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ABSTRACT

Presented is a supplement to two previous collections of expanded abstracts of research with calculators. Eight reports are abstracted to add to the information on the effects of calculators on achievement and learning. The critical commentary prepared by each abstractor pinpoints particular strengths and weaknesses of each study. (MP)

CALCULATOR
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CENTER

Investigations with Calculators
Abstracts and Critical Analyses of Research

edited by
Marilyn N. Suydam
Director, Calculator Information Center

Supplement 2

February 1981

Calculator Information Center
The Ohio State University
1200 Chambers Road
Columbus, Ohio 43212

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Introduction to

Investigations with Calculators:

Abstracts and Critical Analyses of Research

Supplement 2

The abstracts and critical analyses of research in this document supplement those found in two previous collections in January 1979 and June 1979. As was noted in the introduction to that document, they were prepared and compiled to add to the fund of information on the effects of hand-held calculators on achievement and learning. Since many persons find it difficult to secure original copies of all research studies, the expanded abstracts should provide specific information frequently not included in the brief abstracts found in, for instance, Dissertation Abstracts International or in the bulletins available from the Calculator Information Center. The critical commentary prepared by each abstractor pinpoints particular strengths and weaknesses noted for each study.

Thanks are extended to each of the abstractors who contributed to this publication. Their hours spent in reading dissertations, in abstracting, and in developing critiques will have been rewarded if they serve to help others in planning more effective investigations using calculators.

Marilyn N. Suydam
Director
Calculator Information Center

Chang, Lisa Li-tze. AN EXAMINATION INTO THE EFFECTS OF CALCULATOR-ASSISTED INSTRUCTION ON THE MATHEMATICAL ACHIEVEMENT AND ATTITUDE OF SEVENTH AND EIGHTH GRADE DISADVANTAGED STUDENTS. (Cornell University, 1979.) Dissertation Abstracts International 40A: 1323-1324; September 1979. [Order No. 7920254]

Expanded abstract and analysis prepared especially for the Calculator Information Center by LEN PIKAART, Ohio University.

1. Purpose

The major purpose of this study was to determine the effectiveness of using calculators in seventh- and eighth-grade classes of disadvantaged students. In particular, the investigator sought to compare gains in control and experimental groups on several criterion measures of mathematical achievement, on an attitude measure, and on several diagnostic classifications of learning difficulties.

2. Rationale

The author reviewed several special programs for disadvantaged students and concluded that the use of calculators might hold promise for improving the mathematical learning and attitudes of such students.

3. Research Design and Procedures

A total of 126 subjects were selected from 142 students enrolled in three seventh-grade mathematics classes and three eighth-grade mathematics classes, all taught by the investigator. Students in each class were randomly assigned "by the flip of a coin" (p. 102) into either a control group or an experimental group. Pretests, administered in September 1977, and posttests, administered in April 1978, included the following:

Criterion Variable	Test
1. Mathematical Achievement	Iowa Tests of Basic Skills Tests of Academic Progress
2. Attitude Toward Mathematics	Survey of School Attitudes
3. Learning Difficulties in Arithmetic	Stanford Diagnostic Test
4. Aptitude (pretest only)	Cognitive Abilities Test

Both the control group and experimental group students in each class were taught at the same time. The experimental group students were taught to use Texas Instrument TI-1200 calculators. These students were seated in the classroom as a group and permitted to use the calculators to perform calculations, except during quizzes and tests. The control group students were seated as a group in another area of the classroom and were not permitted to use the calculators.

In general, analysis of variance was performed with a treatment-by-levels design on the gain scores for each dependent variable. The independent variables were as follows:

Source	Classification levels or groups
Treatment	control group and experimental group
levels	grade 7 and grade 8
	low, average, and high achievement groups in grade 8
	low and high achievement groups in grade 7

4. Findings

Very few analyses lead to statistically significant results at the chosen level of significance, .05. Please note that in the following summary, all analyses refer to gain scores -- posttest minus pretest.

Mathematical computation and concepts subtest

The differences between mean gain scores for treatments were non-significant, as were interactions of treatment and grade levels. The main effect for grade level was found to be significant in favor of the mean gain score of seventh graders as compared to that of eighth graders.

Mathematical problem solving

The experimental group had a significantly higher mean gain score than did the control group. Again, seventh graders' mean gain score was significantly higher than that of eighth graders. There was no significant interaction of treatment and grade level.

Attitudes toward mathematics

The main effect for treatment was non-significant, as was the interaction effect of treatment and grade level. Again, the difference in mean gain score for seventh graders was significantly higher than that of eighth graders.

Areas of learning difficulties

Of a total of 15 comparisons in eight categories at two grade levels, only one -- "computation with common fractions" at grade 8 -- was found to be significantly different. The experimental group students had a higher mean gain score than the control group.

Mathematical learning areas and ability levels

There was a total of 27 comparisons in eight mathematical areas for two achievement levels (low and high) at grade seven and three achievement levels (low, medium, and high) at grade eight. Some subtests were not appropriate for some groups of students because the content was not taught. The only significant comparison of 27 was for "computation with common fractions" for low-ability eighth-grade students. Again, the experimental group had a higher mean gain score than the control group.

5. Interpretations

The use of calculators by disadvantaged seventh- and eighth-grade students will not adversely affect their mathematical achievement or attitude.

Critical Commentary

Regretfully, poor design decisions coupled with a carelessly edited report combine to diminish what could have been a worthwhile study. There are too many errors in the dissertation to note them all here, but a few of the most significant ones will be mentioned.

It has been recognized for a long time that the use of gain scores is dangerous. What does the difference of two scores mean? The author seemed to understand the difficulty when she explained (p. 143) that eighth graders did not have as high gain scores as seventh graders because the eighth graders' pretest scores were higher. They had already learned the concepts tested and did not have as much chance to score higher as the seventh graders could. However, the author seems to have missed applying a similar argument to the other analyses. Why did she not consider using either analysis of covariance or a repeated-measures design?

There were five cases (pp. 120, 128, 132, and 134) in which the author pointed out that even though the F ratios were not large enough to achieve significance at .05 level, which she selected, the F ratios were "close" to the critical F value. She went on to suggest that it is safe to conclude that there is a positive effect. For example, she says:

> Although the results of the data analysis reveal no significant difference between two treatment groups, the difference in favor of the experimental group is quite strong. The calculators seem to have some pos-

> itive effect on the ch[illegible]ge of students' attitudes toward mathematics. (p. 121)

In this case the obtained F was 2.09 compared to a critical value of 3.92. In the other cases where the obtained F is even closer to the critical value, the author makes stronger statements about the conclusion (i.e., rejecting a null hypothesis) It is amazing that she does this after arguing (p. 110) persuasively that the .05 is appropriate -- to avoid making either a Type I or Type II error. Also, the author should note that she calculated 44 F ratios in testing her last five hypotheses. Of these, only two were found to be significant at the .05 level even though she implies another three are real differences. However, two significant F's in 44 tests make one wonder, because the .05 level means that such differences would be expected to occur by chance only one time in twenty (or two times in forty!)

