}{2})^2 - 5(2) + 2 = 0$

$$\frac{2}{4} - \frac{5}{2} + 2 = 0$$

$$2\tfrac{1}{2} - 2\tfrac{1}{2} = 0$$

When $x = 2$, $2(2)^2 - 5(2) + 2 = 0$

$$8 - 10 + 2 = 0$$

$$10 + 10 = 0$$

The solution of the equation $x = \frac{1}{2}$ or 2.

ii) $2_y^2 - 3y - 21 = 0$: Check for factorisation:

$2 \times -21 = -42$; far less than -3, cannot be factorised.

Using the general formula:

$$y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$a = 2, \; b = -3, \; c = -21$

$$y = \frac{-(-3) \pm \sqrt{(-3)^2 - 4 \times 2 \times -21}}{2 \times 2}$$

$$y = \frac{3 \pm \sqrt{177}}{4}$$

$$y = \frac{3 \pm 13.30}{4} \quad \text{i.e.} \quad \frac{3 + 13.30}{4} \quad \text{or} \quad \frac{3 - 13.30}{4}$$

$$y = \frac{16.30}{4} \quad \text{or} \quad -\frac{10.30}{4}$$

$$y = 4.075 \quad \text{or} \quad -2.575$$

Check: When $x = 4.075$, $2(4.075)^2 - 3(4.075) - 21 = 0$

$33.20 - 12.15 - 21 = 0$

$33.20 - 33.20 = 0$

When $x = -2.575$, $2(-2.575$, $2(-2.575)^2 - 3(-2.575) - 21 = 0$

$13.261 - 5 + 7.725 - 21 = 0$

$21 - 21 = 0$

Hence, the solution of the equation is:

$$x = 4.075 \quad \text{or} \quad -2.575.$$

iii) Solve: $\frac{3}{3 - 1} = 5x$

$3 = 5x(x - 1)$

$3 = 5x^2 - 5x$

$5x^2 - 5x - 3 = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$a = 5, \; b = -5, \; c = -3$

$$x = \frac{-(-5) \pm \sqrt{(-5)^2 - 4 \times 5 \times -3}}{2 \times 5}$$

$$= \frac{5 \pm \sqrt{25 + 60}}{10}$$

$$x = \frac{5 \pm \sqrt{85}}{10}$$

$$x = \frac{5 \pm 9.22}{10}$$

$$x = \frac{14.22}{10} \quad \text{or} \quad \frac{-4.22}{10}$$

$$x = 1.422 \quad \text{or} \quad -0.422$$

Check: When $x = 1.422$

$$5(1.422)^2 - 5(1.422) - 3 = 0$$

$$10.110 - 7.11 - 3 = 0$$

$$10.110 - 10.110 = 0$$

When $x = -0.422$

$$5(-0.422)^2 - 5(-0.422) - 3 = 0$$

$$0.89042 + 2.11 - 3 = 0$$

$$0.89 + 2.11 - 3 = 0$$

$$3.0 - 3.0 = 0$$

Hence, the solution of the equation is

$$x = 1.422 \text{ or } -0.422.$$

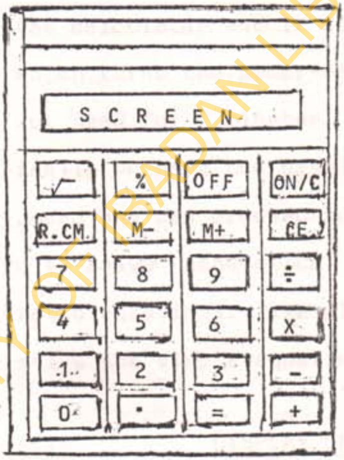
E N D

Pages 336-342 contain the instruction on the use of calculator with the module.

GENERAL INSTRUCTION ON THE USE OF CALCULATOR WITH INSTRUCTIONAL MODULE

Introduction

There are different types of calculators in the market ranging from scientific, non-programmable to programmable ones. However, the type used for this instructional module is shown in the figure below. It has capacity for values up to 8 digits or 7 places of decimal, and it is battery operated.



Model of Modern Electronic Calculator

This type of calculator is capable of performing the following mathematical operations (the operational keys):

1. Addition (+)
2. Subtraction (-)
3. Multiplication (x)
4. Division (÷)
5. Add to the memory (M^+)
6. Subtract from the memory (M^-)
7. Retrieve and compute memory (R.CM).

8. Clear from memory (CE)
9. Square root ($\sqrt{\ }$)
10. Compute percentage (%)
11. Decimal point (.)
12. Equality (=)

Other operational keys are:

ON/C Starts the calculator and clears with zero (0) appearing on the screen.

OFF Shut off the calculator and it also has an automatic shut off which turns the power-off when the calculator is not used for 7 minutes.

Numerals: 0,1 - 9. Finally we have the display screen.

With this background one can proceed to discuss how this calculator can be used to solve mathematical problems on simple, simultaneous and quadratic equations. Example 1 of Part II: Using the calculator solve the simple equation:- 22 = x - 6.

SOLUTION

	OPERATIONAL KEYS	DISPLAY ON SCREEN
	Punch ON/C	0.
	" 2 twice	22.
	" M^+	$22.^{M}$
	" =	$22.^{M}$
	" 7	$7.^{M}$
	" X	$7.^{M}$
Try x = 4)	" 4	$4.^{M}$
or any) other va-) lue)	" M^+	$28.^{M}$
x=1,2,3,etc.)	" - and 6	$6.^{M}$
	" =	$22.^{M}$

which is equal to 22 the value which we have started with. Thus, $x = 4$ is the solution. You amay wish to try other values $x = 1, 2, 3,$ etc. and check if they will be equal to 22.

[Hint: To solve simple equations in fraction forms it is easier to change the fractions into whole numbers.]

Example I of Part III

Use the calculator to solve the simultaneous equations;

$$3x - y = -13 \qquad (i)$$

$$2x + y = 17 \qquad (ii)$$

The solution of these equations implies obtaining values of x and y which will satisfy equations (i) and (ii).

SOLUTION: Eliminate one of the values by method of substitution to reduce it into simple linear equation in just one variable. Then use the calculator to solve the linear equation in one variable. By substitution,

$$y = 3x + 13 \text{ from equation } (i)$$

Put (i) in (ii) $2x + 3x + 13 = 17$

$$5x = 17 - 13$$

Simple linear equation: $5x = 4$

STEP 1 --	OPERATIONAL KEYS		DISPLAY ON SCREEN
	Punch	ON/C	0.
	"	5	5.
Try different values of x	"	X	5.
$x = 1, \frac{1}{2}, 4/5$	"	1	5.
	"	=	5.
	Screen value not equal to 4		
	"	5	5.
	"	X	5.

