THE UNIVERSITY OF MANITOBA

THE EFFECT OF THE USE OF THE CALCULATOR ON SCIENCE-RELATED OUTCOMES

BY

EDWARD M. KEATING

A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfillment of the Requirements

for the Degree of Master of Education

WINNIPEG, MANITOBA

August 1977

THE EFFECT OF THE USE OF THE CALCULATOR ON SCIENCE-RELATED OUTCOMES.

by

Edward M. Keating.

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

Master of Education

ABSTRACT

The purpose of this study was to examine the effect of the use of the calculator on science-related outcomes. The outcomes consisted of the students performance in science, their attitude to some facets of science (four concepts), plus speed, accuracy and achievement in arithmetic.

In this investigation, 18 grade ten students were instructed with the aid of a calculator in two science units, both of which involved fundamental operations in arithmetic. These 18 students were then compared to another group of 18 students who were taught without the use of the calculator. Other factors which were also considered included the effect of calculator usage during testing and the effect of time of testing.

All students were tested prior to and after the instruction. The performance test in science was also given three weeks after the termination of instruction. The findings for attitude suggest that any changes in attitude due to the type of instruction were either parallel changes or non-existent for the two types of instruction.

The changes in arithmetic performance were similar to the changes in attitude. It did not seem to matter which one of the two instructional types were used, since student performance in arithmetic as measured by the facets speed and accuracy improved from pretest to posttest. This suggests that the type of instruction with or without the calculator has no significant effect on arithmetic performance.

There was, however, a significant effect in achievement in science due to instructional type (recalling that this was a post-retention test). The results favored the group using the calculator during instruction.

The implications of the study are that students of similar age and background will score higher on mathematical problem-oriented units in science, if they use a calculator during instruction. At the same time, there is very little difference in attitude between the two groups, and no loss in computational ability in arithmetic.

The results of the study also imply that when problem-oriented science tests are made up, keeping in mind that calculations are to be done manually, there is no effect due to the use of the calculator during testing.

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to Dr. Murray McPherson for his encouragement and guidance throughout the study. The writer is also indebted to Henry Schulz for his assistance at any time in overcoming problems in the study. Appreciation is also expressed to Dr. Hal Grunau, who as a committee member, offered needed assistance.

The writer would also like to thank the science teachers of Gordon Bell High School, especially Bob Lawler, for their help in conducting the investigation.

Finally, special thanks to my wife Elaine, who helped through all stages of the study and for the many hours she contributed to typing this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

TABLE		PAGE

LIST OF FIGURES

CHAPTER I

INTRODUCTION

We are living in an age of future shock, and nowhere is this more evident than in the field of pocket calculators. In the past two or three years, hand calculators have been increasing in number and decreasing in price. The microcircuit technology spin-off from the space industry has given the consumer a handy calculating tool. The full extent to which the availability of electronic calculators will affect the teaching of science and mathematics has yet to be determined.[1]

Background to the Study

There are conflicting views about the effect of the calculator on students. Opponents of calculators say that students will not know the basic paper-and-pencil algorithms

---

[1]Deede Pendleton, "Calculators in the Classroom," Science News, 107, No. 11 (1975), 175.

for addition, subtraction, multiplication, and division, just as television-oriented students no longer seem to know the basics of grammar and spelling.[2] The device, critics contend, will eventually make paper-and-pencil mathematics obsolete.

However, instructors who are using calculators take the opposite stand. They say that calculators allow students to solve more relevant types of problems, therefore stretching their interest and increasing their motivation. Calculators, because of their speed and accuracy, lend themselves to complicated problems previously avoided by school teachers.[3]

These conflicting views together with the greater availability of the calculator have provided the stimulus for this investigation.

Statement of the Problem

The purpose of this investigation is to consider the following problem: What is the effect of the use of the calculator on science-related outcomes? The outcomes chosen

---

[2] Richard J. Shumway, "Hand Calculators: Where Do You Stand?," Arithmetic Teacher, 23, No. 11 (1976), 571.

[3] Ibid., p. 570.

for this study are performance in science, attitude to some facets of science (four components), and performance in arithmetic operations.

The educational research and development in this field is relatively new. Furthermore, the possibility of supplying public schools with calculators will increase as the price decreases. The National Council of Teachers of Mathematics have formally endorsed the use of the calculator in the classroom.[4] Thus there is a need for research in this field.

The effect of the use of the calculator on performance in science courses that require some practical mathematics has been observed, but as far as the writer has ascertained, no research has been done in this area. Gerry Pankiewicz, a science teacher, observed that the use of calculators, with vocational students, improves motivation and the rate at which students can learn science concepts that involve mathematic operations. His rationale for this is that previous to the use of calculators, students became

---

[4]The National Council of Teachers of Mathematics, Newsletter, The National Council of Teachers of Mathematics, No. 11 (1974), p. 3.

so bogged-down in arithmetic calculations, that they were unable to achieve their real objective.[5] Educational research has not been done to determine the effect of the calculator on science performance.

The effect of calculator usage during testing will also be studied in this investigation. This question was posed by Sosebee and Walsh: "Do students having a calculator while writing an exam have an unfair advantage over the students who cannot afford one? Or, on the contrary, is the student who has been using the tool and has it taken away from him at a disadvantage when writing an examination?"[6]

The question of performance in arithmetic operations was chosen because critics of the calculator contend that the calculator will make pencil-and-paper mathematics obsolete. Students will forget the basics and be unable to add if their calculator batteries die.[7] This study should indicate if the

---

[5]Gerry Pankiewicz, "Science 203 Course used at Kildonan East" (paper presented to Dr. K. Slentz, University of Manitoba, 1975).

[6]Jackson Sosebee and Lola Walsh, "Pocket Calculators and Test Scores in Introductory Chemistry," Journal of College Science Teaching, 4, No. 5 (1975), 324.

[7]Pendleton, op. cit., pp. 175-181.

use of the calculator over an eight week period has any effect on arithmetic operations.

This study will also consider the effect of the calculator on attitude because, instructors who have used the device, claim that student motivation is increased.[8] The four facets of attitude--"What I learned in this science course", "How I feel about this science course", "Science student", and "Science teacher"--may give some idea as to what causes this increased motivation.[9]

Jan L. Higgins, an associate professor of Math Education at the Ohio State University, wrote the following:

> "Teachers would be well-advised to begin experimental classwork with pocket calculators, focusing on their use as a basic tool in successful problem solving.
> Concurrently, school administrators and other decision makers should make funds available for the purchase of such equipment for classroom use, for the calculator must be viewed not as a technological curiosity but as an essential implement in the newest mathematics."[10]

Consideration to the above recommendation has been given in

---

[8]Pendleton, loc. cit.

[9]Garth E. Martin, "An Evaluation of the Physical Science 201 and 301 Programs in Manitoba" (unpublished Masters dissertation, University of Manitoba, August 1975).

[10]Jan L. Higgins, "Mathematics Programs are Changing", N.A.S.S.P. Curriculum Reports, 40 (December 1974), 56-58.

this study.

The use of the term calculator in this paper implies that consideration is being given to the performance characteristics of the hand-held calculator. The calculators used in this study were able to add, subtract, multiply, and divide, plus perform chain and mixed calculations.

CHAPTER II

REVIEW OF LITERATURE

There were two basic problems in conducting the review of literature. Firstly, the early literature reviewed relates to the use of the desk calculator in the classroom, as opposed to the hand calculator. Secondly, much of the research that has been conducted refers to the use of the calculator in the mathematics classroom, not the science classroom. Although these studies do not relate directly to this particular study, the dependent variables relied on the use of the calculator. These studies were, therefore, considered relevant for this research.

Previous Studies

Studies were reported by Fehr, McMean and Sobel,[11]

---

[11]H. F. Fehr, George McMean and Max Sobel, "Using Hand-Operated Computing Machines in Learning Arithmetic," The Arithmetic Teacher, 3, No. 10 (1956), 145-150.

Ellis and Corum,[12] and Keough and Burke,[13] suggesting that the calculator improves student performance in mathematical computation. In these studies, homogeneous groups not using calculators established control for the experiment. The length of time for these studies ranged from four months to a full school year with the sample size ranging from sixty-one to three hundred students. These results differ from those of Longstaff, who found that there was no difference in the level of achievement between grade nine and grade five students using the calculator in arithmetic and those not using it. However, Longstaff did observe that the low ability students, who used the calculator, displayed more positive attitudes towards mathematics than those low ability students who did not use the calculator.[14]

Another test which analyzed the effect of using desk

---

[12]June Ellis and Al Corum, Functions of the Calculator in the Mathematics Laboratory for Low-Achievers, 1969, (ERIC ED 040 847).

[13]John J. Keough and Gerald W. Burke, Utilizing an Electronic Calculator to Facilitate Instruction in Mathematics in the Eleventh and Twelfth Grades, July 1969, (ERIC ED 037 345).

[14]F. R. Longstaff, Desk Calculators in the Mathematics Classroom, June 1968, (ERIC ED 029 498).

calculators on the attitudes and achievement of low achieving ninth graders, was conducted by Cech. Based on his analysis, Cech concluded that the use of calculators did not have a significant effect on student attitudes. Furthermore, he concluded that the use of the calculator did not result in any significant improvements of computational skills.[15]

The most extensive study conducted on hand calculators was that of Glasin. With treatment groups of ninth graders in general mathematics, ranging in number from 31 to 48 students, he compared the achievements and attitudes of students who use conventional based algorithms for operations on positive rational numbers, with students who use algorithms which were dependent on the use of the hand calculator.

Glasin's study is based on the instruction to three separate groups. One group performed operations on positive rational numbers according to the usual text approaches, while the second group used the conventional set of algorithms with the calculator. The third group used an alternative algorithmic procedure, where each fractional operand is converted

---

[15]J. Cech, "The Effect of the Use of the Desk Calculator on Attitude and Achievement with Low-Achieving Ninth Graders", Mathematics Teacher, 65 (February 1972), 183-186.

to a decimal using the calculator, and the indicated operation is then performed on the calculator. The five units of instruction taught were addition, subtraction, multiplication, division, and operating on fractions. The students attitude towards mathematics was then measured. Upon completion of each unit, students were given a posttest, after which they began a two week retention period. At the end of the two week period, students completed a fractional retention test.

Using the .05 level of significance, the results of the investigation suggested that, when computational skill with rational numbers is the goal of instruction, the alternative algorithm set with the calculator appears to be a viable alternative to the conventional method of teaching fractions to low ability and low achieving students. When the goal is to develop computational skill with rational numbers, via the conventional methods, use of a calculator does not significantly and consistently affect performance. However, use of an alternative algorithm, which uses the electronic calculator, can produce success for slow learning children.[16]

---

[16]William L. Glasin, "A Comparison of Achievement and Attitudes of Students Using Conventional or Calculator Based Algorithms for Operations on Positive Rational Numbers in Ninth Grade General Mathematics," Research in Mathematics Education, 6, No. 2 (March 1975), 95-108.