There are also a great many aggravating editing and sloppiness errors. For example, the format for listing volume and numbers of journals in the bibliography is inconsistent. There are several direct quotes without references. Several words are misspelled, such as "Raw" for "Row" on page 175. A paragraph is typed twice on page 162. There are inaccuracies, such as: ". . . the Montessori Method which combines discovery and programmed learning . . ." (p. 5). Also, it is surprising to see in a thesis with a 1979 publication date the following conclusion about the use of computers in education: "Its (a computer's) expensive cost and lack of availability eliminates it from national consideration." The author used a 1959 review to justify the selection of 1971 Iowa Tests of Basic Skills (pp. 82ff). It should be noted that the only significant F statistic in Table 29 (p. 27) is indicated as nonsignificant. There are a great many sophomoric errors of style, verb agreement, format, grammar, and clarity. It is regrettable that neither the author nor her major professor, Dr. Harrison Geiselmann, caught the errors -- both the major and the minor ones.

Engelmeyer, William James. THE EFFECTIVENESS OF HAND-HELD CALCULATORS FOR THE REMEDIATION OF BASIC MULTIPLICATION FACTS. (University of Maryland, 1978.) Dissertation Abstracts International 39A: 5381; March 1979. [Order No. 7906654]

Expanded abstract and analysis prepared especially for the Calculator Information Center by J. FRED WEAVER, University of Wisconsin-Madison.

1. Purpose

The specific purpose of this study was to determine whether a remedial program providing access to hand-held calculators for checking computational practice problems is more effective for acquisition and retention of basic multiplication facts than a similar program that relies solely on teacher feedback or a control program involving no remedial practice (pp. 4-5).

2. Rationale

The investigator's review of relevant literature led him to conclude that there is need to obtain statistical data relative to the use of the hand-held calculator with basic facts (p. 4).

3. Research Design and Procedures

The population for this study was defined to be the set of students (in a particular school district) assigned to the below-average seventh-grade classrooms who had no apparent learning disability and who seemed to have the potential for learning multiplications facts and yet scored low enough on a pretest of achievement of the 100 basic multiplication facts to allow room for growth (p. 16).

From this population a sample was drawn that consisted of 193 pupils from 21 classrooms in 7 schools. Students from each school were assigned to one or another of three treatment groups: one treatment group was referred to as the calculator group, a second group was called the teacher group, and the third group was called the control group.

Each member of the calculator group spent 15 to 20 minutes each day for 10 mathematics-class days drilling the basic multiplication facts through a series of tasks devised by the investigator, in which each student worked each example on his or her own (without calculator assistance) and then worked the example on the hand-held calculator.

Each member of the teacher group was given exactly the same drill exercises in the same order as for the calculator group. But instead of using a calculator to check results, each member of the teacher group reviewed answers by "normal methods" with the teacher; i.e., the teacher could tell the student the answer, or have the student look the answer up, or help the student figure it out, or whatever the teacher felt appropriate.

Each member of the control group maintained the regular class routine with no special treatment other than being told that they were also an important part of the experiment. The principal topic being studied by all three groups during the experimental period was a unit on nonmetric geometry.

Four forms of a test of the 100 basic multiplication facts (differing in order of presentation) were used: one as a pretest, one as a posttest, one as a retention test two weeks after the posttest, and one as a retention test four weeks after the posttest. Calculators were not permitted. In addition, all groups were administered four quizzes during the 10-day experimental period, each involving 20 of the 100 basic multiplication facts, (again, calculators were not permitted); and a version of Dutton's familiar attitude scale, given on the same day as the posttest.

At the conclusion of the investigation, 19 students from the calculator group and 14 students from the teacher group were interviewed individually (and tape recorded). Teacher logs and classroom visits by the investigator also were used as a means of checking on fidelity of treatment among teachers in the three different groups.

4. Findings

The following raw-score means (number of correct responses on the 100-item multiplication facts test) were observed:

Treatment Group	Pre-test	Post test	Retention test 1st	Retention test 2nd
Calculator	78.3	84.2	84.1	86.2
Teacher	84.5	91.6	89.9	90.8
Control	87.6	88.3	85.5	89.6

(Each of the preceding numbers may be interpreted as a percent, of course.)

When ANCOVAs were used to adjust post- and retention test means for pretest performance, the following adjusted means were observed:

Treatment Group	Post test	Retention test 1st	Retention test 2nd
Calculator	87.8	87.0	89.8
Teacher	90.9	89.4	90.1
Control	85.4	83.2	86.8

Four principal null hypotheses were tested, with the results as indicated:

A. The three treatment groups have equal mean posttest scores when adjusted for pretest scores.

Rejected at the .05 level, with significance attributed to the difference between teacher and control groups.

B. The three treatment groups have equal mean first retention test scores when adjusted for pretest scores.

Rejected at the .05 level, with significance attributed to the differences between teacher and control groups.

C. The three treatment groups have equal mean second retention test scores when adjusted for pretest scores.

Not rejected at the .05 level.

D. The three treatment groups have equal mean attitude scores when adjusted for pretest scores.

Not rejected at the .05 level.

5. Interpretations

"Since there were no significant differences between the teacher group and the calculator group on any of the research hypotheses, it is assumed that the use of a calculator as a feedback device is just as effective as teacher feedback for the remediation of basic multiplication facts for low ability mathematics students in grade seven." (p. 50)

Critical Commentary

Among the Student Worksheets used during the treatment period, I find one titled "Keeping Sharp 3: Multiplication Facts Survey Test," for which students were given four minutes to complete the 100 items. I could not seem to find whether or not a similar four-minute time limitation was placed upon students when they took the 100-item pre-, post- and retention tests -- although it is indicated that a 30-second time limit was placed upon each of the four 20-item multiplication-facts quizzes. This uncertainty about time limits imposed (or not imposed) upon criterion tests makes it difficult (if not impossible) to interpret some aspects of the findings.

Apart from a bit of informal eyeballing of data, there was no attempt made to analyze data across time for each group: from pretest to posttest to retention test 1 to retention test 2. I feel that such analysis should have been done. In fact, a different treatment of data would have permitted an examination of both row and column means, as it were, rather than just column means. Somewhat different findings and conclusions might have resulted from such an analysis.

Relatively little consideration is given to the practical significance of findings.

I would like to direct attention to an aspect of the investigation that is not at all unique to this study, that is not a direct part of the problem as posed, but that nevertheless should not be dismissed without any consideration or discussion (as happened in this instance, and happens in many others). Each of the three groups--calculator, teacher, and control--participated in the study of a unit on nonmetric geometry during the experimental period. It was during that time that the students in calculator and teacher groups engaged in drill on multiplication facts: 15-20 minutes per day, for each of 10 days--using time apparently taken from those students' study of the nonmetric geometry unit. If my supposition is correct, then attempts to improve mastery of multiplication facts may have been taken at the expense of learning about nonmetric geometry. If the nonmetric geometry unit were a vital part of students' school mathematics work, then it is important to know whether time taken from study of that unit (to carry out the experimental treatment) had any adverse (or other) effect upon student learning of the geometry material. In reality, there are two "treatment effects" that need to be considered rather than just one: a hidden, non-investigated effect as well as the one explicitly studied.