ᵒnch (') and 5	0.5
" =	2.5 : Not equal to 4
" 5	5.
" X	5.
" point (.) and 8	0.8
" =	4 : Equal to 4

So x = 0.8 is one of the solution.

STEP 2: Put x = 0.8 in equation (i) y = 3x + 13.

y = 3(0.8) + 13: So as to obtain value of y

OPERATIONAL KEYS	DISPLAY ON SCREEN
Punch ON/C	0.
" 3	3.
" X	3.
" point (.) and 8	0.8
" =	2.4
" +	2.4
" 1 and 3	13
" =	15.4

y = 15.4 is a solution

The solution of the simultaneous equations are x = 0.8 and y = 15.4

Example of III of Part IV

Solve the quadratic equation

$$2x^2 - 7x + 3 = 0$$

First check if the equation can be factorised. If not, then apply the general formula. Most importantly, all quadratic equations can be solved by the general formula and it is therefore, easier and faster with the calculator to use the formula.

General formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

where a, b and c are constants from the general form of quadratic equation

$$ax^2 + bx + c = 0$$

From this example: a = 2, b = -7, c = 3

$$\therefore \quad x = \frac{-(-7) \pm \sqrt{(-7)^2 - 4 \times 2 \times 3}}{2 \times 2}$$

Pupils note that

$- \times - = +$

$- \times + = -$

$$X = \frac{-1 \times -7 \pm \sqrt{-7 \times -7 - 4 \times 2 \times 3}}{2 \times 2}$$

SOLUTION: Start the operation with the square root value from right to left.

OPERATIONAL KEYS		DISPLAY ON SCREEN
Punch	ON/C	0.
"	7	7.
"	X	7.
"	7	7.
"	=	49.
"	M^+	$49.^M$
"	4	$4.^M$
"	X	$4.^M$
"	2	$2.^M$
"	X	$8.^M$
"	3	$3.^M$
"	=	$24.^M$
"	M–	$24.^M$
"	R.CM	$25.^M$

	Punch	$\sqrt{\quad}$	$5.^{M}$
	"	M^{+}	$5.^{M}$
Positive solution	"	+	$5.^{M}$
	"	7	$7.^{M}$
	"	+	$12.^{M}$

For quadratic equation solution we have ± (the square root values are negative and positive)

	OPERATIONAL KEYS		DISPLAY ON SCREEN
Negative solution	Punch	- and 5	5.
	"	=	5.-
	"	+ and 7	7.
	"	M^{+}	$2.^{M}$

Final solution

$$x = \frac{12}{2x2} \quad \text{or} \quad \frac{2}{2x2}$$

POSITIVE CALCULATION

OPERATIONS	SCREEN
Punch 1 and 2	12.
" ÷ and 2	2.
" =	6.
" ÷ 2	2.
" =	3

NEGATIVE CALCULATION

OPERATION	SCREEN
Punch 2	2.
" ÷ and 2	2.
" =	1.
" ÷ and 2	2.
" =	0.5

∴ x = 3 or 0.5

Note that negative value sign appears to the right of the number on the screen unlike the way it is written down on paper.

Check for values of x = 3 or 0.5 in the equation $2x^2 - 7x + 3 = 0$, and you determine if values on the right hand side (R.H.S.) will be equal to zero.

For x = 3, $2(3)^2 - 7(3) + 3$, is it equal to zero?

OPERATIONAL KEYS		DISPLAY ON SCREEN
Punch	ON/C	0.
"	2	2.
"	X	2.
"	3	3.
"	X	6.
"	3	3.
"	=	18
"	M^+	18^M
"	7	7^M
"	X	7^M
"	3	3^M
"	=	21^M
"	M–	21^M
"	R.CM	$3^{\underline{M}}$
"	3	3^M
"	M^+	3
"	R.CM	0

Here the value $x = 3$ satisfies the equation. You may use the same steps for $x = 0.5$ it should also satisf- the equation.

The few worked examples have been carried out using the calculator you will now practise with your teacher some of the in-class exercises.

APPENDIX 8

A.C.E.R. ML TEST

Name: .... Age Now .... Class: ....

This is a test to see how well you can thing. It contains questions of different kinds. Some examples and practice questions will be given to show you how to answer the questions.

Example A. Four of the following are alike in some way, write the number of the other two in thebrackets at the end of the line.

I. tea 2. Cofee 3. Cocoa 5 Pencil 6. Milk (3 & 5)

Question I. Four of the following are alike in some way. Write numbers of the other two in the brackets.

1. apple 2. pear 3. potato 4. babana 5. carrot 6. oranges (3 & 4)

Question 2. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

1. door 2. window 3. coat 4. wall 5. roof 6. book (3 & 6)

EXAMPLE TOWEL IS TO WATER AS BLOTTING PAPER IS TO -

I. school 2. ink 3. writing 4. deak 5. pen (2)

QUESTION 3. Hand is to finger as foot is to

1. leg 2. arm 3. too 4. man 5. ankle (3)

Question 4. Newspaper to to see as Wireless is to

1. wire 2. hear 3. dial 4. car 5. deaf (2)

EXAMPLE: Which two of the following statements mean most nearly the same?

1. Too many cooks spoils the broosh.
2. Make hay while the sun shines.
3. A stitch in time saves nine
4. It's a long lane that has no turning. (2, 3)
5. Strike while the iron is hot.

Question 5. Which two of the following statements mean most nearly the same?

1. A careless master makes a negligent servant.
2. To resist him that is set in authority is evil.
3. Little is done when many command.
4. When the cat is away the nice play.
5. Where there are seven shephards there is no flock. (3,5).

Question 6. Our gdog bit the postman yesterday? Which of the following statement are together

1. Our dog is the only German shepard dog in the street.
2. The postman was late yesterday
3. The postman is in bed because a German shepard dog bit him yesterday in our street
4. Dogs seem to dislike postmen.
5. The postman had sore leg last week ( )

You will have 30 minutes to do the test. Some questions are earier than ot others. Try each question as you come to it, but if you find any question is too hard, leave it out and come back to it later if you have time. Do not spend too much time on any one question. Try to get as many right as possible.

1. Of the following are alike in some way. Write the number of the other two in the brackets.

1. table 2. chair 3. man 4. bed 5. cupboard 6. towel ( )

2. FILTHY is to DISEASE as CLEAN is to:

1. dirty 2. safety 3. water 4. illness 5. health.

3. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

1. tube 2. artery 3. tunnel 4. string 5. pipe 6. wire ( )

4. INCH is to SPACE as SECOND is to:

1. hour 2. age 3. time 4. clock 5. time ( )

5. Four of the following are alike in some way. Write the number of the other two in the brackets.

1. lagoon 2. pool 3. swamp 4. lake 5. march 6. pond ( )

6. PIN is to HEAD as NEEDLE is to:

1. prick 2. sew 3. eye 4. point 5. threa ( )

7 Four of the following are alike in some way. Write the number of the other two in the brackets.

1. onlooker 2. spectator 3. critic 4. eye-witness 5. author
6. bystander ( )

8. HEAT Is to ASHES as CARPENTRY is to:

1. carpenter 2. sawdust 3. chest 4. furniture 5. wood ( )

9. Four of the following are alike in some way. Write the numbers of the other two in the brackets.

1. sponge 2. water 3. map 4. towel 5. blotting paper 6. dirt.

I0 Which two of the following statements mean most nearly the same?

I Time is a heap that cures all diseases.

2 Anticipation is better than realization.

3 To-day is worth two to-morrow.

4 To speed to-day is tobe set back to-morrow.

5 There is no time like the present ( )

TELEPHONE IS TO VOICE as LETTER is to-

I stamp 2 post office 3 writing 4 correspondent 5 envelope ( )

I2 Which two statements prove that '' JOHN IS A GOOD SWIMMER''?

I Bob goes to the baths every day.

2 John and Bob are friends

3 John beat Bob in a race last week

4 John has challenged Bob to a race. ( )

I3 MANNERS are to POLITE AS MORALS are to-

I politics 2 politeness 3 wealthy 4 virtous 5 strong ( )

I4 Which two statements prove that 'MR SMITH OWNS SOME TAMWORTHS'?

I Tamworths are better pigs than Barshires.

2 One-eight of the pigs in that pen are Tamworths.

3 Most of the pigs in that pen are Bershires.

4 All the pigs in that pen belong to Mr. Smith.

5 Most of the farmers in the district own Tamworths. ( )

I5 In the following are dislike in some way. Write the numbers of the other two in the brackets.

I spire 2 church 3 flagpole 4 steeple 5 tower 6 hall ( )

I6 OCEAN is to LAKE as CONTINENT is to-

I river 2 land 3 mountain 4 island 5 Europe ( )

I7 Which two of the following statements mean most nearly the same?

I Fire that's clossest kept burns fiercest.

2 Set a thief to catch a thief.

3 A dog with a bone know no friend.

4 Fight fire with fire.

5 Sow the wind, reap the whirwind.

I8 Three days in the week have the same number of letters. In the bracket write the first letter of the day which begins with the letter which, of the three, comes first in the alphabet

19 'ONLY PREFECTS WEAR A BADGE' ALL PREFECTS ARE IN FORM VI.
Therefore, which one of the following statements is true? Write its number in the brackets.

I All Form VI boys may-wear a badge.
2 A boy wearing a badge in Form VI.
3 All Ist X boys may wear badges.
4 V Form Prefects do not wear badges. ( )

20 Four of the following are alike in some way. Write the numbers of the other two in the brackets.

I Blame 2 accuse 3 indict 4 loathe 5 censure 6 ape ( )

21 Which two of the following statements mean most nearly the same?

I He who follows two hares will catch neither.
2 To blow and swallow at the same time is not easy.
3 He holds nothing fast who grasps at too much.
4 Despise the man who can blow hot and cold with the same breath.
5 It is easy to despise what you cannot obtain ( )

22 FEW is to MANY as OCCASIONALLY is to-

I seldom 2 never 3 every 4 often 5 always. ( )

23 Four of the following are alike in some way. Write the numbers of the other two in the brackets.

I corrugated 2 involved 3 complicated 4 intricate 5 coarse ( )

24 Which two of the following statements together prove that 'MR REED DOES NOT LI[VE] IN HUME STREET'?

I All the buildings in Hume Street are modern.
2 All the buildings in Hume Street are flats.
3 Mr. Reed lives in comfort
4 Mr. Reed does not live in a flat.
5 Mr. Reed lives five miles from town. ( )

25 If these words were rearranged correctly to form a sentense, with what letter would the middle word begin?

26 GATE is to FENCE as PORT is to-

I land 2 Coast 3 town 4 sea 5 destination ( )

GO STRAIGHT ON WITH THE NEXT PAGE

27 Which two of the following statements mean most nearly the same?

I It's petty expenses that empty the purse.

2 Small gains bring riches in.

3 Even the weak are strong when united.

4 Constant dripping wears away the stone.

5 A chain is as strong as its weakest link.

28 Four of the following are alike in some way. Write the numbers of the other two in the brackets.

I ruler 2 heat 3 clock 4 thermometer 5 rainguage 6 yard ( )

29 Which two of the following statements mean most nearly the same?

I Repentance is poor consolation.

2 More haste less speed.

3 Quick decisions often breed regret.

4 He'll have a bucket of tears for a cup of joy.

5 Marry in haste, repent in Leisure. ( )

30 DRAMATIST is to PLAY as COMPOSER is to-

I orchestra 2 piano 3 symphony 4 performance 5 concert ( )

3I Which of the following statements together prove that 'TODAY IS COLDER THAN YESTERDAY?

I Every Friday this month was a cold day.

2 To-morrow is the first day of the month.

3 Last Thursday was a hot day.

4 The last day of each month this year has been the coldest day in the month

5 Summer is nearly over.

I fugitive 2 enemy 3 evacuee 4 escapee 5 prisoner 6 truant ( )

33 Which two of the following statements mean most nearly the same?

I A great fortune is a great slavery

2 Better beans and bacon in freedom than cakes and ale in bondage.

3 Put a chain round the neck of a slave and the end fastens round your own

4 Lean liberty is better than fat slavery.

Stone walls do not a prison make.

34 In certain code the English word BOARD is written CODVI. What would the English word PAT be in this code?

35 Which two of the following statements mean most nearly the same?

I Forwarned is forearmed.

2 The loss which is unknown is no loss at all

3 No man is happy that does not think so.

4 Uneasy lies the head that wears a crown.

5 Where ignorance is bliss, 'tis folly to be wise. ( )

36 BATTLE is to DUEL as CHORUS IS to-

I twins 2 duet 3 selection 4 music 5 Song. ( )

LOOK BACK OVER YOUR WORK.