A recent investigation employing the hand calculator was conducted by Schnur and Lang. The sample size consisted of sixty students, aged nine to fourteen, all of whom were seeking remedial assistance in arithmetic. The researchers concluded that the incorporation of the minicalculator can yield significantly higher results in the performance of arithmetic computation (.001 level of significance). This increase in achievement was accomplished over a four week period.[17]

The effect of the use of a calculator during an examination is also of interest to the educator. A study in the fall quarter of 1973, by Sosebee and Walsh, made a comparison of students using a calculator during an examination, with those students not using a calculator. One hundred and sixty-nine first year college chemistry students were asked if they had used a calculator during the examination period. The resulting performance outcome showed a level of confidence greater than 99.5% in favor of those students who had used the calculator for the examination. No effort, however, was

---

[17]James O. Schnur and Jerry W. Lang, "Just Pushing Buttons or Learning? - A Case for Minicalculators," Arithmetic Teacher, 23, No. 11 (1976), 559-562.

made to find the interaction of the students' use of a calculator during the testing time with his use during class time. Furthermore, students were not randomly assigned to one group or the other; yet, Sosebee and Walsh still suggest that calculators play a major role in the determination of introductory chemistry grades.[18]

Summary

Although research has been conducted to study the effect of the calculator on achievement, these studies, apart from the work of Glasin, have used the calculator to check work, and then check the effect of this immediate reinforcement on achievement. Results of the research by Fehr, McMean and Sobel,[19] Glasin,[20] and Schnur and Lang[21] provide statistical evidence that use of the calculator does improve computational proficiency as compared to the pencil and paper method.

---

[18]Sosebee and Walsh, op. cit., p. 324.

[19]Fehr, McMean and Sobel, loc. cit.

[20]Glasin, loc. cit.

[21]Schnur and Lang, loc. cit.

The studies by Cech[22] and Longstaff[23] have provided the documentation that calculator usage has no effect upon computational skill as compared to the pencil and paper method.

Donald R. Quinn summarizes the calculator research to date with the following statements:

Students--a) learn to operate calculators easily at almost any grade level,

b) compute better with calculators than without,

c) are able to tackle more "real-life" problems,

d) suffer no loss of paper and pencil computational ability, and

e) enjoy using calculators.[24]

---

[22] Cech, loc. cit.

[23] Longstaff, loc. cit.

[24] Donald R. Quinn, "Calculators in the Classroom," N.A.S.S.P. Bulletin, 60 (January 1976), 77-80.

CHAPTER III

DESIGN OF THE STUDY

Questions

To evaluate the effect of the use of the calculator during the instruction of science units and during testing, a comparison was made with students not using the calculator during either of these times. The dependent measures in the study consisted of: performance in science, performance in arithmetic, and attitude to science. The questions dealt with are summarized below.

The first question concerns the effect of the use of the calculator during instruction on the dependent measures: What will be the effect of using the calculator during instruction on the dependent measures (as indicated above)?

The second question dealt with the use of the calculator during testing: What effect will using the calculator during testing have on the dependent measures?

A third question attempted to point out if there was any difference in attitude or performance in arithmetic from beginning to completion of the program: Will there be a difference in attitude to science, or in performance in arithmetic, upon entering and terminating the program of studies? Another question similar to question three is: What will the effect of the time of testing have on the performance in science as measured by post and retention tests?

Question four attempted to find out if there was any interaction among the independent variables: What is the interaction of the independent variables; instruction and testing, instruction and time of testing, testing and time of testing, and instruction, testing and time of testing?

Other questions which were considered included the following: How are the dependent measures related to one another?, and What rating was given to each concept on each of the scales of the semantic differential used to measure attitude toward science?

Operationalization of Variables

Performance in science was measured by an achievement test described in the section Description and Selection of Instruments.

Performance in arithmetic operations was measured by a Group Test of Speed and Accuracy in Arithmetic Computation: Dominion Test. Performance in arithmetic will consist of three parts: speed, accuracy, and achievement. Each of these facets will be measured as defined by the Group Test of Speed and Accuracy.[25]

Attitudes to science will be measured by the Attitude Survey[26] described in the section Description and Selection of Instruments. The four facets of Attitude measured will be: "What I learned in this science course", "How I feel about this science course", "Science student", and "Science teacher".

Instruction is an independent variable which refers to teaching the science units with or without the calculator.

Testing is an independent variable and refers to having or not having the calculator available for use on the examination.

---

[25]The Dominion Tests, Group Tests of Speed and Accuracy in Arithmetic Computation, Form A and Form B, Department of Educational Research, Ontario College of Education, 1955.

[26]Martin, loc. cit.

Time of testing is an independent variable and refers to the time at which the measures are taken, as a pretest, posttest or retention test.

Procedure

Initially, verbal permission from the principal and the teachers in the science department of a Winnipeg High School was requested. Once permission was obtained at the school level, the Inter-University School Research Committee was approached by letter. Approval to conduct the study was then obtained from the committee (see appendix A).

The length of instructional time was the same for all subjects involved in the study. This instructional time consisted of twenty-eight classroom periods, each fifty minutes in length, over a time span of approximately two and one half months. The time span was chosen on the basis of similar studies by Glasin,[27] and Schnur and Lang.[28]

A test was constructed to measure the level of performance in science. The test was designed to measure the

---

[27]Glasin, loc. cit.

[28]Schnur and Lang, loc. cit.

student achievement of instructional objectives as cited in appendix B. The validation was performed through careful preparation of the test questions, in order to eliminate any errors and ambiguities. Furthermore, four teachers were used in order to determine the suitability of the questions. The teachers were told to assess the questions, keeping in mind that all calculations are to be done manually in one fifty-minute period.

In order to minimize the error, due to the zeal of the teacher, the two classes were taught by the same teachers; the researcher and a staff member from the Gordon Bell High School. The control group (the class without calculators) began the study with the researcher and, after fourteen periods, were transferred into the classroom taught by the staff member. Similarly, the experimental group transferred classrooms after fourteen periods.

At the first meeting, the students participating in the experiment were told that they would be taking part in an experiment to determine the effects of the use of the calculator in science outcomes. They were also told that all work was to be performed during class times only, and that there was to be no work done at home.

The students were then randomly assigned to one of the four treatments. The four treatments of the two groups within each class were as follows:

Treatment 1: The students were taught the science unit and were asked to use the calculator for all the necessary arithmetic. These students were allowed the use of the calculator on all performance testing in science.

Treatment 2: The students received the same treatment as the above group, except they were not allowed the use of the calculator during performance testing in science.

Treatment 3: The students were taught the same science unit as those in treatments one and two, and they were allowed the use of the calculator only during the performance test in science.

Treatment 4: The same as treatment three, except the students were not allowed the use of the calculator at any time.

Diagramatically, the structure of the experiment would appear as shown in Table 1.

TABLE 1

Structure of Experiment

Instruction	Testing	Time of Testing: Pretest	Post test	Retention Test
Calculator	Calculator			
	No Calculator			
No Calculator	Calculator			
	No Calculator			

The pretest and posttest were given to measure the variable performance in science, performance in arithmetic operations, and attitude to science, as defined in the section <u>Operationalization of Variables</u>. The retention test was used to measure only the dependent variable--performance in science. The pretest and posttest used to measure performance in arithmetic, took place without the use of the calculator. The pretest of performance in science, was given to determine the students prior knowledge on the topics "Heat" and "Work". None of the students demonstrated prior knowledge in these topics. As a result, no students were deleted from the program. Also at this time, those students using the calculator during testing were given some instruction in its operation.

Course Content

The first criteria for selecting the material to be instructed in this study was that it satisfy the grade ten requirements of the high school science department. The second requirement was that the instructional units stress practical mathematical manipulations and contain a need for the fundamentals of arithmetic.

As a result, units on "Heat" and "Work" were selected. Work in these units included a considerable amount of practical science mathematics which gave quick and practical results. The basics for the unit on "Heat" was that of chapter eleven of the Introductory Physical Science textbook,[29] the "Work"

---

[29]Educational Services Incorporated, Introductory Physical Science (Englewood Cliffs, N. J.: Prentice-Hall 1972).

unit was taken from Interaction of Matter and Energy.[30]

The general instruction in the concepts of "Heat" and "Work" was a combination of teacher lectures, demonstrations, and student lab activities. The general sequence of instruction was that, firstly, a rationale of the topic was given, and secondly, the teacher, through lecture and demonstration, then described the lab activity. Next in turn, was the lab activity itself. The students worked in pairs, after which they summarized the lab with written reports that were handed to the teacher. Following this was a drill on the theory in the form of verbal questions and student worksheets. This sequence was then repeated for the next lab activity. At the end of the units, the students were given a quiz on the theory.

The general course content and the objectives of the course are given in appendix B.

Selection and Description of the Sample

The subjects used in this study were grade ten

---

[30]Norman Abraham, Patrick Balch, Donald Chaney and Lawrence M. Rohrbaugh, Interaction of Matter and Energy (Chicago: Rand McNally, 1968).

students registered in science at a Winnipeg High School. The high school, a large academic school located in a major urban centre, has a combined junior and senior high system, grades seven to twelve. The school is quite progressive, as it has innovated new programs in the past. The students ranged in ability from "phase one" to "phase three", as grouped by the school's science department. This meant that the students were representative of about 75% of the school's population.

A piloting of the instruments indicated that the variance for performance in science and attitude to science, as measured by concept 1, "What I learned in this science course", concept 2, "How I feel about this science course", concept 3, "Science student", and concept 4, "Science teacher", are as follows: 17.092, 128.743, 259.393, 246.275, and 323.254, respectively. These figures were used as approximations of error variance. Cell sizes were calculated with a desire to point out meaningful differences of one standard deviation between treatment groups. The desire to point out meaningful differences of one standard deviation was chosen because of a desire to point out a large effect size. Brewer suggests that a large effect size is greater than .8 standard deviation.[31] The power of the test was arbitrarily set at 95% for the level of significance at .05.

The treatment group requirement for tests of main effects was ten, and for first order interactions, sixteen. This meant that in order to perform the study with a power of 95% on first order interaction, 64 subjects were required.

Unfortunately, because of timetable restrictions and a limited facility, only 40 students could be made available. Therefore, the actual power would be greater than 95% for main effects, but only 64% for first order interactions. Cohen suggests that if nothing can be done about low power, the research should be run and H_0 tested. If H_0 is not rejected, the failure may be due to low power, or H_0 may be true.[32]

Description and Selection of Instruments

The measurement of the dependent measures was made

---

[31]James K. Brewer, "On the Power of Statistical Tests in the American Educational Research Journal," American Educational Research Journal, 9, No. 3 (Summer 1972), 394.

[32]Jacob Cohen, "Statistical Power Analysis and Research Results," American Educational Research Journal, 10, No. 3 (Summer 1973), 227.

by both standardized tests and project-developed tests. Prior to the study, the instruments used to measure attitude and performance were tested. A week later, the instruments were retested with the same group of students who had a knowledge of the material to be instructed in the study. The results of the piloting of the instruments indicate that the test-retest reliability for performance in science was 0.82. As for the four facets of attitude, measured by the concepts "What I learned in this science course", "How I feel about this science course", "Science student", and "Science teacher", test-retest reliabilities were 0.91, 0.91, 0.80, and 0.86, respectively. These measures indicate that the results of the test should remain constant over time.

Performance Testing in Science

Performance testing will be a measure of the students achievement of instructional objectives, as stated in appendix E. Performance testing, or achievement testing, has been the traditional means by which the evaluation of instructional objectives has taken place in the past. Taylor and Cowley state that, in the past, program evaluation was equated almost exclusively with the administration of a standardized test accompanied by a comparison of two groups.[33]

Program evaluation has developed to the point where achievement testing is no longer standardized. Stake indicates that standardized achievement tests are inadequate for curriculum evaluation.[34] Project developed achievement testing provides an alternative to standardized achievement testing.

Computational Ability in Arithmetic Operations

The test selected was the Group Test of Speed and Accuracy in Arithmetic Computation.[35] The test designed for students in grades five to ten, in the four operations of addition, subtraction, multiplication, and division with whole numbers, measured three facets of computational ability: speed, accuracy, and achievement. The reliability between form A and B of the test, as cited by the publisher was

---

[33]P. Taylor and D. Cowley, "New Dimensions of Evaluation," Readings in Curriculum Evaluations, eds. Taylor and Cowley (Dubuque, Iowa: Wm C. Brown Co., 1972), 1.