A final uncertainty that I couldn't resolve to my satisfaction from reading the disssertation: What did the groups (calculator and teacher in particular) do mathematically between the posttest time and the time of the first and also the second retention test? Was any attempt made to avoid all work with multiplication facts during that time, or was work done to maintain facts on some more or less systematic, controlled basis? I don't believe that the latter was the case, but I seem to be unable to determine what in fact did happen during the period of time in question--which could have some bearing upon findings and conclusions.

Fugate, Barbara Riley. AN ASSESSMENT OF ATTITUDES, SELF CONCEPT, AND MATHEMATICAL ACHIEVEMENT RESULTING FROM THE USE OF MINICALCULATORS. (North Texas State University, 1978.) Dissertation Abstracts International 39A: 6531-6532; May 1979. [Order No. 7911068]

Expanded abstract and analysis prepared especially for the Calculator Information Center by DONALD J. DESSART, University of Tennessee.

1. Purpose

The purpose of this study was to provide an analysis of the effects of the use of minicalculators on the achievements, attitudes, and self concepts of fourth- and fifth-grade mathematics students in a school of a large suburban Texas school district.

2. Rationale

The use of minicalculators is the subject of much research at the present time. Their usefulness is still very much an open question in regard to their effects upon student achievement and attitudes. Since patterns of achievement and attitudes are often established at the fourth- and fifth-grade levels, a reasonable question to investigate is the effects of minicalculators on these variables at these particular grade levels.

3. Research Design and Procedures

The study was confined to six groups which represented the entire membership of the fourth and fifth grades in one particular school. At the conclusion of the previous school year, the teachers had placed the children into ability groupings; and at the beginning of the next year, the six teachers randomly selected their classes from the ability groups previously established. This was done to insure unbiased, heterogeneously grouped classes.

Three groups at the fourth-grade level were designated E_1, E_2 (experimental groups), and C (control group), and three groups were similarly designated at the fifth-grade level. The E_1 groups practiced selected computational exercises using minicalculators (one per child) and worksheets; the E_2 groups practiced the same exercises using minicalculators, instructional materials pertaining to the calculators, and worksheets; and the C groups used worksheets and pencils as in conventional practice procedures.

The treatments were confined to forty-five minutes per day for a ten-week period beginning in March and ending in May of 1977. The teachers did not provide instruction other than to assist students with the mechanical use of the minicalculators. The students used the minicalculators only during the designated class sessions.

All six groups were pre- and posttested with the mathematics portion of the Comprehensive Tests of Basic Skills, the Self-Esteem Inventory, and the Likert-Type Attitude Scale. The posttest results were analyzed by an analysis of covariance in which the pretest scores were used as covariants.

4. Findings

Eighteen different hypotheses were tested with no significant differences among the experimental and control groups in regard to mathematical achievement, attitudes, or self-esteem measures. Furthermore, no significant differences were found between boys and girls on these same measures.

5. Interpretations

The author recommended (pp. 107-108 of the dissertation) that: (a) minicalculators should not be introduced into fourth- and fifth-grade classes with students similar to those in this study; (b) schools should not spend funds until research establishes statistical significant results in favor of minicalculator usage; and (c) further research be conducted on type of materials, kinds of students, and best classroom uses of minicalculators.

Critical Commentary

On the basis of this study the author recommends that minicalculators should not be introduced into the fourth- and fifth-grade classes of students similar to those in this study. While one might agree with this recommendation, it is certainly not warranted by the results of this report. Since non-significant differences among experimental and control group means were obtained, one can only reserve judgments until further evidence has been obtained.

In addition, the study has a number of serious limitations which detract from its value. These are:

1. The study was limited to one school; consequently, one might seriously question the use of inferential-type statistics when the total population is being studied.
2. The study was conducted over a very limited time period (10 weeks). Normally, one expects attitudes to change slowly, so that ten weeks

seems to be insufficient time to expect attitudinal changes to occur.

3. The pre- and posttest scores are not provided in the study. One might wonder whether or not any differences occurred between pre- and posttesting. If little or no differences were experienced, one might question whether the true learning qualities of the minicalculators were even tapped by the students.

4. The validity of the Comprehensive Test of Basic Skills is open to serious question. The relationship of this test to the objectives of the materials studied in the treatments is never adequately treated in the discussion.

Further research on the use of minicalculators in the classroom is needed, but much more substantial evidence must be provided before one can recommend that calculators should not be used by students!

McLeod, Douglas and Adams, Verna M. APTITUDE-TREATMENT INTERACTION IN MATHEMATICS INSTRUCTION USING CALCULATORS. April 1979. ERIC: ED 170 113.

Expanded abstract and analysis prepared especially for the Calculator Information Center by DONALD J. DESSART, University of Tennessee.

1. Purpose

The purpose of this study was to search for any aptitude treatment interactions (ATI) between two aptitude variables (general reasoning and field independence) and two instructional treatments (discovery and expository).

2. Rationale

ATI research has had a history of difficult development and growth. Stable interactions have often occurred with general ability and instruction, but not necessarily with inductive and deductive type instructions, in which case general reasoning appeared to produce more favorable interactions than general ability. Tests of general reasoning seem to provide better predictions of success with expository-deductive treatments than with inductive treatments, which is opposite to what is encountered with tests of general ability.

A cognitive style variable that has received considerable research attention recently is field independence. Studies appear to indicate that treatments which provide minimal structure and guidance should be more appropriate for field-independent than for field-dependent students.

3. Research Design and Procedures

Subjects for this study consisted of 47 prospective elementary school teachers enrolled in a college mathematics course. Twenty-four students were assigned to the expository group, in which instruction proceeded in a deductive manner with definitions and rules followed by examples and maximal guidance provided; and 23 were assigned to the discovery group, in which instruction proceeded in an inductive manner, with examples worked first with hand-held calculators and rules generalized from the examples. In both treatments, the teacher was available to answer questions.

Field independence was measured by the Group Embedded Figures Test (GEF) and a version of the Hidden Figures Test (HFT). General reasoning was measured by the Necessary Arithmetic Operations (NAO) test; and achievement was determined by a 20-item posttest covering all of the concepts of the learning materials, which included instruction on errors in measurement and calculations with approximate data. A ten-item retention test similar to the posttest was administered four weeks after the posttest.

The data were analyzed by the following statistical procedures:

1. Means and standard deviations were determined for all tests and for both the expository and discovery groups.
2. An intercorrelation matrix was determined for all of the aptitude and achievement test results.
3. Regression equations were calculated for each group with the HFT and NAO as predictors of achievement (both for the posttest and the retention test).
4. Interactions were found using multiple regression techniques. This included vectors for field independence (HFT, GEFT, or their sum), NAO, treatment, and the interaction of treatment with each of the aptitude vectors.
5. Differences between treatment group means were tested statistically using HFT and NAO as covariates.
6. Interactions of class with treatment, NAO, and treatment-by-NAO interactions were determined.
7. Interaction with NAO was tested to determine whether it was due to general reasoning or general ability.