APPENDIX 9

A.C.E.R. MQ TEST

Name: .... Age now: ....
Date of Test: .... Birthday: ....
School: .... Class: ....

This is a test to see how well you can think. It contains questions of different kinds. Some examples and practice question will be given to show you how to answer the questions.

EXAMPLE: (a) Find out how the following numbers go
Write the missing numbers in the brackets:

2 5 8 * 14 17 * 23 .. .. (11 & 20)

Question 1: Find out how the following numbers. Write the missing numbers in the brackets.

4 5 6 * 5 * 7 10 * .. .. (8 & 9)

Question 2: Find out how the following numbers go.
Write the missing numbers in the brackets.

1 3 5 7 * 11 * 15 .. .. (9 & 13)

Question 3.: Find out how the following numbers go.
Write the missing numbers in the brackets

26 23 20 17 14 * 8 * .. .. (11 & 5)

EXAMPLE (b) Find the number which should be in the square with the question mark and write it in the brackets

3	5	7
6	8	10
9	11	?

.. (13)

Question 4: In this table two numbers are missing. find the number which should be in the square with the question mark and write it in the brackets.

2	5	9
6	.	13
11	14	?

.. (18)

<u>Question 5.</u>: Find the number which should be in the q square with the question mark, and write it in the brackets.

1	3	5
3	.	7
5	7	?

.. .. (19)

<u>Question 6</u>. Find the number which should be in the square with the question mark, and write it in the brackets.

17	13	9
15	11	?
9	.	1

.. .. .. (7)

You will have 20 minutes to do the test. Some questions are easier than others. Try each question as you come to it, but if you find any question is too hard, leave it out and come back to it later if you have time.

<u>S T A R T</u>

Do not spend too much time on any one question.

Try to get as many right as possible.

1. Find out how the following numbers go. Write the missing numbers in the brackets:

   1 5 - 13 - 2 21 25 29 .. .. .. (9 & 17)

2. What change should I got from a ₦1 note if I buy two theatre tickets @ 25k each ? .. .. .. (50k)

3. Find the number which should be in the square with the question mark, and write it in the brackets.

2	1	5
7	6	10
12	?	15

.. .. .. (11)

4. Find out how the following numbers go. Write the missing numbers in the brackets.

   19 9 18 8 - 7 16 - .. .. .. (17 & 6)

5. Oliver is three times as old as his sister Pat. Their father who is 35, is seven times as old as Pat. How old is Oliver ?

   .. .. (15 yrs.)

6. Find the number which should be in the square with the question and write it in the brackets.

6	10	17
8	•	19
12	16	?

.. .. (23)

7. Find out how the following numbers go. Write the missing number in the brackets:

512 256 128 64 – 16 – 4 .. .. (32 & 8)

8. Which of the following prices for oranges is the cheapest?
(1) 5k each; (2) 10 for 45k; (3) 5 for 24k; (4) 4 for 18k
(5) 3 for 12k .. .. .. (3 for 12k)

9. Find the number which should be in the square with the question and write it in the brackets.

32	8	2
°	16	4
96	24	?

.. .. (6)

10. Find out how the following numbers go. Write the missing numbers in the brackets:

87 78 76 67 65 56 54 – .. .. (65 & 45)

11. The total cost of ten books bound in leather is ₦20.00. Each book in an ordinary edition costs one Naira. How much extra do I pay on each book for the leather binding? (₦10.00)

12. Find the number which should be in the square with the question mark, and write it in the brackets. ..

2	4	8
6	9	24
18	36	?

.. .. (72)

13. John and Mary are twins whose ages together are half their mother's Their father, who is three years' older than their mother, is 51. How old is John ? .. .. (12)

14. Find the number which should be in the square with the question mark, and write it in the bracket.

1	3	9
2	25	10
5	7	?

.. .. (13)

15. It took me four times as long to climb a mountain 6000m high as it took me to come down. I decended 3000m in an hour. How many hours did it take to climb up ? .. .. (8)

16. Find the number which should be in the square with the question mark, and write it in the brackets.

1	o	9
4	12	36
?	48	144

.. .. (16)

17. What are two numbers whose sum is 16, such that the first divided by the second gives three ? .. .. .. (4, 12)

18. Find out how the following numbers go. Write the missing numbers in the brackets

0 - 3 5 6 8 - 11 .. .. .. (2, 9)

19. Find the number which should be in the square with the question mark and write in the brackets.

13	9	5
7	5	?
1	o	1

.. .. (3)

20. Find out how the following numbers go. Write the missing numbers in the brackets:

4 8 7 - 13 26 - 50 .. .. .. (44 & 25)

21. If nine framed pictures cost ₦27.00, and each picture unframed only costs one-third as much, how many unframed pictures could I buy for the same money ? .. (27)

22. Find the number which should be in the square with the question mark, and write it in the brackets.

o	4	6
4	•	12
8	16	?

23. Find out how the following numbers go. Write the missing number in the brackets.

1 3 - - 81 243 729 .. .. .. (9 & 27)

24. I bought an equal number of 5k magnazined and 2½k exercise books, which cost me 45k altogether. How many of each did I buy? .. .. (6)

25. Find out how the following numbers go. Write the missing number in the brackets.

41 35 30 26 - 21 20 .. .. .. (23)

26. A vegetable farmer finds that by selling his carrots at 40k per kilogram, he rakes exactly the same profit as by selling at 30k per bunch, what is the average weight of each bunch of his carrots ? .. .. .. ($\frac{3}{4}$ kg.)

27. A furniture dealer bought 12 chairs at ₦48.00. In selling them, he received as much for two chairs as he had paid for three chairs. What was the selling price for the twelve chairs ? .. .. (₦72.00)

28. Find the number which should be in the square with the question mark, and write its number in the brackets.

18	3	6
2	•	2
9	3	?

.. (3)

29. I can buy $5\frac{1}{2}$kg. of potatoes for ₦3.30k. How much do I pay for $4\frac{1}{2}$kg. ? .. .. .. (₦2.70)

30. In a class of 46 pupils, there are 8 more boys than girls. How many boys are there ? .. .. (27 boys)

31. Find the number which should be in the square with the question mark, and write it in the brackets.

•	1	8
18	2	?
27	•	24

.. (16)

32. Three new books cost 45k, 90k and ₦1.05 respectively. If I buy them second-hand, I only pay two thirds of the new price. How much money do I save ? .. .. (80k)

33. A piece of wood 35cm long is to be cut in three parts, each successive part being twice as long as the previous part. What is the length of the longest ? .. .. (20cm)

34. A Kitten is 3 days old and a puppy is 11 days old. In how many days will the puppy be twice as old as kitten ? (5 days)

35. A dairy serves a mixture of two parts cream and three parts milk. How many litres of cream will it take to make 15 litres of the mixture ? .. .. (6 litres)

36. Find out how the following numbers go. Write the missing numbers in the brackets,

87 74 63 54 47 - 39 - .. .. (42, 38)

APPENDIX 10

Attitude questionnaire to be completed by pupils in secondary schools on the use of electronic calculator

Please, complete this section:
Name of School:...