[34]R. Stake, "Toward a Technology for the Evaluation of Educational Programs," Perspectives in Curriculum Evaluation, ed. B. Othanel Smith (Chicago: Rand McNally and Co., 1968), 6.

[35]The Dominion Tests, loc. cit.

0.91, 0.64, and 0.91, respectively, for speed, accuracy, and achievement (see appendix C).

Attitudes

As indicated by Shaw and Wright, attitudes are the end products of the socialization process, and they significantly influence man's responses to cultural products, to other persons and to groups of persons.[36] If one can determine the attitude of a person toward a given object, or class of objects, then this information can be used in conjunction with situational and other dispositional variables to predict and explain reactions of the person to that class of objects.

Cronbach stated "attitudes are prominent among the outcomes with which course developers are concerned".[37] Evaluators must attempt to measure these attitudes, and attempt to relate them to the program as a whole.

In this study, a semantic differential was used to

---

[36]M. E. Shaw and J. M. Wright, Scales for the Measurement of Atttitudes (New York: McGraw-Hill, 1967).

[37]L. Cronbach, "Course Improvement Through Evaluation," Teachers' College Record, 64, No. 8 (1963), 673.

evaluate attitudes. The semantic differential consists of a number of bipolar adjective pairs, separated by a seven point space. A number of such pairs are placed with a given concept and a subject is asked to rate each set of adjectives in relation to the concept.

Since the purpose of this study was not to design an instrument for measuring attitudes, a search was made to find a suitable instrument. After careful consideration, the writer decided to use the semantic differential as designed by Garth Martin.[38] The rationale for this decision is as follows:

1. The test was designed for a group of science students.
2. The group of students used in this study are similar in age and ability to those used in Martins' investigation.
3. The instrument is clear and concise.

This instrument was used with the permission of the author (see appendix D).

---

[38] Martin, loc. cit.

Structural Model

Kirk, using the design presented in this chapter, suggests a structural model to help answer questions one to four cited in the first section of chapter three.[39] The model will answer the preceding question for the variates, attitude to science as measured by the concepts: "What I learned in this science course", "How I feel about this science course", "Science student", and "Science teacher"; performance in science, and, speed, accuracy and achievement in arithmetic.

The model, and an explanation of the symbols used in it, are as follows:

$$X_{ijkm} = \mu + \alpha_i + \gamma_k + \alpha\gamma_{ik} + \pi_{m(ik)} + \beta_j + \alpha\beta_{ij} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + \beta\pi_{jm(ik)} + \varepsilon_{ijkm}$$

The components of the model are defined for each dependent variable:

X: dependent variable (person's score on criterion),

μ: mean of all subjects in the study on the dependent variable,

---

[39]Roger E. Kirk, Experimental Design: Procedures for the Behavioral Sciences (Belmont, California: Wadsworth Publishing Company, Inc., 1968), 283.

α: effect due to use of the calculator during instruction,

γ: effect due to use of the calculator during testing,

β: effect due to time of testing,

π: effect due to individual differences,

ε: residual error,

i: levels of instruction, i = 2,

j: levels of testing, j = 2,

k: levels of time of testing, k = 2,

m: levels of students.

Hypotheses

To answer the questions cited earlier, a series of null hypotheses were stated based on the preceding structural model:

Question 1; effect due to instruction:

$$H_{01}: \alpha_j = 0,$$

Question 2; effect due to testing:

$$H_{02}: \beta_k = 0,$$

Question 3; effect due to time of testing:

$$H_{03}: \gamma_m = 0.$$

The null hypotheses, which test for interaction, are the following:

H_{04}: $(\alpha\beta)_{jk} = 0$,

H_{05}: $(\alpha\gamma)_{jm} = 0$,

H_{06}: $(\beta\gamma)_{km} = 0$,

H_{07}: $(\alpha\beta\gamma)_{jkm} = 0$.

Statistical Procedures

If any inferential statistical procedures are to be used in analyzing the data, certain assumptions about that data must be satisfied.[40] Tests were carried out on this data to validate the assumptions prior to using any inferential statistical procedures.

In order to draw proper inferences from the analysis of the data, the data must fulfill two important assumptions. The first assumption regarding the data is that it is normal in distribution. In this study, population normality was inferred from measures of skewness and kurtosis on the dependent variables. The second assumption is that of homogeneity of variance for the dependent variables. The assumption of

---

[40] W. James Popham and Kenneth A. Sirotnik, Educational Statistics Use and Interpretation, second edition (New York: Harper and Row, 1973), 208.

homogeneity of variance will be tested by means of the $\underline{F}_{max}$ test, as recommended by Kirk.[41]

The statistical tests used in this study were the Analysis of Variance, and the Pearson Product Moment Correlation. Lindquist has noted that these statistical tests are reliable in spite of mild variations in the assumptions of normality and homogeneity of variance.[42] As a result of these observations, the assumptions of normality and homogeneity of variance will be tested at the .01 level of significance.

Assumptions

A number of assumptions had to be made with regard to the students, the instruments, and the program of studies. Firstly, the assumption was made that the students answered the questions on the performance and attitude tests to the best of their ability. Secondly, the order in which the program of studies was given did not affect the performance. The third assumption was that there was no arithmetic practice

---

[41]Kirk, loc. cit.

[42]E. F. Lindquist, "The Norton Study of the Effects of Non-normality and Heterogeneity of Variance," Contemporary Problems in Statistics, ed. Bernhardt Lieberman (Toronto: Oxford University Press, 1971), 358.

from pretest to posttest. This assumption was made after a discussion with the mathematics teachers of the school revealed that the mathematic topics studied by these classes were taken from geometry. The fourth assumption was that there was no further learning of the concepts taught in the course from posttest to retention test. The topics taught to the students following the study were on crystallography, and involved no mathematics.

The final assumptions were that students did all of the work during class time and that those students who were provided with the calculators used them.

CHAPTER IV

ANALYSIS OF RESULTS

Descriptive Statistics

Reported in Table 2 are: sample size, theoretical expected mean, mean, range, variance, maximum and minimum, and measures of skewness and kurtosis. These statistics are reported for the pretests and posttests of the four concepts of attitude. In the tables which follow, concept one will refer to the attitude measured by "What I learned in this science course", concept two will refer to "How I feel about this science course", concept three will refer to the "Science student", and concept four will refer to the "Science teacher". Also reported in Table 2 are the statistics for the pretest and posttest for speed, accuracy, and achievement in arithmetic, as well as the posttest and retention test for performance in science.

As shown in Table 2, the sample size was 36 with a mortality rate of 10% (one student from each of the four treatment groups). The theoretical expected mean is simply the midpoint of the possible range of scores. A comparison, between the pretest means and the expected means, indicates that the subjects tend to respond markedly toward the positive end. A possible explanation of this is that the test was designed for students ranging from grade five to grade ten. Since these students are in grade ten, results to the higher end of the scale should be expected. A comparison, between the expected mean of performance in science with the actual mean, shows that the results are slightly below the expected means, and that the performance test was slightly difficult. The maximum and minimum scores indicate that the instruments can discriminate, since the absolute maximum and minimum bounds were achieved in only three cases; one subject received a score of zero on the posttest and retention test in performance in science, while another received a zero in the retention test.

A characteristic of the data is that the range of scores decreased from pretest to posttest for all measures except achievement in arithmetic. Another characteristic is that the variance for all but two of the measures decreased from pretest to posttest, for all measures except attitude

TABLE 2

Descriptive Statistics

Statistics	Attitude: Concept 1 Pre	Concept 1 Post	Concept 2 Pre	Concept 2 Post	Concept 3 Pre	Concept 3 Post	Concept 4 Pre	Concept 4 Post	Accuracy Pre	Accuracy Post	Arithmetic Speed Pre	Arithmetic Speed Post	Achievement Pre	Achievement Post	Performance Post	Performance Retention
Sample Size	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Theoretical Expected Mean	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	71.5	71.5	143	143	200	200	14	14
Mean	73.306	71.639	69.944	70.861	70.139	75.167	75.667	75.833	87.417	94.972	187.778	206.944	339.694	335.194	13.389	11.139
Range	73.000	52.000	75.000	58.000	71.000	58.000	74.000	69.000	92.000	87.000	166.000	136.000	102.000	164.000	26.000	24.000
Variance	212.047	193.094	251.368	237.723	192.237	189.286	256.343	258.029	439.279	421.285	1462.806	1292.054	637.532	1455.990	51.673	38.809
Maximum Score	97.000	91.000	95.000	93.000	93.000	99.000	105.000	98.000	138.000	141.000	267.000	273.000	391.000	394.000	26.000	24.000
Minimum Score	24.000	39.000	20.000	35.000	22.000	41.000	31.000	29.000	46.000	54.000	101.000	137.000	289.000	230.000	0.000	0.000
Skewness	-1.016**	-0.885	-0.752	-0.651	-1.177**	-0.693	-0.734	-0.874	0.399	0.028	-0.013	0.105	-0.404	-0.624	-0.026	0.047
Kurtosis	2.286**	0.088	1.581	-0.242	2.944**	0.138	1.022	0.567	-0.023	-0.523	-0.291	-0.518	-0.250	0.321	-0.774	-0.693

**significant at .01

toward the science teacher and achievement in arithmetic. There is no apparent reason for these characteristics of the two sets of measures.

The measures of skewness were tested at the .01 level of significance. Two of the variables showed significant negative skewness: the pretest for attitude toward "What I learned in this science course", and the pretest for attitude toward "Science student". Thus, the direction of skewness indicates that the majority of students responded to the positive end of the scale.

The measures of kurtosis were also tested at the .01 level of significance. Two of the variables showed significance: the pretest for attitude toward "What I learned in this science course", and the pretest for attitude toward "Science student". As a result, the kurtosis of the two variables were leptokurtic, indicating an extreme bunching of the scores near the mean.

Variable Intercorrelations

The non-normal distribution of data for the measures attitude toward "What I learned in this science course", and toward "Science student", may affect the Pearson Product

Moment Correlation. Norris and Hjelm undertook a study in an attempt to pin down any effects of non-normality on Pearson's *r*. In general, the study concluded that for populations where there were no correlations the sampling distributions based on non-normal populations did not differ markedly from those where the theoretical assumptions of normality could be met. However, for populations where there were significant correlations the level of significance was inflated by departures from normality. The proportion of significant coefficients was from two to more than seven times greater than those obtained for normal populations.[43]

As a result of departures in normality in the data, the decision was made to establish a more stringent cutoff to maintain the level of significance at .05. On the basis of the study reported above, the level of significance for those concepts in attitude which have shown departures in normality is reported at the .01 level. The level of significance for correlations between all other variables is reported

---

[43]Raymond C. Norris and Howard F. Hjelm, "Non-Normality and Product Moment Correlation," *Reading in Statistics for the Behavioral Sciences*, ed. Emil F. Heermann and Larry A. Braskamp (Englewood-Cliffs, New Jersey: Prentice Hall, 1970), 349-360.

at the .05 level.

The Pearson Product Moment Correlations were calculated between all possible pairs of variables. The level of significance is reported at the .05, .01, and .001 levels. Significant correlations existed between all pretest and posttest measures on the same variable, except for concept four, attitude toward the "Science teacher". A possible explanation of this is that the students were taught by different teachers prior to the experiment.

All intercorrelations between the pretest and post-test for speed, accuracy and achievement in arithmetic are significant. This indicates that results of the pretest are good predictors of future performance in these aspects of arithmetic over time.

Further to the above, all tests of attitude are positively correlated. Also, most of the tests are significant; the exception being concept four, which does not give significant intercorrelations with the pretest and posttest for concepts one and two. An explanation of this is that concept four assessed the attitude towards two sets of different teachers.