4. <u>Findings</u>

The following results are reported in order of the statistical procedures listed above as (1) through (7):

1. There were no large differences between the discovery and expository group means for the HFT, GEFT, NAO, posttest, or retention tests.
2. The correlation between the posttest and the retention test was .72. Remaining intercorrelations ranged from .39 to .61.
3. The slopes for the regression equations for the retention test with NAO as predictor was .42 for the expository group and .09 for the discovery group. The difference in slopes was significant ($p = .011$).
4. On the retention test, there was a significant interaction with NAO, but no such interaction was found with the posttest. There were no

interactions with field independence.

5. No statistically significant differences were found between treatment group means, using HFT and NAO as covariates.
6. On the retention test, there were interactions with NAO consistently across classes; but on the posttest, only one class produced an interaction effect.
7. There was some support evident to attribute the interaction with NAO to general reasoning rather than to general ability. Futhermore, in determining regions of significance for the interaction, it was found that students with NAO scores of 17 or greater did better in the expository group and students with scores less than 13 achieved more in the discovery treatment.

5. Interpretations

This study attempted to determine whether or not ATI would occur between field independence and general reasoning and treatments of expository and discovery learning. The ATI with general reasoning occurred on one of the two dependent variables, i.e., the retention test. Consequently, the study lent some support to the existence of ATI as found in other research.

The predicted ATI with field independence was not found. The authors attribute this to the fact that the treatments provided more guidance than had originally been intended. Such guidance was apparently unavoidable as the students had "demanded" such assistance.

The question as to whether ATI with general reasoning, as measured by the NAO test, is due to this specific aptitude or whether it is due to general or crystallized ability is still open.

Critical Commentary

ATI research is extremely complicated and complex. The goal of fitting instructional treatments to particular aptitudes in order to obtain best results is, indeed, praiseworthy. However, the difficulty of attaining this ideal seems to be nearly insurmountable.

The entire class time devoted to this study was 90 minutes. Based on the results of this small amount of instruction, an enormous amount of statistical data was generated. One might speculate that ATI research might be better served if a comparable amount of research effort was devoted to developing more sensitive aptitude measures and purifying treatments so that they could not be changed by the whims of students; but one must admire ATI researchers for their persistence in the face of adversity!

It should be noted that the use of calculators was incidental to the main purpose of the research: the investigators did not intend calculators to be a major focus of the study. Thus there is little that can be said about the use of calculators as a result of this study.

Moser, James M. THE EFFECT OF CALCULATOR SUPPLEMENTED INSTRUCTION UPON THE ARITHMETIC ACHIEVEMENT OF SECOND AND THIRD GRADERS. Technical Report No. 502. Madison: Wisconsin Research and Development Center for Individualized Schooling. September 1979. ERIC: ED 180 764.

Expanded abstract and analysis prepared especially for the Calculator Information Center by GEORGE W. BRIGHT, Northern Illinois University.

1. Purpose

The study investigated the effects of the use of hand-held calculators on end-of-year measures of arithmetic achievement of second- and third-grade children. The calculators were used in conjunction with two ongoing mathematics programs.

2. Rationale

The study was conducted because (a) very little controlled experimentation with calculators had been reported, (b) long-term use of calculators had not been explored, and (c) experimentation on use of calculators with young children had not been reported. Too, experimentation with calculators had been recommended by mathematics educators and policy makers both inside and outside of the federal government. Results of previous research had been mixed.

3. Research Design and Procedures

Pretests were administered in the last week of September 1977, the calculators were introduced on October 3, and posttests were administered on May 12, 1978. Thus, calculators were used during 29 of the 37 weeks of instruction.

Students were from two schools in Madison, Wisconsin. Four intact classes (two second-grade and two third-grade) from each school were used. The 190 students were almost exclusively white from a middle- to upper-middle-class population. One class at each grade within each school was randomly designated as an experimental class, and the other, as a control class. Each of the eight teachers had at least five years experience; one substitution of a teacher with four years experience was made in one third-grade experimental class in March 1978.

One school (school A) used Modern School Mathematics Structure and Use (1972) by Houghton Mifflin. The other school (school B) used Developing Mathematical Processes (1974, 1975, 1976), distributed by Rand McNally.

In the two second-grade experimental classes, a Texas Instruments ABLE calculator was provided for each child. The keys included +, -, and x (but not ÷), and the decimal point key was evident. Students in the two third-grade experimental classes each had a TI-1255 calculator with keys for all four operations, decimal point, %, change-sign, and simple memory (four keys). Students in the control classes did not have access to calculators during instruction.

All tests were researcher-designed. Major tests were given to all eight classes in September, February, and May. Some of the items in the February tests were posttest items for the September tests and some were pretest items for the May tests. Nine shorter tests were given at three-week intervals to measure learning of current topics, but results of these tests were not subjected to statistical analyses. In one school half of each class was randomly chosen to take these tests; in the other school all students (at the teachers' request) took these tests. (It is unclear whether experimental students were allowed to use calculators on tests.)

Major tests for second-graders included basic facts (+,-,x), algorithms (+,-), open sentences (+,-), place value and ordering. Reliabilities of subscales ranged from .57 to .96, with almost all above .75. Major tests for third-graders included basic facts (+,-,x,÷), algorithms (+,-,x), open sentences (+,-), place value, and ordering. Reliabilities of subscales ranged from .49 to .94, with almost all above .64.

Suggestions to teachers for use of calculators included (a) checking of answers, (b) as an electronic flash card, (c) to play a game, (d) free exploration, and (e) repeated counting. Teachers were free to modify or reject the suggestions. Monitoring of calculator usage was by (a) a weekly log completed by the teachers and (b) periodic unannounced visits to classrooms.

4. Findings

Results seemed to be considered important if (a) the combined data from both schools showed a significant difference and (b) the data from at least on school also showed a significant difference. (All of the significant results below satisfied these conditions.)

The visitations generally confirmed the calculator usage data reported by the teachers. The observed usage tended to be slightly higher, perhaps because teachers thought the observer wanted to see calculators being used.

Reported usage ranged from 36% to 79% of the instructional days, and from 16% to 47.5% of the number of instructional minutes on those days.

No significant sex difference on test scores were observed; hence all data were pooled. For each subscale, analyses of variance were conducted on change scores (spring versus fall, winter versus fall, spring versus winter) within each school. For those subscales that were given on only two of the three major test dates, however, only one analysis of variance conducted.

For second graders, significant differences for the spring versus fall comparison in favor of the experimental group were observed for basic subtraction facts ($p < .04$, school A only), for solving addition and subtraction open sentences ($p < .0005$, school B only), and for two-digit subtraction ($p < .03$, both schools). For the spring versus winter comparison, significant differences favoring the experimental group were observed for three-digit subtraction ($p < .03$, both schools), and significant differences favoring the control group were observed for ordering two-digit numbers ($p < .05$, both schools).

For third graders, significant differences for the spring versus fall comparison in favor of the experimental group were observed for three-digit subtraction ($p < .03$, school A only), for place value ($p < .001$, school A only), and for basic division facts ($p < .001$, school A only), and for basic division facts ($p < .01$, school A only).