Address of School:...

Male/Female:......................... Age:.........................

Class:...

This is not an examination. Please, give your honest opinion on each item. You should only thick (✓) under the most appropriate response according to the format.

SA - 5 Strongly Agree

A - 4 Agree

U - 3 No Opinion (Undecided)

D - 2 Disagree

SD - 1 Strongly Disagree.

A:	ATTITUDES TOWARD MATHEMATICS	5 SA	4 A	3 U	2 D	1 SD
1.	Mathematics is one of the subjects I have always enjoyed studying					
2.	I approach mathematics class with a feeling of hesitation resulting from fear of not being able to do mathematics.					
3.	I like mathematics, and I am happier in a mathematics class than in any other class.					
4.	Mathematics is very interesting to me because I enjoy working with numbers.					
5.	Mathematics makes me feel secure, and at the same tim it is stimulating.					
6.	When I hear the word 'Mathematics', I have feeling of dislike.					
7.	My mind goes blank, and I am unable to think clearly or remember anything when doing Mathematics.					

		5 SA	4 A	3 U	2 D	1 SD
8.	I feel a sense of insecurity when attempting Mathematical problems.					
9.	I feel at ease with Mathematics and I like it very much.					
10.	Mathematics makes me feel uncomfortable, restless, irritable, and impatient.					
11.	I am poor in formulae and they scale me whenever I do Mathematics.					
12.	I always react positively to Mathematics because it is enjoyable.					
B.	ATTITUDES TOWARD THE USE OF ELECTRONIC CALCULATORS IN MATHEMATICS					
1.	Calculator increases one's computational skill in mathematics, schools should encourage it's use.					
2.	I think four figure table is more useful in the classroom and in examinations, calculator will not be necessary.					
3.	Calculators will make one lazy, it should not be used in Mathematics.					
4.	I will like to see people use more of calculators.					
5.	Sometimes I feel that the calculators are desirable and sometimes I doubts it.					
6.	The calculator is one of the few things I enjoy using in Mathematics.					
7.	Pupils who use calculators in the classroom and in examinations should be punished.					
8.	Many pupils lack the ability to do simple calculations, so calculators can be useful.					
9.	The use of calculators by pupils in schools should be decided by teachers alone.					
10.	Pupils should be permitted to use calculators only in their final examinations.					

		5 SA	4 A	3 U	2 D	1 SD
11.	There would be very little progress in Mathematics without the calculator.					
12.	The computational advantage of the calculator is bound to weaken the mental ability of those who use it.					
13.	As of now calculators are completely bad for school pupils.					
14.	Calculator will help me in solving Mathematics problems.					

APPENDIX 11

Internal consistency reliability coefficient of the attitude measure

No.	X (Odd)	Y (Even)	X2	Y2	XY
1.	105	101	11025	10201	10605
2.	101	99	10201	9801	9999
3.	96	95	9216	9025	9120
4.	94	92	8836	8464	8648
5.	89	88	7921	7744	7832
6.	88	86	7921	7396	7568
7.	85	84	7225	7056	7140
8.	84	83	7056	6889	6972
9.	81	79	6561	6241	6399
10.	78	77	6084	5929	6006
11.	77	77	5929	5929	5929
12.	77	77	5929	5929	5929
13.	76	76	5776	5776	5776
14.	76	76	5776	5776	5776
15.	72	71	5184	5041	5112
16.	69	69	4761	4761	4761
17.	69	68	4761	4761	4692
18.	64	57	4096	4761	4692
19.	57	52	3249	2704	2964
20.	45	44	2025	1936	1980

$\sum(XY) = 126779$

$N\sum(XY) = 2535580$

$\sum X \sum Y = 2453650$

$N\sum X^2 = 2587100$

$N\sum Y^2 = 2480100$

$(\sum X)^2 = 2505889$

$(\sum Y)^2 = 2402500$

Computing: $= \frac{N(\sum XY) - (\sum X)(\sum Y)}{\sqrt{(N\sum X^2) - (\sum X)^2 (N\sum Y^2) - (\sum Y)^2}} =$

$= \frac{81900}{83862.219}$

$= 0.98$

Y = 0.98 (reliability coefficient of odd and Even)
(Split half reliability).

Using Spearman-Brown formula, R = N(r)/(1 + (N-1)r)

R is the reliability co-efficient

R = Nr/1+(N-1)r) = 19.6/19.62

= 0.99

APPENDIX 12

Correlation between 27% Upper Score and 27% Lower Score on Attitude Scale (MAS And CAS)

27% Upper Score			27% Lower Score		D	D²
S/R	X	Rank of X	Y	Rank of Y	X-Y	$(X-Y)^2$
1	105	10	69	9	1.0	1
2	101	8.5	69	9	-0.5	0.25
3	101	8.5	69	9	-0.5	0.25
4	99	7	7	7	0	0
5	98	6	6	6	0	0
6	95	5	4.5	4.5	0.5	0.25
7	94	4	4.5	4.5	-0.5	0.25
8	92	3	3	3	0	0
9	89	2	2	2	0	0
10	88	1	1	1	01	0

Using Spearman - Rank Order Correlation Coefficient

$$r = 1 - \frac{6\Sigma D^2}{N(N^2-1)} \qquad \Sigma D^2 = 3$$

$$r = 1 - \frac{6 \times 3}{10(99)} \qquad N = 10$$

$$= 1 - \frac{21}{990}$$

$$= 0.98.$$

APPENDIX 13

Significant mean difference in mathematics attitude score (MAS) and calculator attitude score (CAS) for 27% upper score

S/N	AGE IN YEARS	SEX M/F	MAS X	MAS X^2	CAS Y	CAS Y^2
1.	17	M	53	2809	52	2704
2.	18	M	49	2401	52	2704
3.	17	M	44	1936	57	3249
4.	16	F	45	2025	54	2916
5.	16	F	34	1156	62	3844
6.	14	F	43	1849	52	2704
7.	17	M	49	2401	45	2025
8.	15	F	51	2601	41	1681
9.	16	F	51	2601	38	1441
10.	17	F	26	676	36	1296