The posttest and retention test measures of perfor-

TABLE 3

Pearson Correlation Coefficients

			Attitude: Concept 1 Pre	Attitude: Concept 1 Post	Attitude: Concept 2 Pre	Attitude: Concept 2 Post	Attitude: Concept 3 Pre	Attitude: Concept 3 Post	Attitude: Concept 4 Pre	Attitude: Concept 4 Post	Accuracy Pre	Accuracy Post	Arithmetic Speed Pre	Arithmetic Speed Post	Achievement Pre	Achievement Post	Performance Post	Performance Retention
Attitude	Concept 1	Pre																
		Post	.3634**															
	Concept 2	Pre	.8687***	.2697*														
		Post	.4193**	.9471***	.3380**													
	Concept 3	Pre	.7158***	.3636**	.8286***	.4387**												
		Post	.4261**	.4165**	.5210***	.4865***	.7564***											
	Concept 4	Pre	.4838***	.1248	.6477***	.1857	.4863***	.3682**										
		Post	.1610	.7835***	.0657	.8085***	.2731*	.4025**	.1813									
	Accuracy	Pre	-.0237	.1201	.0634	.0855	.0700	-.0157	-.1835	-.1166								
		Post	.0335	.2373	.1091	.1967	.0849	-.0032	-.1653	-.0001	.9152***							
Arithmetic	Speed	Pre	-.0168	.1446	.0552	.0942	.0894	.0189	-.2267	-.1211	.9516***	.8649***						
		Post	.0135	.1898	.1057	.1578	.0788	.0139	-.1839	-.0893	.8987***	.9297***	.9270***					
	Achievement	Pre	-.0150	-.1067	.0643	-.0990	-.0076	-.1265	-.0333	-.1581	.6068***	.5542***	.3721*	.3338*				
		Post	-.0159	.1916	-.0134	.1302	.0072	-.0381	-.1113	.1401	.5076***	.6661***	.3526*	.3673*	.7164***			
Performance		Post	-.0484	.3653**	-.1317	.2897*	.0201	.1975	-.2953*	.3049*	.4904***	.4646**	.4434**	.3502*	.3887**	.4671**		
		Retention	-.1202	.3927**	-.1524	.3125*	-.0039	.1537	-.2712*	.3197*	.5322***	.4874***	.4574**	.3561*	.4796**	.5273***	.9009***	

*significant at .05
**significant at .01
***significant at .001

mance in science, and the four concepts of attitude, are all positively correlated. Three of these four measures are significant, indicating that the measures of attitude are a fair predictor of performance in science. Furthermore, the measures of arithmetic correlated significantly with the measures of performance in science.

An interesting feature of the correlation matrix is that the pretest of attitudes does not correlate positively with speed, accuracy, and achievement in arithmetic or with performance in science. There is no apparent reason for the lack of positive correlation.

Test for Homogeneity of Error Terms

Before considering the analysis of variance to be an appropriate test of the null hypotheses, the data must conform to the assumption of homogeneity of variance and covariance. Homogeneity of each of the error terms; mean square of subjects within groups and the mean square of the time of testing crossed with subjects within groups, can be tested by means of the F_{max} test. The procedure is outlined by Kirk.[44] The

[44]Kirk, loc. cit.

results of the partitioning of the two error terms and the $\underline{F}_{max}$ ratios are shown in appendix F.

Since the Analysis of Variance test is quite robust with respect to the assumptions of normality and homogeneity of variance,[45] the $\underline{F}_{max}$ test was tested at the .01 level of significance. The results of the test of homogeneity of variance are shown in Tables 15 to 22 inclusive. The $\underline{F}_{max}$ test indicates that the assumption of homogeneity of the partitioned parts of the within cell variance is no significant at the .01 level.

In the test for the equality of the correlations between the repeated measures, the $\underline{F}_{max}$ test proved to be significant in the following cases: the attitude of students toward concept one "What I learned in this science course", concept three "Science student", and concept four "Science teacher". In addition to being heterogeneous in variance, the data for concepts one and three were also non-normal. However, in both cases the treatment populations have the same distribution, that is, negatively skewed and leptokurtic.

---

[45] G. E. P. Box, "Non-normality and Tests on Variance," Biometrika, 40 (1953), 318-335.

According to Myers, the combination of two violations, heterogeneity of variance and non-normality, is not especially worse than heterogeneity of variance alone, provided that all treatment populations have the same distribution function.[46]

Studies cited by Myers indicate that the level of significance is inflated by heterogeneity of variance. If all treatment groups are of the same size and approximately normally distributed, the inflation is slight. In a computerized experiment run by Myers, with two groups equal in size and a twenty to one variance ratio, the $\underline{F}$'s required for significance at the .01 and .05 levels were exceeded in .02 and .07, respectively, of the experiments run.

In order to alleviate the problem of non-normal data and heterogeneity of variance, the decision was made to establish a more stringent cutoff level to maintain the level of significance. On the basis of the study reported by Myers, the level of significance was arbitrarily changed to the .03 level from .05 for those concepts in attitude which have shown departures from normality and homogeneity of variance.

---

[46] Jerome L. Myers, Fundamentals of Experimental Design, second edition (Boston: Allyn and Bacon, Inc., 1973), 70-75.

This adjustment was an attempt to keep the actual level of significance at approximately .05, despite the change in the actual test level of significance.

Analysis of Variance Results

The independent variables were instruction, testing, and time of testing; the dependent measures were scores on each test. The results of the analysis of variance is given in Tables 4 and 5. The *F*-statistic generated involves a ratio of mean squares between groups to mean squares within groups. Each of the effects involving time of testing (K), was tested against time of testing (K) crossed with subjects within groups effect. The remaining effects were tested against the effect due to subjects within groups.

From Table 4, null hypothesis H_{03} was rejected at the predetermined level of .03, the *F*-ratio being 10.30260 with 1 and 32 degrees of freedom. All other null hypotheses, with respect to the four concepts of attitude, could not be rejected.

The rejection of H_{03} means that time of testing did have an effect on students scores, on the concept "Science student". An examination of Table 6, on cellular means, indicates that subjects scored lower before receiving the treatments (70.13 before, and 76.88 after).

An examination of Table 5 indicates that H_{01} can be rejected for performance in science; and H_{03} for speed and accuracy in arithmetic, and performance in science, at the .05 level of significance. All other null hypotheses with respect to arithmetic and performance in science could not be rejected.

Examination of the cellular means of Table 6 shows that subjects achieved lower scores on the two facets of arithmetic, speed and accuracy, before instruction (mean over four groups 187.86 for speed, and 87.41 for accuracy), than after instruction (206.94 for speed, and 94.97 for accuracy). The rejection of these two hypotheses indicates that time of testing did have some effect on student performance of speed and accuracy in arithmetic.

The rejection of H_{01} for performance in science indicates that there is an effect, due to instruction. Examination of cellular means indicates that the groups using the calculators during instruction (mean 14.83) achieved higher test scores than the group not using the calculator during instruction (mean 9.72). Rejection of H_{03}

TABLE 4

Analysis of Variance for Speed, Accuracy and Achievement in Arithmetic and Performance in Science

Source of Variance	df	Accuracy MS	F	df	Arithmetic Speed MS	F	df	Achievement MS	F	df	Performance MS	F
I: Instruction	1	5.56250	0.00205	1	45.11719	0.04922	1	50.06250	0.03412	1	400.16504	5.02426*
J: Testing	1	193.31250	0.07110	1	30.67578	0.03347	1	355.43750	0.15149	1	13.46924	0.16911
I x J	1	84.50000	0.03108	1	13.34375	0.01456	1	501.37500	0.21369	1	0.94458	0.01186
Subjects Within Groups (IJ)	32	2718.90625		32	916.56836		32	2346.29688		32	79.64650	
K: Time of Testing	1	6922.16797	62.59599***	1	1035.12500	28.49521***	1	162.00391	0.41381	1	75.00104	21.17010***
K x I	1	256.88354	2.50381	1	86.68018	2.38616	1	193.38672	0.49397	1	4.67180	1.31868
K x J	1	93.38721	0.91023	1	28.12476	0.77423	1	9.38672	0.02398	1	6.89418	1.94598
K x I x J	1	1.38867	0.01354	1	1.12500	0.03097	1	22.21875	0.05675	1	6.15338	1.73688
K x Subjects Within Groups (IJ)	32	102.59709		32	36.32628		32	391.49683		32	3.54278	

* significant at .05
** significant at .01
*** significant at .001

TABLE 5

Analysis of Variance for Concept 1, Concept 2, Concept 3, and Concept 4 in Attitudes

Source of Variance	Concept 1 df	Concept 1 MS	Concept 1 F	Concept 2 df	Concept 2 MS	Concept 2 F	Concept 3 df	Concept 3 MS	Concept 3 F	Concept 4 df	Concept 4 MS	Concept 4 F
I: Instruction	1	373.53906	1.34005	1	506.66016	1.48863	1	34.72656	0.09739	1	37.54688	0.12090
J: Testing	1	449.98828	1.61431	1	165.00391	0.48480	1	180.48828	0.50618	1	150.22656	0.48373
I x J	1	490.89063	1.76105	1	678.35156	1.99309	1	20.05078	0.05623	1	98.00000	0.31556
Subjects Within Groups (IJ)	32	278.74951		32	340.35229		32	356.56787		32	310.56079	
K: Time of Testing	1	46.71875	0.35083	1	19.01172	0.11137	1	480.50000	10.30260***	1	0.88672	0.00392
K x I	1	6.71875	0.05045	1	13.34375	0.07816	1	68.05518	1.45920	1	0.88672	0.00392
K x J	1	180.49609	1.35542	1	21.12109	0.12372	1	60.49976	1.29720	1	80.21875	0.35480
K x I x J	1	6.71875	0.05045	1	10.12109	0.05929	1	112.49927	2.41214	1	10.88672	0.04815
K x Subjects Within Groups (IJ)	32	133.16626		32	170.71460		32	46.63873		32	226.09190	

* significant at .05
** significant at .03
*** significant at .01
**** significant at .001

TABLE 6

Cellular Means (each cell has 9 subjects)

Instruction	Testing	Measure		Time of Testing Pre	Post
Calculator	Calculator	Attitude	Concept 1	65.00	66.33
			Concept 2	63.22	64.77
			Concept 3	67.55	77.33
			Concept 4	75.88	74.00
		Arithmetic	Accuracy	87.88	91.66
			Speed	187.66	201.00
			Achievement	345.33	334.77
		Performance		16.11*	13.55**
	No Calculator	Attitude	Concept 1	78.11	72.11
			Concept 2	72.88	71.22
			Concept 3	72.77	75.55
			Concept 4	67.11	76.00
		Arithmetic	Accuracy	87.88	94.77
			Speed	190.33	208.00
			Achievement	342.44	334.33
		Performance		16.55*	13.11**
No Calculator	Calculator	Attitude	Concept 1	73.88	75.44
			Concept 2	72.22	75.44
			Concept 3	68.33	70.88
			Concept 4	79.77	79.22
		Arithmetic	Accuracy	87.22	96.00
			Speed	185.00	205.66
			Achievement	336.11	336.00
		Performance		10.33*	10.22**
	No Calculator	Attitude	Concept 1	76.22	72.66
			Concept 2	70.44	72.00
			Concept 3	71.88	75.77
			Concept 4	73.22	74.11
		Arithmetic	Accuracy	86.66	97.44
			Speed	188.44	213.11
			Achievement	334.88	335.55
		Performance		10.55*	7.77**

* Posttest for performance in science
** Retention test for performance in science

for performance in science and an examination of cellular means also shows that students achieved higher scores on the posttest for performance in science (mean 13.39) than the retention test (mean 11.16).