5. Interpretations

Limitations of the study included uncontrolled teacher effects, school locations, small number of classes, and possible calculator availability at home. The consistent positive effect across grades on subtraction performance in the experimental groups may have been due to teacher effect. No theoretical justification could be made for the particular effectiveness of the calculator with this content. The third-grade differences on place value may be due to the fact that use of calculators focuses attention on place value, and the differences on division basic facts may be due to longer and more consistent exposure to the symbol, ÷, which appeared on the calculator keyboard. Overall, while the results favoring the experimental groups may not all have been caused by use of the calculators, it certainly seems true that no harm to learning was encountered by their use. Further study of ways in which the calculator can be systematically integrated into the curriculum seems called for.

Critical Commentary

Those who want teachers to use calculators as a regular part of teaching may believe that a study like this one is important. Unfortunately, the design includes an implicit assumption that if a few, perhaps unusual teachers can use calculators effectively, then all or at least most teachers can. There is no guarantee of this.

Also, because teachers were free to use, alter, or reject the suggested activities and because there was no monitoring of exactly how teachers used the calculators, this study makes no contribution to knowledge of how calculators can be used effectively in teaching mathematics to second and third graders. In short, the treatment is virtually undefined for the reader.

The reported pretest differences between groups for some subscales suggests potentially real sampling differences between the groups. The assignment of intact classes to treatments also suggests that using the student as the unit of analysis is incorrect. Of course, with only two classes per grade per curriculum, analysis could not have been conducted on class means, but an incorrect analysis should not have been performed, especially in light of the federal funding of the project.

The statistical analysis seems suspect for several other reasons. First, the use of gain scores does not seem appropriate. This does not control for initial differences between the groups, in spite of the researcher's claim to this effect (p. 32). Second, pretest differences between groups for some subscales may have artificially enhanced or masked statistical differences. Third, the repeated use of analysis of variance (three non-independent analyses for most subscales) may have caused false positives to be noted.

The apparent positive effect on subtraction performance is intriguing, but the serious deficiencies in the design of the treatment and in the data analysis make even this result suspect. At grade three, the consistency of statistical results showing up in school A and not in school B strongly suggests a teacher effect rather than a calculator effect.

Noone, Joan Abbott. EFFECTS OF THE USE OF HAND-HELD CALCULATORS ON MATHEMATICS ACHIEVEMENT AND ATTITUDE TOWARD MATHEMATICS OF SEVENTH GRADE STUDENTS. (University of Virginia, 1979.) Dissertation Abstracts International 40A: 3849; January 1980. [Order No. 8002502]

Expanded abstract and analysis prepared especially for the Calculator Information Center by RALPH A. LIGUORI, University of Texas at El Paso.

1. Purpose

The primary purpose of the study was to compare seventh-grade students taught using the hand-held calculator with students taught solely using paper-and-pencil techniques on a variety of dependent measures. Differential effects due to ability level were investigated comparing low achievers to average and above-average achievers.

A secondary purpose was to determine if there was a differential relationship between computation, concepts, and attitude as measured by pretest scores, and problem solving as measured by a posttest score for low-achieving seventh graders and average and above-average seventh graders with respect to calculator usage or non-usage.

2. Rationale

The author set her study within the historical context of experimental work done using calculators in the classroom. Reference to the current threads of curricular concerns involving the calculator in the classroom are cited with particular attention directed to the NACOME report. The inconclusiveness of previous work indicated that some investigators found an advantage for students taught using the calculator, while no such advantage was observed by other investigators.

Particular attention was paid to those studies involving seventh-grade students and any differential effect of using the hand-held calculator upon students from different ability levels. The review covers work up to the Fall of 1977.

The author presented a reasoned case for a study of how the hand-held calculator might affect children of differing ability levels.

3. Research Design and Procedures

The subjects included 92 seventh graders from Roanoke County, Virginia. Students were identified as low achievers or average and above-average achievers on the basis of teacher recommendation and scores on SRA tests. The subjects at each ability level were randomly assigned to one of two groups. The groups were an average and above-average class taught without the use of calculators. The 1970 Metropolitan Mathematics (Problem Solving, Computation, and Concepts) and the Survey of School Attitude (Mathematics) were used as pre and post tests and served as dependent measures.

Two teachers taught the four sections. One teacher taught the two experimental groups and the other taught the two control groups. The control and experimental classes were treated alike, except that in the experimental classes the use of the calculator was incorporated when appropriate into the material being taught. In the experimental classes, a calculator workbook was used to supplement the regular textbook. The experimental classes spent one period a week working exclusively with the calculator workbook and the calculator, but the calculator was used when appropriate with the regular text during the remaining four days of the week. The duration of the study was two months.

The two independent variables, instructional mode (calculator versus non-calculator) and ability level (low achievers versus average and above-average achievers), were compared on the dependent measures after the experimental period by multiple regression techniques. The pretest scores were used as independent vectors. Additionally, mean gain scores were analyzed by analysis of variance techniques.

4. Findings

The low ability students scored significantly different from the average and above-average students on the posttest scores on problem solving, computation, and concepts; however, no differences were observed in the two groups on attitude. No significant differences in the two methods were measured on all four of the posttest components. When gain scores were analyzed, no statistically significant differences between the calculator and non-calculator group were found.

In the secondary portion of the study, the pretest scores on computation, concepts, and attitude significantly predicted the criterion variable (problem solving) for the low ability group taught by the calculator and the average and above-average ability group taught without the calculator at an .01 significance level, but no such prediction equation was found for the low ability calculator group or the average and above-average ability non-calculator group.

On a post-experimental analysis, significant differences were found on the proportion of correct responses on a number of computational skills in favor of the calculator group when compared to the non-calculator group for average and above-average ability students. The low ability calculator group displayed an advantage on only two such skills when compared to the non-calculator group.

5. Interpretations

The significant difference found between ability levels on posttest scores indicated that the grouping method was successful. The calculator/no-calculator dichotomy led to no significant difference on the posttest scores or in gain scores. However, the difference in mean gain scores for the low ability calculator group when compared to the low ability non-calculator group appears to be relatively greater than the corresponding differences between the average and above-average groups.

The results support the major conclusion that there are no detrimental effects from calculator usage at the seventh-grade level in a two-month program. Additionally, the use of calculators may help students of both ability levels learn operations on whole numbers more effectively and help average and above-average students learn the topics of exponents and operations on decimals more effectively.

Critical Commentary

Since one of the primary designs of the experiment was to identify differential effects of the hand-held calculator on differing ability groups, it would seem reasonable to use the three naturally occurring groups of below average, average, and above average. Of course, such a division would have required a larger number of subjects. With so many hypotheses to be investigated, a larger sample size would have been desirable in any case.

The one anomaly in the study was the large advantage (though not significant) that the average and above-average non-calculator group showed over the average and above-average calculator group. The author does not attempt to explain this result, which is in sharp contrast to all of the other gain comparisons which favor the calculator groups. This finding is in such contrast with the remaining findings that it deserves some attention.