Mean Age = 16.2 yrs. $\bar{X} = X/N = {}^{445}/10$ $N = 10$

$$\bar{Y} = \Sigma Y/N = \frac{489}{10} = 48.9$$

$$\sigma_x^2 = \frac{\Sigma X^2}{N-1} - \frac{N \Sigma \bar{X}^2}{N-1} = \frac{20455}{9} - \frac{19802.5}{9} = 72.5$$

$$\sigma_y^2 = \frac{\Sigma Y^2}{N-1} - \frac{N \Sigma \bar{Y}^2}{N-1} = \frac{24564}{9} - \frac{23972.1}{9} = 72.43$$

$$\text{t-ratio} \quad \frac{\bar{X} - \bar{X}}{\sqrt{\frac{\sigma x^2}{N_x} + \frac{\sigma y^2}{N_y}}} = \frac{48.9 - 44.5}{\sqrt{\frac{72.5}{10} + \frac{72.43}{10}}} = \frac{4.4}{\sqrt{14.493}}$$

$= 1.16$ at $X = .05$

APPENDIX 14

Significant mean Difference in Mathematics attitude Score (MAS) and Calculator Attitude Score (CAS) for 27% Lower Score

	AGE	SEX	MAS		CAS	
S/N	IN YEARS	M/F	X	X²	Y	Y²
1	16	M	41	1681	28	784
2	16	F	43	1849	26	676
3	16	F	47	2209	22	484
4	18	M	21	4441	47	2009
5	16	F	31	961	33	1089
6	17	M	35	1225	22	484
7	15	F	39	1521	18	324
8	19	M	28	784	24	576
9	17	M	21	441	24	576
10	15	M	21	441	23	529

Mean Age = 16.6 years $N_x = 10$, $N_y = 10$

$$\bar{X} = \Sigma N/N = 307/10 = 30.7,$$

$$= \bar{X} = 30.7, \quad \bar{Y} = 26.7$$

$$\sigma_x^2 = \frac{\Sigma X^2}{N-1} - \frac{N\Sigma\bar{X}^2}{N-1} = \frac{11553}{9} - \frac{9424.9}{9} = \underline{236.5}$$

$$\sigma_y^2 = \frac{\Sigma Y^2}{N-1} - \frac{N\Sigma Y^2}{N-1} = \frac{7731}{9} - \frac{7128.9}{9} = \frac{602.1}{9} = 66.9$$

$$t\text{ - ratio} = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{\sigma_x^2}{N_x} + \frac{\sigma_y^2}{N_y}}} = \frac{30.7 - 26.7}{\sqrt{\frac{236.5}{10} + \frac{66.9}{10}}}$$

$$t\text{-ratio} = \frac{44}{\sqrt{30.14}} = \underline{0.73} \text{ at } \alpha = 0.05$$

APPENDIX 15

Internal reliability co-efficient of mathematics pre-test scores

S/N	AGE	SEX	SCORE OUT OF 15
1.	14	F	5
2.	14	M	11
3.	18	M	7
4.	18	M	12
5.	18	M	14
6.	16	F	9
7.	16	F	7
8.	14	F	6
9.	17	M	9
10.	13	F	10
11.	15	M	3
12.	17	F	4

No. of test-items = 15

RANGE = 3 - 14

MEAN $\bar{X}$ = 8.00

STANDARD DEVIATION, SD: 3.35

RELIABILITY COEFFICIENCE, r = 0.67

Female = 6, Male = 6.

APPENDIX 16

Questionnaire directed to teachers of mathematics in the secondary school.

PLEASE COMPLETE:

Name of School ______________________

The School was established in 19______________

Your Sex: ____________ Your Age in Years __________

Your qualifications to date: ______________________

____

Your years of experience in the teaching of mathematics:

____

Classess taught mathematics to date:

Class	No. of Years
V	________
IV	________
III	________
I & II	________

One would appreciate your responses to the following items please complete the correct response where applicable:

1. If you teach mathematics in forms IV or/and V, do you always cover the mathematics syllabus fully or partially in preparing your schemes of work? underline partially or fully.

2. Which of the following types of equations have you taught in your class?

	Equations	Class
(i)	Simple	______
(ii)	Simultaneous	______
(iii)	Quadratic	______

3. List the types of instruments used by you or your students in facilitating quick and reliable numerical calculations.

1. ____________ 4. ____________
2. ____________ 5. ____________
3. ____________ 6. ____________

4. If you teach in forms IV or/and V you would assess your student's performance in mathematics as (i) above average, (ii) average and (iii) below average:

Class arm	Assessment
______	______
______	______
______	______
______	______
______	______

5. You would consider the electronic calculator as (i) very

(i) effective

(ii) effective

(iii) not effective

teaching learning aid.

6. If you consider the electronic calculator as an effective teaching - learning aid; indicate in which class or classes it can be used.

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* Face and content validity of the questionnaire were carried ou by the author and some lecturers in the Teacher Education Department, University of Ibadan.

APPENDIX 17

Data from Main Study

GROUP A

NOS.	SEX	VARIABLES						
		VAR 01 MAT	VAR 02 PEA	VAR 03 PET	VAR 04 POA	VAR 05 POT	VAL 06 MAS	VAL 07 CAS
1.	F	42	79	9	78	25	49	29
2.	M	37	64	10	88	26	47	41
3.	M	52	72	12	106	22	53	53
4.	M	38	77	11	103	13	49	54
5.	F	37	74	9	115	18	55	60
6.	F	38	105	8	99	12	49	50
7.	M	44	74	14	78	24	59	19
8.	F	37	87	6	90	20	46	44
9.	M	39	93	11	107	29	54	53
10.	M	49	78	4	109	24	50	59
11.	M	39	80	9	79	19	56	23
12.	F	39	60	13	77	20	43	34
13.	F	37	60	6	77	15	27	50
14.	F	45	93	13	54	23	51	3

Male (7) Female (7)

VAR 01: MAT - Mental ability TEst Scores (72)

VAR 02: PEA - Pre-Attitude questionnaire scores (130)

VAR 03: PET - Pre-test scores (15)

VAR 04: POA - Post-Attitude questionnaire scores (130)

VAR 05: POT - Post-test scores (30)

VAR 06: MAS - Mathematics Attitude scores (60)

VAR 07: CAS - Calculator Attitude Scores (70)