Findings Related to Attitude

Osgood states that the affective domain is made up of several components. In an analysis of 76 scales from *Roget's Thesaurus*, Osgood distinguished eight factors or major components of the semantic space. Ten of the fifteen scales used in the researcher's study were chosen from those scales used by Osgood. These ten scales were characteristic of four of the eight components distinguished by Osgood. From his study the scales high in the evaluation factor were: good-bad, pleasurable-painful, meaningful-meaningless, important-unimportant, positive-negative, and wise-foolish. The scale high in the potency factor was heavy-light. The scale high in the activity factor was complex-simple; and the scales high in the receptivity factors were colorful-colorless and interesting-boring.[47]

---

[47] C. Osgood, G. Suci and P. Tannenbaum, *The Measurement of Meaning* (Urbana: University of Illinois Press, 1957), 47-66.

The above method of categorizing scales has been used previously in studies by Ashley,[48] Ashley and Butts,[49] and Butts and Raun.[50]

The fact that only one scale was used in describing the factors potency and activity was of some concern. However, this number of scales was used in a previous study by Butgow.[51] As a result of Butgow's study this number of scales was considered to be viable for this study.

The questions asked, the hypotheses stated, and the structural model used with regard to these factors of attitude

---

[48]James P. Ashley, "A Study of the Impact of an Inservice Education Program on Teacher Behavior" (unpublished Ph. D. dissertation, University of Texas at Austin, August 1967), 157.

[49]James P. Ashley and David P. Butts, "A Study of the Impact of an Inservice Education Program on Teacher Behavior," Research and Curriculum Development in Science Education, Vol. 2, Curriculum Implementation in Elementary School Science, ed. David P. Butts (Austin: Science Education Centre University of Texas, December 1970), 96-116.

[50]David P. Butts and Chester E. Raun, "A Study of Teacher Attitude Change," Research and Curriculum Development in Science Education, Vol. 2, Curriculum Implementation in Elementary School Science, ed. David P. Butts (Austin: Science Education Centre University of Texas, December 1970), 151-155.

[51]J. Butgow, "A Semantic Differential Science Interest Test," School Science and Mathematics, 74, No. 8 (1974), 189-196.

parallel those used in Chapter III. The difference in this parallel being that the dependent measures consist of the four factors evaluation, potency, activity and receptivity for each of the four components.

To answer the questions, separate factor scores were computed for each subject. An evaluation score was computed by summing over the six evaluation scales (a possible range of score from 6 to 42); a potency score over the one potency scale (range 1 to 7); an activity score over the one activity scale (range 1 to 7); and a receptivity score over the two receptivity scales (range 2 to 14). This was done for the pretest and posttest ratings.

Tables 7, 8, 9 and 10 report the sample size, theoretical expected mean, mean, range, maximum and minimum and measures of skewness and kurtosis for the pretest and posttest of the factor score for each concept. The measures of skewness and kurtosis were tested at the .01 level of significance.

Departures from normality were observed for the following: the pretest for the evaluation factor for concepts one, two and three; the posttest for evaluation for concept four; the pretest for the potency factor for concept three; the posttest for the activity factor for concept one, and the pretest for receptivity for concept three.

As a result of the departures from normality, together with the fact that 106 tests were performed in the Analysis of Variance (chance alone might make some tests significant), a more stringent cutoff was used and significance was reported at the .01 level. The Analysis of Variance results for the four factors under each of the concepts are given in Tables 11 to 14.

Tables 11 and 13 indicated that null hypotheses H_{03} were rejected for the factor potency for concept one and the factor evaluation for concept three. An examination of the means from pretest to posttest from Tables 7 and 9 indicate that students are more favorable toward the concept "Science student" than had previously been judged. Further examination of Table 7 reveals that students also felt that what they learned in this science course was more powerful than what they had previously learned.

Null hypothesis H_{04} was rejected for the factor receptivity under concept two. An examination of Figure 1 illustrates the interaction between the two independent variables instruction and testing. The graph of the means of the four treatment groups indicates that the group not using the calculator during testing was more receptive when instructed without the calculator than when the calculator was used during instruction. There does not seem to be an explanation for this effect on the receptivity factor for concept two.

No other null hypotheses could be rejected for any other factor over any other concept. These results would seem to indicate that there was either no significant change in attitude for any factor towards any concept, or, changes that did occur were parallel changes for all groups.

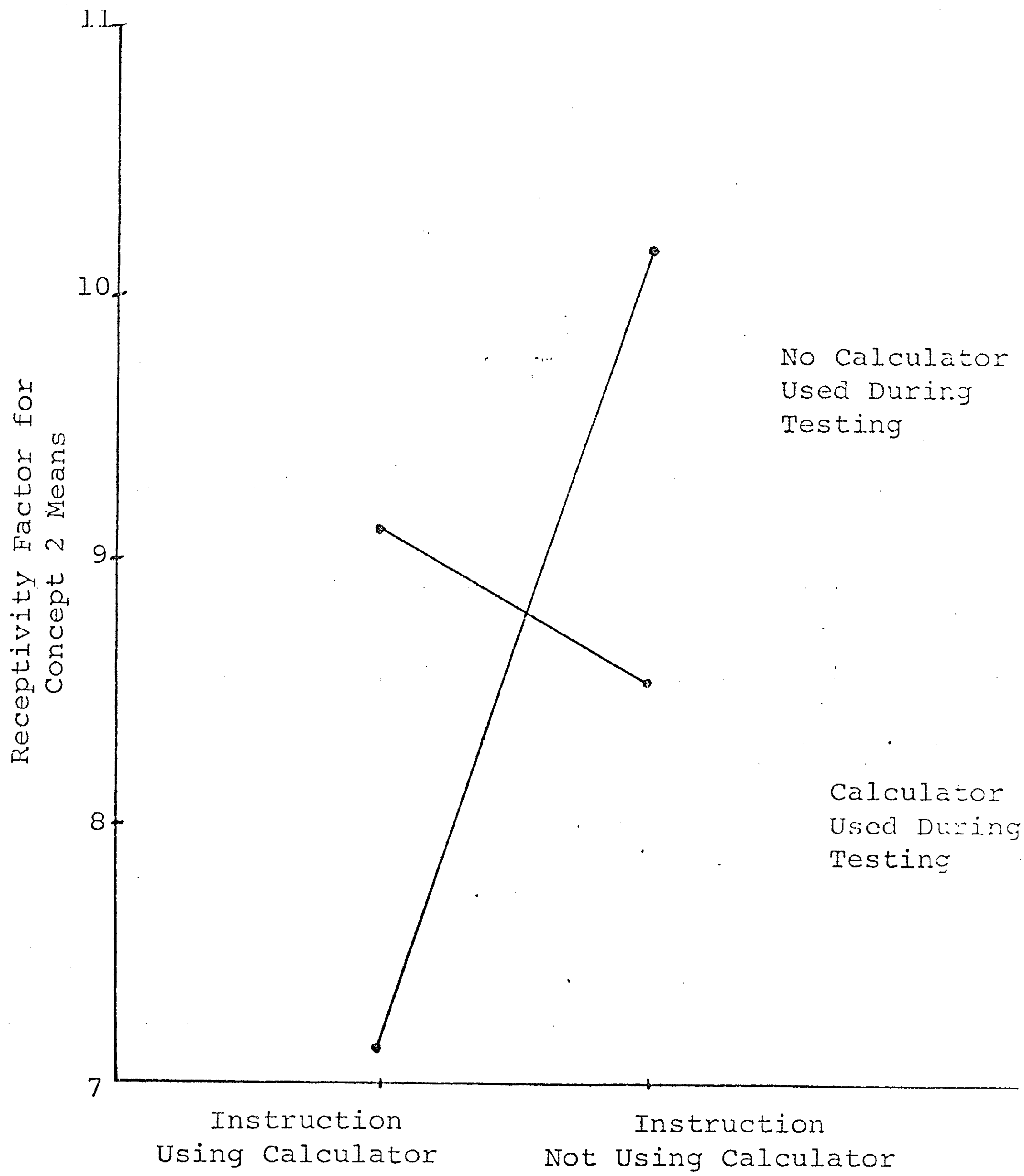

Figure 1: Receptivity Factor for Concept 2:
Instruction-Testing
Interaction Effect

TABLE 7

Descriptive Statistics for Factor Scores for Concept 1:

"What I Learned in This Science Course"

Statistics	Evaluation Pre	Evaluation Post	Potency Pre	Potency Post	Activity Pre	Activity Post	Receptivity Pre	Receptivity Post
	Concept 1							
Sample Size	36	36	36	36	36	36	36	36
Theoretical Expected Mean	24	24	4	4	4	4	8	8
Mean	31.639	32.111	3.639	4.444	4.306	4.639	9.000	9.056
Range	31.000	25.000	5.000	6.000	6.000	6.000	12.000	11.000
Variance	42.409	38.502	1.380	2.425	3.875	2.980	7.657	7.368
Maximum Score	41.000	42.000	6.000	7.000	7.000	7.000	14.000	14.000
Minimum Score	10.000	17.000	1.000	1.000	1.000	1.000	2.000	3.000
Skewness	-1.044**	-0.719	-0.802	-0.467	-0.120	-0.284	-0.488	-0.806
Kurtosis	2.361**	-0.263	0.580	-0.037	-1.260	-1.102**	-0.045	-0.074

**significant at .01

TABLE 8

Descriptive Statistics for Factor Scores for Concept 2:

"How I Feel About This Science Course"

Statistics	Concept 2 Evaluation Pre	Evaluation Post	Potency Pre	Potency Post	Activity Pre	Activity Post	Receptivity Pre	Receptivity Post
Sample Size	36	36	36	36	36	36	36	36
Theoretical Expected Mean	24	24	4	4	4	4	8	8
Mean	30.278	31.694	4.056	4.472	4.139	4.917	8.389	9.028
Range	35.000	27.000	6.000	6.000	6.000	6.000	12.000	12.000
Variance	53.749	50.504	2.054	2.485	4.066	2.307	9.673	7.913
Maximum Score	42.000	41.000	7.000	7.000	7 000	7.000	14.000	14.000
Minimum Score	7.000	14.000	1.000	1.000	1.000	1.000	2.000	2.000
Skewness	-1.017**	-0.694	-0.719	-0.201	-0.134	-0.577	-0.228	-0.609
Kurtosis	2.023**	-0.196	0.698	-0.496	-1.078	-0.170	-0.846	-0.025

**significant at .01

TABLE 9

Descriptive Statistics for Factor Scores for Concept 3:

"Science Student"

Statistics	Concept 3							
	Evaluation		Potency		Activity		Receptivity	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Sample Size	36	36	36	36	36	36	36	36
Theoretical Expected Mean	24	24	4	4	4	4	8	8
Mean	28.222	31.611	3.972	4.111	4.083	4.139	9.361	10.111
Range	34.000	28.000	5.000	5.000	6.000	6.000	12.000	10.000
Variance	43.778	36.930	0.599	1.816	1.964	2.294	7.152	4.902
Maximum Score	40.000	42.000	6.000	6.000	7.000	7.000	14.000	14.000
Minimum Score	6.000	14.000	1.000	1.000	1.000	1.000	2.000	4.000
Skewness	-0.930	-0.898	-0.734	-0.512	-0.222	-0.301	-1.018**	-0.700
Kurtosis	2.371**	1.185	7.650**	-0.008	0.424	-0.448	1.694	0.478

**significant at .01

TABLE 10

Descriptive Statistics for Factor Scores for Concept 4:

"Science Teacher"