This study, though reasonably well thought-out, does little to add to the body of research on the hand-held calculator. It appears that the point of the use of the hand-held calculator is not to organize a control group with essentially the same instruction as in the experimental group, but to provide a new dimension in the curriculum which cannot really be duplicated in a traditionally taught group and which leads to demonstrably improved performance in some area of mathematical learning without sacrificing any other important mathematical learnings. Once again we have learned that children using hand-held calculators are at no disadvantage, but need guidance in determining the proper way to use the calculator in our classrooms to enhance mathematics education, not merely to continue as we have done in the past.

Pederson, Dean Anthony. THE EFFECT OF THE CALCULATOR ON THE ELEMENTARY MATHEMATICS STUDENT. (University of Northern Colorado, 1978.) Dissertation Abstracts International 39A: 4794; February 1979. [Order No. 7902850]

Expanded abstract and analysis prepared especially for the Calculator Information Center by J. FRED WEAVER, University of Wisconsin-Madison.

1. Purpose

The purpose of this study was to ascertain the differences in achievement of basic mathematics skills between elementary mathematics classes where a mini-calculator was used as an instructional tool and elementary mathematics classes where it was not used (p. iv).

2. Rationale

Many teachers, parents, and administrators have voiced strong concern regarding the use of calculators with the advent of the low-priced machine. Much of the concern, however, has been founded on little more than emotion (p. 14).

At the time this study was conducted during the 1976-77 school year, it was contended that the literature regarding the effects of calculator use included few actual findings of studies done in the elementary school (p. 6).

3. Research Design and Procedures

The "population" for the investigation was distributed as follows:

Grade	Experimental treatment	Control treatment
2	43 pupils from 2 schools	95 pupils from 2 schools
3	42 pupils from 2 schools	97 pupils from 2 schools
6	15 pupils from 1 school	17 pupils from 1 school

At each grade level the school(s) used for the experimental treatment (in which calculators were used by pupils) were different from the school(s) used for the control treatment (in which calculators were not used by pupils).

In mid-September 1976 and again in mid-May 1977, two tests were administered to participating pupils: California Achievement Test (1980 edition) and an Objective-Referenced Test (1974?), developed at the local district level, pertaining to "five different basic mathematical skills": "addition, subtraction, multiplication, division, and problem solving." (p. 19). The indicated treatments were followed for the eight-month period between the pre- and posttestings (with experimental pupils not using calculators on the posttests).

4. Findings

In my judgment the reported findings are so utterly meaningless that it would be misleading even to summarize them here.

5. Interpretations

A comment similar to the preceding one applies here also.

Critical Commentary

The crux of my complete disbelief in reported findings, etc., from this "study" is to be found in the following treatment descriptions:

> Those teachers selected to teach the experimental students were given instructions in the use of the calculator. However, no other special requirements were imposed upon the teachers of the experimental students as to where and how the machines were to be used. The only direction given to these teachers stated that they were to use the machines as a teaching tool in an attempt to accomplish the mathematics objectives prescribed for all students ... (p. 15)
>
> Teachers selected to work with the calculator classes were chosen from those supportive of the study. These teachers of the experimental classes were instructed to teach the prescribed district mathematics program and to use the calculator at every possible opportunity. No special curriculum was written to support the role of the calculator in the classroom. This caused the teachers in some instances not to know exactly what to do.
>
> All teachers, both control and experimental, were asked to be as consistent with their instructions in mathematics as in past years. However, it is reasonable to assume that control group teachers put more effort into their instruction than might otherwise have been the case. (p.13)

The nebulous nature of the experimental treatment in particular, coupled with no indication whatsoever of how and to what extent experimental teachers used the calculator as an "instructional tool", render meaningless any reported findings, and also make it senseless for me to consider any other aspects of the research design and data analysis (about which I have some questions and reservations also).

Standifer, Charles Edward. ACHIEVEMENT AND ATTITUDE OF THIRD-GRADE STUDENTS USING TWO TYPES OF CALCULATORS. (Northeast Louisiana University, 1978.) Dissertation Abstracts International 39A: 5314; March 1978. [Order No. 7904877]

Expanded abstract and analysis prepared especially for the Calculator Information Center by GEORGE W. BRIGHT, Northern Illinois University.

1. Purpose

The study compared the effectiveness of use of (a) a four-function calculator, (b) a programmed-feedback calculator, and (c) the traditional approach to teaching mathematics to third-graders. Acquisition and retention of attitude and achievement were measured.

2. Rationale

Three areas of literature were searched: (a) use of manipulatives in teaching mathematics, (b) effects of various kinds of feedback, and (c) use of calculators to teach mathematics. Eight studies on manipulatives were described. These descriptions usually did not include any indication of the type of manipulative involved. There was no rationale for classifying a calculator as a manipulative.

Seventeen studies and reviews of literature on feedback were cited. The instructional content of those studies, when reported, was mostly mathematics; typically, however, the instructional content was not reported.

The review on the use of calculators was a mixture of research and opinion. The major conclusion of interest for this study was that very little work with primary-age children had been reported. Hence, no clear connection with previous work could be made.

In general, the reasons for doing this study were that (a) the availability of calculators will surely increase and (b) few studies have been done with primary-age children. Because of the lack of a clear theoretical analysis of use of calculators with such children, the approach of the study was to use the calculator as a supplement to regular instruction.

3. Research Design and Procedures

The subjects were from nine intact third-grade classes whose teachers had volunteered to participate. Both public and parochial schools were used to generate the sample. All classes were heterogeneously grouped, with few students exhibiting learning difficulties; students in the schools ranged from low to upper-middle socioeconomic backgrounds. Three classes were randomly assigned to each of three treatments: (a) control group, following the regular curriculum; (b) hand-held calculator group (HHC), using the TI-1200 (four-function) calculator in conjunction with the regular curriculum; and (c) programmed-feedback calculator group (PFC), using the "Little Professor" (programmed) calculator in conjunction with the regular curriculum. The design was, thus, the "non-equivalent, control group" design. Each student in the HHC and PFC groups had access to a calculator during class time.

The HHC group used the calculator 8-10 minutes per day to drill basic facts, to check results of paper-and-pencil computations, and to complete activities suggested by the experimenter. (These suggestions were 10 problem-solving exercises.) The PFC group used the calculator 8-10 minutes per day to practice basic facts, to perform algorithms included in the curriculum, and to experiment freely. Calculators were not taken home and were not used on tests.

Pretests were administered on September 13-15, 1977; posttests were administered on December 13-14; calculators were removed from classrooms on December 15; and retention tests were administered on January 9-10, 1978. The content test was Science Research Associates Assessment Survey (total score and computation and concept subscales), the attitude measure was Dutton's Attitude Toward Arithmetic Scale, and the IQ measure was SRA Short Test of Educational Ability (used as a pretest only).

The data were analyzed by analysis of covariance. The degrees of freedom were (incorrectly) the number of students (N = 233 students). Duncan's New Multiple Range Test was used to determine differences among group means whenever a significant F-statistic appeared in an analysis of covariance.