GROUP B

NOS.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	M	34	78	10	86	19	54	32
2.	F	36	74	7	87	16	54	33
3.	M	34	75	10	113	17	56	57
4.	F	30	56	8	74	15	48	26
5.	M	35	78	5	74	12	41	33
6.	F	36	63	5	83	19	56	27
7.	F	30	104	9	103	20	49	54
8.	M	35	89	6	111	17	50	61
9.	F	30	85	9	77	22	50	27
10.	F	36	77	6	72	19	54	18
11	M	32	87	12	98	15	51	47
12.	F	35	83	7	89	18	41	48
13.	M	31	87	8	81	16	38	43
14.	M	36	78	11	123	17	57	66

MALE (7) FEMALE (7)

GROUP C

Nos.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	M	26	79	2	83	11	45	38
2.	F	27	80	9	103	11	38	65
3.	M	27	78	11	93	17	57	36
4.	F	26	75	6	84	11	45	39
5.	M	27	68	11	84	13	31	53
6.	M	28	72	11	80	16	48	32
7.	F	27	27	6	72	12	35	37
8.	M	29	90	6	74	14	37	37
9.	F	29	67	5	73	12	38	35
10.	F	2[illegible]	72	9	100	14	55	45
11.	F	28	82	4	89	20	44	45
12.	M	27	86	7	77	12	49	28
13.	M	28	77	5	59	16	30	29
14.	F	28	78	4	78	19	42	36

MALE (7) FEMALE (7)

GROUP D

NOS.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	F	47	72	11	81	18	47	34
2.	M	44	88	12	85	16	51	34
3.	F	46	79	13	91	17	53	38
4.	M	42	58	13	86	9	49	37
5.	F	58	69	15	86	20	46	40
6.	M	54	64	12	78	16	44	34
7,	F	50	74	11	78	21	51	27
8.	F	50	84	14	83	17	50	33
9.	F	45	63	12	78	19	53	25
10.	F	48	86	9	93	11	47	45
11	M	45	85	10	82	17	51	31
12.	M	50	71	13	71	17	51	20
13.	M	50	73	12	77	14	53	24
14.	M	46	76	12	69	12	49	20

MALE (7) FEMALE (7)

GROUP E

NOS.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	F	47	72	11	81	18	47	34
2.	M	44	88	12	85	16	51	34
3.	F	46	79	13	91	17	53	38
4.	M	43	58	13	86	9	49	37
5.	F	58	69	15	86	20	46	40
6.	M	54	64	12	78	16	44	34
7.	F	50	74	11	78	21	51	27
8.	F	50	84	14	83	17	50	33
9.	F	45	63	12	78	19	53	25
10.	F	48	86	9	92	11	47	45
11.	M	45	85	10	82	17	51	31
12.	M	50	71	13	71	17	51	20
13.	M	50	73	12	77	14	53	24
14.	M	46	76	12	69	12	49	20

MALE (7) FEMALE (7)

GROUP F

NOS.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	M	30	99	10	71	12	57	14
2.	M	32	88	6	90	13	56	34
3.	M	30	82	7	83	17	52	31
4.	M	29	81	5	80	5	54	26
5.	M	32	80	7	82	8	56	26
6.	M	32	112	10	119	10	57	62
7.	F	28	79	7	84	12	52	32
8.	F	31	72	6	58	8	32	26
9.	F	30	66	7	68	10	46	22
10.	F	30	97	5	75	11	55	20
11.	F	26	89	6	82	6	36	46
12.	M	27	95	6	82	9	44	38
13.	F	25	81	9	77	10	48	29
14.	F	32	105	2	86	6	48	38

MALE (7) FEMALE (7)

GROUP G

NOS.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	M	44	85	9	97	9	52	45
2.	M	52	90	7	97	9	51	46
3.	M	48	88	6	72	8	51	21
4.	M	45	72	5	80	14	48	32
5.	M	51	78	9	79	12	50	29
6.	M	49	99	5	95	9	49	46
7.	M	43	61	5	77	7	32	45
8.	F	43	102	11	96	12	51	45
9.	F	41	93	14	89	9	55	34
10.	F	41	95	15	77	12	41	36
11.	F	51	83	14	100	14	53	47
12.	F	47	94	15	107	25	47	60
13.	F	45	79	13	81	20	52	29
14.	F	52	83	15	79	17	53	26

MALE (7) FEMALE (7)

GROUP H

NOS.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	M	39	114	11	105	19	55	50
2.	M	37	84	11	80	12	47	33
3.	M	40	98	13	91	19	48	43
4.	M	40	63	8	79	14	43	36
5.	M	37	88	4	83	12	45	38
6.	M	35	95	8	82	16	42	40
7.	M	40	84	7	74	10	45	29
8.	F	39	79	14	78	18	42	36
9.	F	37	101	13	113	14	52	61
10.	F	36	73	9	72	11	48	24
11.	F	40	78	12	80	14	47	33
12.	F	38	82	7	78	11	45	33
13.	F	40	82	12	80	14	49	31
14.	F	34	84	9	91	12	47	44

MALE (7) FEMALE (7)

GROUP I

NOS.	SEX	MAT	PEA	PET	POA	POT	MAS	CAS
1.	M	33	78	13	82	19	50	32
2.	M	33	92	2	76	8	31	45
3.	M	30	90	3	65	7	35	30
4.	M	33	78	4	82	8	48	34
5.	M	26	74	5	77	8	48	29
6.	M	27	94	13	75	15	51	24
7.	M	25	77	12	74	14	54	20
8.	F	27	64	6	50	6	20	30
9.	F	33	94	4	65	9	47	18
10.	F	33	87	5	104	6	46	58
11	F	31	72	6	78	7	36	42
12.	F	33	83	6	79	12	29	30
13.	F	28	104	9	105	6	47	58
14.	F	25	69	11	81	14	47	32

MALE (7) FEMALE (7)

APPENDIX 16

Data from the Pilot Study

GROUP A

NOS.	SEX	VARIABLES				
		VAR 01	VAR 02	VAR 03	VAR 04	VAR 05
		MAT	ATS	ACT	MAS	CAS
1.	M	400	89	7	52	37
2.	F	38	101	8	43	52
3.	F	37	74	10	38	36
4.	M	43	76	9	47	29
5.	F	34	79	7	45	34
6.	M	43	67	16	49	18
7.	M	44	60	9	31	29
8.	M	44	66	14	39	27
9.	F	33	73	12	44	29
10.	F	33	76	11	43	33

MALE (5) FEMALE (5)

VAR 01 : MAT - Mental ability scores (72)