Statistics	Concept 4 Evaluation Pre	Evaluation Post	Potency Pre	Potency Post	Activity Pre	Activity Post	Receptivity Pre	Receptivity Post
Sample Size	36	36	36	36	36	36	36	36
Theoretical Expected Mean	24	24	4	4	4	4	8	8
Mean	31.972	32.778	3.750	4.194	4.333	4.833	9.417	10.083
Range	34.000	35.000	6.000	6.000	6.000	6.000	12.000	12.000
Variance	60.942	56.921	2.021	2.561	3.314	2.543	8.993	8.307
Maximum Score	45.000	42.000	7.000	7.000	7.000	7.000	14.000	14.000
Minimum Score	11.000	7.000	1.000	1.000	1.000	1.000	2.000	2.000
Skewness	-0.669	-1.422**	-0.478	-0.026	-0.408	-0.831	-0.259	-0.854
Kurtosis	0.596	2.847**	0.617	-0.228	-0.809	0.317	-0.465	0.470

**significant at .01

TABLE 11

Analysis of Variance for Four Factor Scores for Concept 1:

"What I Learned in This Science Course"

Source of Variance	Evaluation df	Evaluation MS	Evaluation F	Potency df	Potency MS	Potency F	Activity df	Activity MS	Activity F	Receptivity df	Receptivity MS	Receptivity F
I: Instruction	1	3.12622	0.05186	1	0.68060	0.24749	1	2.00008	0.37871	1	26.88940	2.80180
J: Testing	1	74.01660	1.22779	1	0.01387	0.00504	1	2.72215	0.51544	1	9.38892	0.97830
I x J	1	136.12549	2.25805	1	1.68051	0.61110	1	0.22223	0.04208	1	37.55444	3.91307
Subjects Within Groups (IJ)	32	60.28456		32	2.74999		32	5.28124		32	9.59718	
K: Time of Testing	1	4.01392	0.19248	1	11.68048	10.57861**	1	2.00000	1.12281	1	0.05554	0.01360
K x I	1	3.12500	0.14985	1	3.12498	2.83019	1	6.72221	3.77389	1	0.88889	0.21769
K x J	1	19.01367	0.91175	1	4.01387	3.63522	1	0.88889	0.49903	1	12.49988	3.06120
K x I x J	1	0.01367	0.00066	1	0.34721	0.31446	1	1.38889	0.77973	1	0.88889	0.21769
K x Subjects Within Groups (IJ)	32	20.85403		32	1.10416		32	1.78124		32	4.08333	

**significant at .01

TABLE 12

Analysis of Variance for Four Factor Scores for Concept 2:

"How I Feel About This Science Course"

Source of Variance	Evaluation			Potency			Activity			Receptivity		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F
I: Instruction	1	66.13135	0.90402	1	0.68060	0.23673	1	0.05556	0.01155	1	25.68115	3.06769
J: Testing	1	78.12744	1.06801	1	1.68050	0.58452	1	7.99985	1.66351	1	0.12500	0.01493
I x J	1	62.34692	0.85229	1	1.12497	0.39129	1	0.0	0.0	1	58.67920	7.00941**
Subjects Within Groups (IJ)	32	73.15265		32	2.87499		32	4.80902		32	8.37148	
K: Time of Testing	1	36.12476	1.05861	1	3.12498	1.78571	1	10.88882	5.75412	1	7.34717	0.90543
K x I	1	0.34717	0.01017	1	6.12497	3.49999	1	0.0	0.0	1	3.12476	0.38508
K x J	1	0.34717	0.01017	1	0.12498	0.07142	1	0.05554	0.02935	1	0.01367	0.00168
K x I x J	1	8.68042	0.25437	1	1.12498	0.64285	1	0.50000	0.26422	1	0.34717	0.04278
K x Subjects Within Groups (IJ)	32	34.12483		32	1.74999		32	1.89235		32	8.11456	

**significant at .01

TABLE 13

Analysis of Variance for Four Factor Scores for Concept 3:

"Science Student"

Source of Variance	Evaluation df	Evaluation MS	Evaluation F	Potency df	Potency MS	Potency F	Activity df	Activity MS	Activity F	Receptivity df	Receptivity MS	Receptivity F
I: Instruction	1	24.49585	0.35466	1	0.01387	0.01040	1	1.99989	0.72632	1	2.34668	0.24000
J: Testing	1	107.55884	1.55726	1	0.01387	0.01040	1	4.49991	1.63427	1	0.12476	0.01276
I x J	1	14.22144	0.20590	1	0.68053	0.51040	1	0.50000	0.18159	1	6.12451	0.62637
Subjects Within Groups (IJ)	32	69.06917		32	1.33333		32	2.75347		32	9.77774	
K: Time of Testing	1	206.72144	14.82469**	1	0.34721	0.30302	1	0.05554	0.03326	1	10.12492	3.57351
K x I	1	0.50000	0.03586	1	3.12498	2.72727	1	0.05554	0.03326	1	5.01385	1.76960
K x J	1	17.99976	1.29082	1	0.68054	0.59393	1	0.22221	0.13305	1	0.68054	0.24019
K x I x J	1	3.55542	0.25497	1	0.68054	0.59393	1	0.22221	0.13305	1	4.01389	1.41667
K x Subjects Within Groups (IJ)	32	13.94440		32	1.14583		32	1.67013		32	2.83332	

**significant at .01

TABLE 14

Analysis of Variance for Four Factor Scores for Concept 4:

"Science Teacher"

Source of Variance	Evaluation			Potency			Activity			Receptivity		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F
I: Instruction	1	10.12695	0.14496	1	0.49994	0.20279	1	0.22218	0.06237	1	0.88892	0.08620
J: Testing	1	74.01025	1.05939	1	0.05554	0.02253	1	14.22191	3.99212	1	20.05469	1.94470
I x J	1	51.68115	0.73977	1	4.49995	1.82534	1	0.05554	0.01559	1	3.55518	0.34475
Subjects Within Groups (IJ)	32	69.86105		32	2.46527		32	3.56250		32	10.31246	
K: Time of Testing	1	11.68042	0.21547	1	3.55554	1.65161	1	4.49998	2.03774	1	7.99976	1.02762
K x I	1	0.12476	0.00230	1	5.55554	2.58065	1	3.55554	1.61006	1	1.38887	0.17841
K x J	1	11.68042	0.21547	1	1.99998	0.92903	1	0.88887	0.40251	1	0.0	0.0
K x I x J	1	7.34692	0.13553	1	0.0	0.0	1	1.38887	0.62892	1	0.49998	0.06423
K x Subjects Within Groups (IJ)	32	54.20815		32	2.15277		32	2.20833		32	7.78471	

**significant at .01

CHAPTER V

SUMMARY

In general, the purpose of this study was to examine the effect of the calculator on science-related outcomes. The outcomes consisted of the students' performance in science, their attitude to some facet of science (four components), plus speed, accuracy and achievement in arithmetic.

In this investigation, 18 grade ten students were instructed in two science units, both of which involved fundamental operations in arithmetic. These 18 students were then compared to another group of 18 students who were taught without the use of the calculator. Other factors which were also considered included the effect of calculator usage during testing, and the effect of time of testing.

The criteria involved an assessment of the degree of achievement in the two science units, an assessment of student attitudes to the program, and an assessment of student performance in speed, accuracy and achievement in arithmetic.

All students were tested on the dependent measure prior to and after the instruction. The performance test in science was also given three weeks after the termination of instruction.

The effects of instruction, testing, and time of testing were examined using an Analysis of Variance. The dependent measures were correlated to estimate their relationship. The dependent variable intercorrelations generally suggest that these variables are positively related. Thus, it shows that the feeling towards the course and towards what was learned in the course is related to performance in science. It also shows that arithmetic skills and performance in science are positively related.

The only concept from the semantic differential which was affected was attitude toward the concept "Science student". All four groups rated this concept higher from pretest to posttest. No other hypotheses were rejected for attitude. This indicates that the type of instruction does not affect attitude to a great degree.

The results of the Analysis of Variance suggest that there is a significant effect in achievement in science, due to instructional type. The results favored the group using the calculator during instruction. All groups showed a significant effect in performance in science from posttest to retention test, with higher scores on the posttest.

The four groups also showed significant differences in arithmetic performance in the facets speed and accuracy, from pretest to posttest. It did not seem to matter what instructional type was used, since student performance increased for both groups. No null hypotheses were rejected for the dependent measure, performance in arithmetic. This suggests that the type of instruction, with or without the calculator, has no significant effect on arithmetic performance.

Implications of the Study

The results of the study suggests that students of similar age and background will score higher on mathematical problem-oriented units in science, if they use a calculator during class time. At the same time, there is very little difference in attitude among the two groups, and no loss in computational ability in arithmetic.

The results of the study also imply that when problem-oriented science tests are made up, keeping in mind that calculations are to be done manually, there is no effect due to the use of the calculator during testing.

Limitations

The findings of the study are limited for the following reasons:

1. Due to the small sample size, there is a low power for first order interactions.
2. Performance testing in science was problem testing only.
3. No consideration was given to sex differences of the sample.
4. The sample was representative of only 75% of the school's population.
5. No consideration was given to the age of the students in the sample, nor to the possibility that some may have repeated grades.

Suggestions for Further Research

As stated by Glasin, some educators have the opinion that the advent of a machine-based curriculum would lead to machine-dependent learners.[52] The students in this study showed no dependence on the calculator to perform arithmetic

---

[52]Glasin, loc. cit.

computations quickly and accurately. However, this investigation was over a relatively short period of time, and this opinion might be further researched over an extended time span.

This study could have been improved by a greater sample size. A larger sample size will improve the possibility of showing differences due to interaction.

Hopefully, additional uses of the hand-held calculator in the science classroom will be developed. It is logical to propose that machine use could allow some aspects of many topics that are currently omitted.

REFERENCES

Abraham, Norman, Patrick Balch, Donald Chaney, and Lawrence M. Rohrbaugh. Interaction of Matter and Energy. Chicago: Rand McNally, 1968.

Ashley, James P. "A Study of the Impact of an Inservice Education Program on Teacher Behavior." Unpublished PhD dissertation, University of Texas at Austin, 1967.

Beck, Lois L. "A Report on the Use of Calculators," The Arithmetic Teacher, 7, No. 2 (1960), 103.

Bell, Max S. "Calculators in Elementary Schools? Some Tentative Guidelines and Questions Based on Classroom Experience," The Arithmetic Teacher, 23, NO. 11 (1976), 502-09.

Boyle, Patrick J. "Calculator Charades," The Mathematics Teacher, 99, No. 4 (1976), 281-84.

Box, G. E. P. "Non-Normality and Tests on Variance," Biometrika, 40, 1953, 318-35.

Brewer, James K. "On the Power of Statistical Tests in the American Educational Research Journal," American Educational Research Journal, 9, No. 3 (Summer, 1972), 391-401.

Butgow, J. "A Semantic Differential Science Interest Test," School Science and Mathematics, 74, No. 8 (1974), 189-96.

Butts, David P. Research and Curriculum Development in Science Education, Vol. 2, Curriculum Implementation in Elementary School Science. Austin: University of Texas, 1970.

Cech, Joseph P. "The Effect of the Use of the Desk Calculator on Attitude and Achievement with Low-Achieving Ninth Graders," Mathematics Teacher, 65, No. 2 (1972), 183-86.

Cohen, Jacob. "Statistical Power Analysis and Research Results," American Educational Research Journal, 10, No. 3 (Summer, 1973), 225-30.

Cronbach, L. "Course Improvement Through Evaluation," Teachers College Record, 64, No. 8 (1963), 672-83.