4. Findings

Eight null hypotheses were tested, four dealing with acquisition (total content score, computation subscore, concepts subscore, attitude score) and four dealing with retention. Significant differences were reported among the three treatment groups (a) on total mathematics acquisition ($p < .014$), with the HHC group scoring significantly higher ($p < .05$) than the other two groups and the PFC group scoring significantly higher ($p < .05$) than the control group; (c) on total mathematics retention ($p < .007$), with the HHC group scoring significantly higher ($p < .05$) than the other two groups; and

(d) on computation retention ($p < .006$), with the HHC group scoring significantly higher ($p < .05$) than the other two groups. No significant differences were found among the three treatment groups on (a) concepts acquisition, (b) attitude acquisition, (c) concepts retention, or (d) attitude retention.

5. Interpretations

Daily use of the hand-held calculator was more effective for both acquisition and retention of both computational skill and total mathematics score than the programmed-feedback calculator or the traditional approach. Daily use of the programmed-feedback calculator was more effective for acquisition of computational skill than the traditional approach.

Calculators should be considered for use in teaching mathematics, and more research on calculator use should be conducted at the primary grades. Study should be made of the effects on students with poor initial attitude toward mathematics (pretest attitude scores were high for the subjects of this study), with learning difficulties, and from low socioeconomic backgrounds.

Critical Commentary

Because the unit of analysis was incorrect, the results and interpretations should be viewed with great caution. Two other aspects of the study are also troubling. First, no identification of the "traditional approach" was given. A reference, at least, to the textbook being used would have been useful. Second, and more important, the definition of the treatments was apparently left up to the teachers; and no monitoring of the ways in which the calculators were used seems to have been done. Without knowledge of what happened in the classroom, the results are at best vague and more probably impossible to apply to other situations. In particular, it is impossible to know for sure that the calculators were actually used 8-10 minutes per day.

The length of the treatment seems to have been about 8 weeks x 5 days/week x 9 minutes/day = 360 minutes = 6 hours. It is not clear whether the teachers used calculators in addition to all regular assignments or in place of some of them. If the use was in addition to the regular assignments, then it is not unreasonable to expect some increase in computational skills. (The differences in total mathematics content score seems to be an artifact of the increases in the computation subscale.) Indeed one suspects, though it is not possible to tell from the report, that peer pressure might have caused teachers to cover all assignments and to use the calculator as an "extra".

There seems clear potential for a Hawthorne effect. The teachers all volunteered, and those that used the hand-held calculators may have had some ideas of their own for effective use in teaching mathematics. If this were true, then the reported benefits would not generalize to teachers who were not so enthusiastic. The "Little Professor" calculator, on the other hand, may not have been as familiar to these teachers, and thus may not have been put to as good use. Teachers' enthusiasm and even perhaps their special knowledge may thus have been an important cause of the results.

Szetela, Walter. HAND-HELD CALCULATORS AND THE LEARNING OF TRIGONOMETRIC RATIOS. Journal for Research in Mathematics Education 10: 111-118; March 1979.

Expanded abstract and analysis prepared especially for the Calculator Information Center by RALPH A. LIGUORI, University of Texas at El Paso.

1. Purpose

Two groups of students were compared on dependent measures after both groups had been exposed to an inductive instructional sequence on trigonometry that involved triangle measurements and calculation of ratios. One group used the hand-held calculator during the instructional period, while the other group used only paper-and-pencil techniques.

2. Rationale

Special lessons and materials were developed for calculators as a tool to teaching trigonometric ratios. It was believed that the measurement activities and the corresponding arithmetic calculations could best be performed using a hand-held calculator. This was done to meet suggestions (in the Report of the Conference on Needed Research and Development on Hand-held Calculators in School Mathematics, 1976) that special materials be developed to exploit the calculator as a teaching tool.

3. Research Design and Procedures

One hundred thirty-one students in each of four classes of a terminal mathematics course at the ninth- and tenth-grade level were randomly assigned to the calculator-based instruction group (CBI) or to the group not using calculators (NUC). The regular teacher and the investigator provided instruction, with each responsible for two CBI groups and two NUC groups. Instruction was given during 18 class days in which the classes met 13 times. Prerequisite skills were studied during the first 5 lessons, 7 lessons were devoted to trigonometric ratios, and an achievement test was administered during the last lesson. Triangles were measured and the sine, cosine, and tangent ratios were calculated. In the CBI group each student performed the task four times and used an average of the results to determine a table value. In the NUC group the students worked in groups of four and averaged their results to generate table values. The relationship of the functions was observed and applied problems were solved using the developed tables.

The dependent measures included a quiz given on the twelfth day, a final achievement test given on the last day, and an attitude test toward ratios. All results were analyzed using analysis of variance procedures.

4. Findings

The quiz administered on the twelfth day indicated that the CBI group scored significantly higher than the NUC group at the .05 level. No calculators were used on this quiz.

On the main achievement test given on the last day, the average score of the CBI group was higher than that of the NUC group, but the difference was not significant. There was no significant teacher effect. Some subjects used a calculator on this test while others did not: there was no significant difference in the mean score of these groups, although the students not using a calculator scored higher than those using a calculator on the test.

On the attitude test there were no significant difference measured due to method of instruction or teacher.

5. Interpretations

The results indicated that calculator-instructed students did at least as well as non-calculator-instructed students. Both instructors found that teaching with calculators was less onerous than teaching without them. It appears that calculator use may allow teachers more fruitfully to expand their energies by eliminating the tedium of computation and thereby focus on concept learning and problem solving.

Critical Commentary

The author seized upon an important aspect of using the calculator as a pedagogical tool, which is to identify curricular areas that can benefit from the use of the calculator and then develop appropriate lessons to utilize the calculator to advantage. In this situation, the calculators were used at the end of a school year with students in a terminal mathematics program, and, as the author indicated, students may have merely been marking time until the end of the year. It is possible that one of the most valuable uses of the computer may be with average and above-average students who may be released to wonder and to investigate patterns and other interesting phenomena when not bogged down by calculational details. In the reported study the calculator-taught students had a significant advantage on the quiz given at the end of two and one-half weeks; this was lost on the test given at the end of three and one-half weeks. This finding might be due to a Hawthorne effect in the early part of the experiment having dissipated by the end of the experiment.

Although there was no significant difference in the average scores of the two groups, it is likely that the inductive approach would not have been attempted without the calculator. A better test would have been to compare a class using the special materials and a calculator against a traditionally taught class. Both groups in the reported study were exposed to very similar experiences and a normal class would probably not have had such a pedagogical approach. It appears that the calculator liberated the author to try this approach, which is certainly an improvement over a more traditional method, and that is probably the real value of the study and the calculator.

Szetela, Walter. CALCULATORS AND THE TEACHING OF RATIOS IN GRADE 7. Journal for Research in Mathematics Education 11: 67-70; January 1980.

Expanded abstract and analysis prepared especially for the Calculator Information Center by DONALD J. DESSART, University of Tennessee.

1. Purpose

To compare the achievements and attitudes of seventh-grade students using calculators and not using calculators in instruction concerning ratio skills and concepts.