VAR 02 : ATS - Attitude questionnaire scores (130)

VAR 03 : ACT - Post-achievement Scores (30)

VAR 04 : MAS - Mathematics Attitude Scores (60)

VAR 05 : CAS - Calculator Attitude Scores (70)

GROUP B

NOS.	SEX	MAT	ATS	ACT	MAS	CAS
1	M	29	86	9	38	48
2.	F	30	69	10	41	28
3.	M	30	57	7	35	22
4.	F	29	87	5	47	40
5.	F	29	86	12	35	51
6.	M	28	101	9	44	57
7.	F	28	90	5	44	46
8.	F	26	81	8	44	37
9.	M	28	69	6	43	26
10.	M	27	95	7	43	52

MALE (5) FEMALE (5)

GROUP C

NOS.	SEX	MAT	ATC	ACT	MAS	CAS
1	F	23	52	4	28	24
2.	M	22	84	4	43	41
3.	M	22	97	6	48	49
4.	F	18	92	9	51	41
5.	M	21	77	5	41	36
6.	M	22	98	7	50	48
7.	F	18	99	5	45	54
8.	F	16	78	9	58	20
9.	F	23	64	4	31	33
10.	M	21	77	3	36	41

MALE (5) FEMALE (5)

GROUP D

NOS.	SEX	MAT	ATS	ACT	MAS	CAS
1.	M	35	76	9	39	37
2.	M	36	88	11	28	60
3.	M	36	94	14	49	45
4.	M	37	77	13	41	36
5.	M	42	63	8	30	33
6.	F	32	76	6	46	30
7.	F	34	58	14	36	22
8.	F	32	81	10	44	37
9.	F	32	89	7	51	38
10.	F	44	96	6	34	62

MALE (5) FEMALE (5)

GROUP E

NOS.	SEX	MAT	ATS	ACT	MAS	CAS
1	M	28	76	10	46	30
2.	F	26	73	9	35	38
3.	M	28	72	11	20	52
4.	F	27	88	7	47	41
5.	F	28	68	8	43	25
6.	M	29	79	9	49	31
7.	F	27	58	10	34	24
8.	M	30	73	12	52	21
9.	F	29	75	12	52	23
10.	M	27	76	6	42	34

MALE (5) FEMALE (5)

GROUP F

NOS.	SEX	MAT	ATS	ACT	MAS	CAS
1.	M	20	88	9	26	62
2.	F	23	105	5	53	52
3.	F	23	85	2	45	40
4.	M	22	73	7	45	28
5.	F	19	76	8	56	20
6.	F	20	76	10	39	37
7.	F	19	69	7	47	22
8.	M	20	57	8	39	18
9.	M	21	78	5	52	26
10.	M	19	83	4	50	33

MALE (5) FEMALE (5)

GROUP G

NOS.	SEX	MAT	ATS	ACT	MAS	CAS
1.	M	46	77	6	58	19
2.	F	35	84	8	46	38
3.	M	36	82	7	52	30
4.	F	33	88	13	54	34
5.	M	32	79	6	50	29
6.	F	48	72	11	41	31
7.	F	45	71	4	40	31
8.	M	33	66	13	21	47
9.	M	33	66	19	38	30
10.	F	33	77	16	43	34

MALE (5) FEMALE (5)

GROUP H

NOS.	SEX	MAT	ATS	ACT	MAS	CAS
1.	M	27	45	11	21	24
2.	M	29	92	5	55	37
3.	F	27	81	8	54	37
4.	F	26	76	10	49	27
5.	F	28	84	6	44	36
6.	F	26	80	4	49	43
7.	M	27	92	4	49	43
8.	M	28	85	14	48	37
9.	F	29	44	12	21	23
10.	M	30	47	9	32	15

MALE (5) FEMALE (5)

GROUP I

NOS.	SEX	MAT	ATS	ACT	MAS	CAS
1.	M	21	82	5	48	34
2	M	19	68	7	38	30
3.	F	20	75	7	50	25
4.	F	20	99	6	39	60
5.	M	22	78	3	36	42
6.	F	21	79	4	50	29
7.	F	20	65	9	47	18
8.	M	22	90	5	44	46
9.	M	19	50	4	30	20
10.	F	18	70	6	40	30

MALE (5) FEMALE (5)

APPENDIX 19

List of secondary schools in Ibadan Municipality sampled for the study

	Name of School	Year Established
1.	Mount Olivet Grammar School, Bodija, Ibadan	1965
2.	** Holy Trinity Grammar School, Old Ife Road, Ibadan	1966
3.	Bishop Phillips Academy, Iwo Road, Ibadan	1964
3.	*Adekile Goodwill Grammar School, Aperin, Ibadan	1964
5.	C.A.C. Grammar School, Aperin, Ibadan	1960
6.	Adelagun Memorial Grammar School, Odinjo, Ibadan.	1967
7.	** Ibadan City Academy, Eleta, Ibadan.	1946
8.	*Ahmadiyya Grammar School, Eleyele, Ibadan	1955
9.	Baptist Grammar School, Idi-Isin, Ibadan	1966
10.	Ibadan Grammar School, Molete, Ibadan	1913
11.	Methodist High School, Express Road, Ibadan.	1961
12.	Eyinni High School, Lagos Road, Ibadan	1966
13.	Renascent High School, Aremo, Ibadan.	1964
14.	African Church Grammar School, Apata, Ibadan.	1960
15.	** Islamic High School, Basorun, Ibadan	1957
16.	Oke 'Badan High School, Oluyoro, Ibadan.	1964

* Five schools selected for pilot and main study

** Three schools selected for the main study

APPENDIX 20

Analysis of Variance of Post-attitude Scores of HMA, AMA and LMA Groups

SOURCE	df	SUM OF SQUARES	MEAN SQUARES	F-RATIO	SIGNIF OF F
MAIN EFFECTS	2	822.9375	411.4688	2.418	0.091 ns
EXPLAINED	2	822.9376	411.4689	2.418	0.091 ns
RESIDUAL	123	20942.000	170.2602		
TOTALQ	125	21764.9376	174.120		

ns : Not Significant at P = .04

Analysis of Variance of Post-Attitude Scores of UCU, RCU and NCU Groups

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-RATIO	SIGNIF OF F
MAIN EFFECTS	2	471.443	235.722	1.218	0.299 ns
EXPLAINED	2	471.445	235.723	1.218	0.299 ns
RESIDUAL	123	23811.625	193.590		
TOTAL	125	24283.070	194.265		

ns : Not Significant at P = .05