Dayton, C. Mitchell, William D. Schafer, and Bruce G. Rogers. "On Appropriate Uses and Interpretations of Power Analysis: A Comment," American Educational Research Journal, 10, No. 3 (Summer, 1973), 231-34.

Educational Services Incorporated. Introductory Physical Science. Englewood Cliffs, N. J.: Prentice-Hall, 1972.

Ellis, June and Al Corum. Functions of the Calculator in the Mathematics Laboratory for Low-Achievers. Miami: 1969. (ERIC ED 040 847).

Fehr, H. F., George McMeen, and Max Sobel. "Using Hand-Operated Computing Machines in Learning Arithmetic," The Arithmetic Teacher, 3, No. 10 (1956), 145-50.

Glasin, William L. "A Comparison of Achievement and Attitudes of Students Using Conventional or Calculator Based Algorithms for Operations on Positive Rational Numbers in Ninth Grade General Mathematics," Research in Mathematics Education, 6, No. 2 (March, 1975), 95-108.

Heerman, Emil F. and Larry A. Braskamp, eds. Reading in Statistics for the Behavioral Sciences. Englewood Cliffs, New Jersey: Prentice-Hall, 1970.

Higgins, Jan L. "Mathematics Programs are Changing," Educational Digest, 40 (December, 1974), 56-58.

Immerzsel, George. "The Hand-Held Calculator," The Arithmetic Teacher, 23, NO. 4 (1976), 230-31.

Keough, John J. and Gerald W. Burke. Utilizing an Electronic Calculator to Facilitate Instruction in Mathematics in the Eleventh and Twelfth Grades. New York: July, 1969. (ERIC ED 037 345).

Kerlinger, Fred N. Foundations of Behavioral Research. New York: Holt, Rinehart and Winston, 1973.

Kirk, Roger E. Experimental Design: Procedures for the Behavioral Sciences. Belmont, California: Wadsworth Publishing Company, Inc., 1968.

Kirk, Roger E. Statistical Issues: A Reader for the Behavioral Sciences. California: Brooks/Cole Publishing Company, 1972.

Lieberman, Bernhart, ed. Contemporary Problems in Statistics. Toronto: Oxford University Press, 1971.

Longstaff, F. R. Desk Calculators in the Mathematics Classroom. Ottawa: June, 1968. (ERIC ED 029 498).

Machloivitz, E. "Electronic Calculator-Friend or Foe of Instruction," Mathematics Teacher, 69, No. 2 (1976), 104-06.

Maguire, Thomas O. "Semantic Differential Methodology for the Structuring of Attitudes," American Educational Research Journal, 10, No. 4 (Fall, 1973), 299-306.

Martin, Garth. "An Evaluation of the Physical Science 201 and 301 Programs in Manitoba." Unpublished Masters dissertation, University of Manitoba, 1975.

Myers, Jerome L. Fundamentals of Experimental Design. 2d ed. Boston: Allyn and Bacon, Inc., 1972.

Osgood, C., G. Suci, and P. Tannenbaum. The Measurement of Meaning. Urbana: University of Illinois Press, 1957.

Pendleton, Deede. "Calculators in the Classroom," Science News, 107, No. 11 (March 1975), 175-81.

Popham, W. James and Kenneth A. Sirotnik. Educational Statistics Use and Interpretation. 2d ed. New York: Harper and Row, 1973.

Quinn, Donald R. "Calculators in the Classroom," NASSP Bulletin, 60 (January, 1976), 77-80.

Schnur, James O. and Jerry W. Lang. "Just Pushing Buttons or Learning-A Case for Minicalculators," The Arithmetic Teacher, 23, No. 11 (1976), 559-62.

Shaw, M. E. and J. M. Wright. Scales for the Measurement of Attitudes. New York: McGraw-Hill, 1967.

Shere, Worris. "Some Calculating Moves are Needed in the Classroom," The Winnipeg Tribune, May 9, 1977, 9.

Shumway, Richard J. "Hand Calculators: Where Do You Stand?," The Arithmetic Teacher, 23, No. 11 (1976), 569-72.

Smith, B. Othanel, ed. Perspectives in Curriculum Evaluation. Chicago: Rand McNally and Co., 1968.

Sosebee, Jackson and Lola Walsh. "Pocket Calculators and Test Scores in Introductory Chemistry," Journal of College Science Teaching, 4, No. 5 (1975), 324.

Stultz, L. "Electronic Calculators in the Classroom," The Arithmetic Teacher, 22, No. 2 (1975), 135-38.

Taylor, P. and D. Cowley. "New Dimensions of Evaluation," Readings in Curriculum Evaluation. Iowa: Wm C. Brown Co., 1972.

APPENDICES

APPENDIX A

CORRESPONDENCE

SWAN VALLEY REGIONAL SECONDARY SCHOOL

TELEPHONE 734-4511 — BAG SERVICE NO. 1

SWAN RIVER, MANITOBA ROL 1ZO

PRINCIPAL
L. E. HARAPIAK, B.A., B.ED.

VICE-PRINCIPAL
J. D. BAKER, B.A., B.ED.

February 10, 1977

Mr. Ted Keating
83 Lindcrest Road
Winnipeg, Manitoba

Dear Ted:

Please accept this as a letter of permission for use of the semantic differential from the thesis An Evaluation of the Physical Science 201 and 301 Program in Manitoba, 1975.

Yours truly,

Garth E. Martin

GM/hdp

REQUEST FOR SCHOOL RESEARCH SAMPLE

Date Feb. 2/77

Name of Project An Experimental Study of some of the effects of th use of the Calculator in Grade Ten Scien

Name of Experimenter(s) Ted Keating

Reason for Study

( ) Faculty Research
( ) Ph.D. Dissertation
( ) Predoctoral Research
(x) M.Ed. Thesis
( ) Student Research (Year 1 2 3 4)**
( ) Pilot Study

** Circle appropriate year

Proposed Research Sample(s)

Schools: ( ) Pre-School
( ) Elementary
( ) Jr. High School
(x) Sr. High School

Indicate School(s) of preference:

Gordon Bell

Other groups (agency, institution, organization, etc you intend to contact:

I. Research Proposal:

A. Title and design of study, including hypotheses, description of task(s): (Continue on back of this sheet.) (Attach a copy of the questionnaire or test if one is being used.)

The subject matter which is to be taught in this study will consist of units on heat and work as regularily taught in grade ten science at Gordon Bell. The teaching will be done by experienced classroom teachers. The testing sessions will be the only time required of students beyond that of regular classroom time, and this can be considered as valuable review.

The purpose of my investigation is to consider the following problem: What is the effect of the use of the calculator on science related outcomes? The outcomes chosen for this study are performance in science, attitude to some facets of science (four components), and performance in arithmetic operations.

The educational research and development in this field is relatively new. The possibility of supplying public schools with calculators will increase as the price decreases. The National Council of Teachers of Mathematics has recommended that every student be introduced to the calculator by the eigth grade. Thus there is a need for research in this field.

The study can be broken down into two more specific problems. Is there a positive effect on teaching of science concepts that involve mathematics operations due to use of the calculator? Secondly, is there a negative effect on the performance of the student who has been using the calculator in class, and has it taken away from him when writing an examination?

For the design of the study, hypotheses and description of tasks, please see attached sheets.

B. Type of response required of child: classroom type tests; see dependent measures

C. Reward, if any: None

II. Subjects:

A. Children needed: Number 40 Age 15 - 16 Sex M & F

B. Special Characteristics: Science Students

C. Number of ~~sessions~~ per child: 8 weeks teaching ~~3 testing periods approximately~~

Approximate length of each session: 50 mins/period ~~testing session 40-50 mins.~~

Testing Procedure individual ______ group x

size of group 20

III. Sample Characteristics:

(Indicate below whether a random sample of classes or schools is necessary or if a stratified sample is required).

40 students in two regular classrooms will randomly be assigned to the treatments.

IV. Facilities and equipment:

(Indicate facilities needed and equipment to be used that must be obtained from the school).

None

Persons conducting research: Ted Keating Telephone: ______

______ " ______

______ " ______

Faculty member supervising research. ______ Telephone: ______

University: University of Manitoba

Beginning Date of research: Feb.14/77 Anticipated completion: Apr. 4/77

COMPLETE AND RETURN AS SOON AS POSSIBLE TO RESEARCH COORDINATOR.

THE UNIVERSITY OF WINNIPEG
WINNIPEG, CANADA R3B 2E9

February 9, 1977

Mr. Ted Keating
c/o Dr. A. M. McPherson
Department of Curr. and Instruction (Mathematics)
Ed. Building
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

Dear Mr. Keating:

I am pleased to report that the Inter-University School Research Committee has approved your research proposal and wishes you the best of luck in its conduct.

Sincerely yours,

Gary Granzberg
Co-Chairman

GG/js

c.c. R. Longfield
D. Berg

APPENDIX B

COURSE CONTENT AND OBJECTIVES

COURSE CONTENT

A. Work and Simple Machines

1. Work and Friction

   - work
   - coefficient of friction
   - efficiency of machines

2. Inclined Plane

   - inclined plane
   - advantages
   - mechanical advantage

3. Lever

   - the lever
   - advantages
   - work and the lever

4. Pulleys

B. Heat

1. Quantity of Heat: The Calorie

   - heating different substances

2. Specific Heat

   - heat lost by a substance in cooling
   - specific heat of a solid

3. Heat of Reaction

4. Heat of Fusion

5. Heat of Vaporization

OBJECTIVES FOR UNITS ON WORK AND HEAT

General Instructional Objectives	Specific Learning Outcomes
Understands the measurement of work	- is able to compute the work done by simple machines using the formula Work = Force X Distance
Knows how to calculate the coefficient of friction	- understands the meaning of force of friction - calculates the coefficient of friction using the formula $K = \frac{F}{N}$
Understands the measurement of mechanical advantage	- is able to compute the mechanical advantage of the simple machines, the inclined plane, the lever, and the pulley system
Understands the measurement of efficiency	- is able to compute the efficiency of an inclined plane, a lever and a pulley system
Understands the measurement of heat	- is able to compute the heat gained or lost by a substance using the formula Heat = Mass X Specific Heat X Change in Temperature
Measures the heat of reaction and comprehends the cause	- measures the heat of reaction for a chemical reaction
Measures the heat of fusion	- measures the heat of fusion of ice to water
Measures the heat of vaporization	- measures the heat of vaporization of water to steam

APPENDIX C

EXCERPTS FROM THE ARITHMETIC TESTS

Administration of the Test

Administration of the Test. (The parts below in CAPITALS are to be read aloud, carefully and distinctly, by the examiner.)

When the examiner is certain that all the necessary preliminaries have been attended to, he says:

THIS IS A TEST IN SPEED AND ACCURACY IN ARITHMETIC. I AM GOING TO GIVE EACH OF YOU ONE OF THESE BOOKLETS. DO NOT OPEN IT UNTIL I TELL YOU TO DO SO. (Examiner distributes the tests, taking care to see that none is opened, and keeping a copy for himself.)

NOW FILL IN THE INFORMATION ASKED FOR ON THE COVER PAGE OF YOUR BOOKLET. (Examiner either tells the pupils to go ahead on their own, or says: AFTER "NAME" PRINT YOUR NAME IN CAPITALS, YOUR LAST NAME FIRST, THEN YOUR FIRST NAME. Examiner continues in this way until all the blanks have been filled in.)

Examiner then says:

NOW LISTEN CAREFULLY TO WHAT I SAY. THE DIRECTIONS ON THE COVER PAGE OF YOUR BOOKLET TELL YOU HOW TO DO THE TEST. LOOK AT THE DIRECTIONS AND READ THEM SILENTLY AS I READ THEM ALOUD.

The examiner then reads the first paragraph of the directions aloud from his copy of the test. While the second row of sample questions is being done by the pupils, the examiner walks around and checks their work. When these examples have been completed, examiner says:

THE CORRECT ANSWER FOR THE 1st QUESTION IS 1539. THE CORRECT ANSWERS FOR THE OTHER THREE QUESTIONS ARE: 2nd QUESTION, 437; 3rd QUESTION, 11,822; 4th QUESTION, 12, REMAINDER 5. ARE THERE ANY QUESTIONS? (Examiner makes any necessary explanations.)

Examiner then reads aloud the remaining paragraph. When he is sure that the pupils understand what they are to do, the examiner takes his copy of the test booklet, without letting the pupils open theirs, and says:

WHEN I TELL YOU TO DO SO, OPEN YOUR BOOKLET AND START AT TEST 1. IF YOU FINISH A TEST AHEAD OF TIME, CHECK YOUR WORK, BUT ON THAT TEST ONLY. DO NOT TURN TO ANOTHER PAGE OR CHECK AN EARLIER TEST.

YOU ARE TO ANSWER THE QUESTIONS BY ROWS: FIRST, THE TOP ROW, THEN THE SECOND ROW, AND SO ON, LIKE THIS (demonstrate). DO YOUR WORK AS QUICKLY AND ACCURATELY AS YOU CAN. YOU WILL NOT LIKELY FINISH ALL THE QUESTIONS IN THE TIME ALLOWED. YOU ARE TO START WORK AS SOON AS I SAY "BEGIN" AND YOU MUST STOP WHEN I SAY "STOP".

NOW OPEN YOUR BOOKLET TO TEST 1, AND FOLD BACK THE PAGE LIKE THIS (demonstrate). (Pause) REMEMBER THAT YOU ARE TO ADD. READY - BEGIN! (Examiner records the time on the Timing Form or uses his stop-watch.)

After exactly 5 minutes, say:

STOP! TURN TO TEST 2, AND FOLD BACK THE PAGE LIKE THIS (demonstrate). (Pause) REMEMBER THAT IN THIS TEST YOU ARE TO SUBTRACT. READY - BEGIN! (Examiner records the time.)

After exactly 5 minutes, say:

STOP! TURN OVER YOUR BOOKLET TO TEST 3. (Pause) REMEMBER THAT IN THIS TEST YOU ARE TO MULTIPLY. READY - BEGIN! (Examiner records the time.)

After exactly 6 minutes, say:

STOP! TURN OVER TO TEST 4, AND FOLD BACK THE PAGE LIKE THIS (demonstrate). (Pause) REMEMBER THAT IN THIS TEST YOU ARE TO DIVIDE. SHOW ANY REMAINDER IN THE USUAL PLACE. DO NOT SPEND TIME CHANGING A REMAINDER TO A FRACTION OR A DECIMAL. READY - BEGIN! (Examiner records the time.)

After exactly 6 minutes, say:

STOP! PLACE YOUR PENCIL ON YOUR DESK. CLOSE YOUR BOOKLET.

Examiner collects booklets immediately.

Sample Questions

ADD

Test 1

A

719 800 193	796 848 527	309 790 930	417 918 954	709 622 430	441 398 840
681 916 566	127 656 827	667 659 837	289 460 576	841 424 784	225 937 809
963 306 122	504 806 270	683 738 498	462 801 844	837 524 819	540 755 819

SUBTRACT

Test 2

A

829 107	243 210	856 127	805 131	470 402	812 737
548 260	521 439	856 368	923 756	171 102	751 658
512 381	940 610	479 209	906 129	400 269	983 850

MULTIPLY

Test 3

A

27 51	71 69	40 67	740 20	32 37
28 25	96 84	35 82	916 75	53 50

DIVIDE

Test 4

A

8)436	7)552	8)828	16)659
9)610	18)196	12)201	22)337

Scoring

Types of Scores. Three types of scores are obtained from the test, for each of the four subtests and for the total test:

1. The Achievement Score is the number of items correct.
2. The Speed Score is obtained by substituting the corresponding values in the following formula:

$$\frac{\text{No. Items Attempted}}{\text{Time of Test}} \times 10.$$

3. The Accuracy Score is obtained by substituting the corresponding values in the following formula:

$$\frac{\text{No. Items Correct}}{\text{No. Items Attempted}} \times 100.$$

DATA CHART

	Test 1 Add.	Test 2 Subt.	Test 3 Mult.	Test 4 Div.	Total Test
Total No. of Items	42	60	25	16	143
Time of Test (in minutes)	5	5	6	6	22
No. of Items Correct					
No. of Items Wrong					
Total No. Attempted (No. Correct + No. Wrong)					
SCORES: Achievement (No. Items Correct)					
Speed $\left(\frac{\text{No. Items Attempted}}{\text{Time of Test}} \times 10\right)$					
Accuracy $\left(\frac{\text{No. Items Correct}}{\text{No. Items Attempted}} \times 100\right)$					

APPENDIX D

SEMANTIC DIFFERENTIAL

Attitudes Toward A Science Program

The purpose of this study is to measure your attitude toward the Science program you are now taking by having you judge certain ideas against a series of descriptive scales. In taking this test, please make your judgements on the basis of what these ideas mean to you. On each page of this booklet you will find a different idea to be judged and beneath it a set of scales. You are to rate the idea on each of these scales in order.

Here is how to use these scales:

If you feel the concept at the top of the page is very closely related to one end of the scale you should place your check mark as follows:

Fair X : _ : _ : _ : _ : _ : _ Unfair

or

Fair _ : _ : _ : _ : _ : _ : X Unfair

If you feel that the concept is quite closely related to one or the other end of the scale (but not extremely), you should place your check-mark as follows:

Good _ : X : _ : _ : _ : _ : _ Bad

or

Good _ : _ : _ : _ : _ : X : _ Bad

If the concept seems only slightly related to one side as opposed to the other side (but is not really neutral), then you should check as follows:

Important _ : _ : X : _ : _ : _ : _ : Unimportant

or

Important _ : _ : _ : _ : X : _ : _ : Unimportant

The direction toward which you check, of course, depends upon which of the two ends of the scale seem most characteristic of the concept you are judging.

If you consider the concept to be neutral on the scale, both sides of the scale equally related to the concept, or if the scale is not in any way related to the concept, then you should place your check mark in the middle space:

Pleasant _ : _ : _ : X : _ : _ : _ Unpleasant

IMPORTANT: 1) Place your check marks in the middle of spaces, not on the boundaries

This : X : _ : _ : _ : _ : X _ : _ Not This

2) Be sure to check every scale for every concept - do not omit any

3) Never put more than one check mark for each scale.

4) Some of the scales are reversed

Sometimes you may feel as though you have had the same item before on the test. This will not be the case, so do not look back and forth through the items. Do not try to remember how you checked similar items earlier in the test. Make each item a separate and independent judgement. Work at a fairly high speed through this test. Do not worry or puzzle over individual items. It is your first impressions, the immediate "feelings" about the items, that we want. On the other hand, please do not be careless, because we want your true impression.

What I Learned in This Science Course

1)	Good	_ : _ : _ : _ : _ : _ : _	Bad
2)	Pleasurable	_ : _ : _ : _ : _ : _ : _	Painful
3)	Meaningless	_ : _ : _ : _ : _ : _ : _	Meaningful
4)	Important	_ : _ : _ : _ : _ : _ : _	Unimportant
5)	Negative	_ : _ : _ : _ : _ : _ : _	Positive
6)	Wise	_ : _ : _ : _ : _ : _ : _	Foolish
7)	Heavy	_ : _ : _ : _ : _ : _ : _	Light
8)	Colorful	_ : _ : _ : _ : _ : _ : _	Colorless
9)	Complex	_ : _ : _ : _ : _ : _ : _	Simple
10)	Interesting	_ : _ : _ : _ : _ : _ : _	Boring
11)	Awful	_ : _ : _ : _ : _ : _ : _	Nice
12)	Fair	_ : _ : _ : _ : _ : _ : _	Unfair
13)	Fresh	_ : _ : _ : _ : _ : _ : _	Stale
14)	Annoying	_ : _ : _ : _ : _ : _ : _	Pleasing
15)	Precise	_ : _ : _ : _ : _ : _ : _	Vague

How I Feel About This Science Course

1) Good	_ : _ : _ : _ : _ : _ : _	Bad
2) Pleasurable	_ : _ : _ : _ : _ : _ : _	Painful
3) Meaningless	_ : _ : _ : _ : _ : _ : _	Meaningful
4) Important	_ : _ : _ : _ : _ : _ : _	Unimportant
5) Negative	_ : _ : _ : _ : _ : _ : _	Positive
6) Wise	_ : _ : _ : _ : _ : _ : _	Foolish
7) Heavy	_ : _ : _ : _ : _ : _ : _	Light
8) Colorful	_ : _ : _ : _ : _ : _ : _	Colorless
9) Complex	_ : _ : _ : _ : _ : _ : _	Simple
10) Interesting	_ : _ : _ : _ : _ : _ : _	Boring
11) Awful	_ : _ : _ : _ : _ : _ : _	Nice
12) Fair	_ : _ : _ : _ : _ : _ : _	Unfair
13) Fresh	_ : _ : _ : _ : _ : _ : _	Stale
14) Annoying	_ : _ : _ : _ : _ : _ : _	Pleasing
15) Precise	_ : _ : _ : _ : _ : _ : _	Vague

Science Student

1) Good	_ : _ : _ : _ : _ : _ : _	Bad
2) Pleasurable	_ : _ : _ : _ : _ : _ : _	Painful
3) Meaningless	_ : _ : _ : _ : _ : _ : _	Meaningful
4) Important	_ : _ : _ : _ : _ : _ : _	Unimportant
5) Negative	_ : _ : _ : _ : _ : _ : _	Positive
6) Wise	_ : _ : _ : _ : _ : _ : _	Foolish
7) Heavy	_ : _ : _ : _ : _ : _ : _	Light
8) Colorful	_ : _ : _ : _ : _ : _ : _	Colorless
9) Complex	_ : _ : _ : _ : _ : _ : _	Simple
10) Interesting	_ : _ : _ : _ : _ : _ : _	Boring
11) Awful	_ : _ : _ : _ : _ : _ : _	Nice
12) Fair	_ : _ : _ : _ : _ : _ : _	Unfair
13) Fresh	_ : _ : _ : _ : _ : _ : _	Stale
14) Annoying	_ : _ : _ : _ : _ : _ : _	Pleasing
15) Precise	_ : _ : _ : _ : _ : _ : _	Vague

Science Teacher

1)	Good	_ : _ : _ : _ : _ : _ : _	Bad
2)	Pleasurable	_ : _ : _ : _ : _ : _ : _	Painful
3)	Meaningless	_ : _ : _ : _ : _ : _ : _	Meaningful
4)	Important	_ : _ : _ : _ : _ : _ : _	Unimportant
5)	Negative	_ : _ : _ : _ : _ : _ : _	Positive
6)	Wise	_ : _ : _ : _ : _ : _ : _	Foolish
7)	Heavy	_ : _ : _ : _ : _ : _ : _	Light
8)	Colorful	_ : _ : _ : _ : _ : _ : _	Colorless
9)	Complex	_ : _ : _ : _ : _ : _ : _	Simple
10)	Interesting	_ : _ : _ : _ : _ : _ : _	Boring
11)	Awful	_ : _ : _ : _ : _ : _ : _	Nice
12)	Fair	_ : _ : _ : _ : _ : _ : _	Unfair
13)	Fresh	_ : _ : _ : _ : _ : _ : _	Stale
14)	Annoying	_ : _ : _ : _ : _ : _ : _	Pleasing
15)	Precise	_ : _ : _ : _ : _ : _ : _	Vague