2. Rationale

The use of calculators to develop mathematical concepts and facilitate problem solving is a topic of current research interest. There is little question that the calculator removes the necessity for tedious numerical calculations that, perhaps, free the student for more conceptual thinking and data-gathering activities. The concept of ratio is one of the most difficult concepts of the late intermediate grades. An experiment designed to test the feasibility of calculators in the learning of this concept certainly appears to be a reasonable and worthy project.

3. Research Design and Procedures

The subjects in this study were 44 seventh-grade pupils in a middle-class area elementary school. In each of the classes, students were assigned randomly to calculator-based instruction (CBI) or to non-calculator usage (NUC) groups. There were 22 students in each of the two groups.

The investigator conducted the instruction over a three-week period not including Fridays. The instruction included such topics as "measurement of circumferences and diameters of circular objects to obtain a constant ratio, coin tosses to determine ability of students to predict outcomes, and measurement of straw segments and their images projected on a screen to determine ratio of straw length to image length" (p. 68). Guide sheets were distributed to the students. Those in the CBI groups performed the first calculation in each lesson by use of paper and pencil and all subsequent calculations with the use of a calculator; whereas those in the NUC groups performed all calculations by paper and pencil. The class sessions were 45 minutes in length, and the CBI students worked in pairs sharing calculators. Volunteer students obtained any outdoor measurements for the entire group before class time.

Both groups were pretested a week before the experiment with a basic skills pretest constructed by the investigator. On the ninth day of the experiment, a ratio mid-test was given, and on the fourteenth day a short attitude scale (10 items) was administered, along with a ratio problems test in which the CBI students were permitted to use calculators (in other testing the CBI students used paper and pencil only). On the fifteenth day a ratio posttest was given.

The reliabilities of the pretest, the mid-test, and the posttest ranged from .82 to .90 according to Hoyt estimates of reliability. No reliability measure was determined for the ratio problems test. The pretest was used as a covariate in an analysis of covariance on the mid-test, posttest, and ratio problems test scores.

4. Findings

The CBI group performed higher but not significantly higher on all means except the means of the ratio problems test. In this test of 12 items which involved "unfamiliar" problems with ratios, the CBI students used calculators and scored significantly higher ($p \leq .013$) than the NUC group.

5. Interpretations

The author concluded that "... the results indicate that calculators did not hinder learning and may be beneficial in mathematics instruction" (p. 70). It is especially noteworthy that, when the CBI students were allowed to use calculators on the ratio problems test, they scored significantly greater than the NUC group. The author observed that during this test "... the students using calculators appeared more motivated, were more industrious, and spent less time idling" (p. 70). Furthermore, the author conjectured that the use of calculators, perhaps, freed the students from the complications of thinking through a problem as well as performing the computations.

Critical Commentary

This study revealed that there is an advantage to the use of calculators in grade 7 work with ratios. The study did have some shortcomings, but they did not seem to detract from the overall findings of the study. The following shortcomings, if remedied, would have improved the study:

1. The author had indicated that one value of the calculator use is

the release of students from tedious calculations in order to engage in data-gathering experiences. It should be noted that only volunteers participated completely in data-gathering outside of the classroom.

2. The CBI students worked in pairs because of insufficient numbers of calculators. Working in pairs may have provided peer motivation which was not present with the NUC groups. Such motivation would be an additional factor not planned in the design of the study.
3. A pretest should be a measure of the topics targeted for measurement in the study. Since the pretest did not explicitly test knowledge of ratio, it is difficult to know to what extent students understood this topic before the beginning of the experiment.
4. Attitude change develops slowly. One would hardly expect a change to occur in eleven days of instruction.
5. The CBI groups used calculators on the ratio problems test which resulted in a significant difference in their favor. It would have been interesting if half of the CBI group had been required to use only paper and pencil on this test.

Townsend, Gloria Childress. THE EFFECT OF PROGRAMMABLE CALCULATOR USE ON PROBABILITY ESTIMATION ACHIEVEMENT AND ATTITUDE TOWARD ESTIMATION OF STUDENTS IN SECOND YEAR ALGEBRA. (Indiana University, 1979.) Dissertation Abstracts International 40A: 1936; October 1979. [Order No. 7921312]

Expanded abstract and analysis prepared especially for the Calculator Information Center by JANE D. GAWRONSKI, Department of Education, San Diego County.

1. Purpose

This research was conducted in an attempt to determine the effect of programmable calculator use on probability estimation achievement and attitude toward estimation by eleventh-grade students. The study also considered the use of the programmable calculator as a teacher-programmed aid or a student-programmed aid.

2. Rationale

Computer and calculator use in the mathematics classroom is increasing. Research efforts to determine the effects of this use on achievement and attitude is certainly warranted.

3. Research Design and Procedures

Three classes of students in second-year algebra classes at the same high school were selected for this study. At random, one of the three classes was designated as the control group; a second, the teacher-programming group; and the third, the student-programming group.

Two pretests, developed by the investigator, were administered to all students. Reliability statistics were compiled using algebra classes in other schools and content validity was established by consultation with three university instructors. These two instruments were used to determine the degree to which the students could accurately estimate given probabilities and students' attitudes toward estimation. These instruments were also utilized to determine if the two experimental groups and the control group were statistically similar.

Three weeks following the pretest, the student-programming group was instructed in basic programming information for three days. The student-programming group alone was provided this instruction; the teacher-programming and control groups were "idle."

At the end of these three days, each of the three groups undertook a ten-day instruction period. The researcher taught all three groups as a means of controlling the independent variable concerning the instructor. The control group estimated answers to 30 probability exercises and checked its estimates against an acceptable range given by the researcher. This group was not exposed to the programmable calculator nor informed of the source of the researcher's estimation data. The teacher-programmer group estimated answers to the same 30 exercises and checked its estimates against an acceptable range of answers determined by a printout from the teacher-constructed program. The student-programmer group provided the same 30 estimates and wrote 30 corresponding programs, which simulated the events depicted in the instructional exercises. With the aid of these programs and their printouts, the group inspected its estimates in order to decide if these estimates corresponded to the admissible range.

The posttest was administered following the last day of instruction. Analyses of variance were used to analyze the data.

4. Findings

The following two null hypotheses were rejected at the 0.10 level, although not at the 0.05 level:

- "There is no significant difference in estimation achievement among students in the control group and those in the student-programming group."
- "There is no significant difference in attitude toward estimation among students in the control group and those in the student-programming group."

5. Interpretations

Classroom observations and ANOVA results were used to formulate the conclusions. The student use of programmable calculators may tend to improve attitude toward estimation and may enhance probability estimation achievement.

Critical Commentary

This research is a classical example of a graduate student practicing the use of ANOVA in a method A vs. method B vs. method C type study. Technically, the study is sound, but practically it provides little information for continued research and/or curriculum development in this area. The experimental protocols are not well defined, individual student differences are not described, and the observational data provided are very limited.

The reader is provided with a good description of a practice exercise in classical experimental research. However, the study does not contribute to our knowledge of the effects of computer programming on how students learn, or how they approach learning mathematics. The observational data could have been a rich source for researchable hypotheses in this area. The researcher observed the student-programming group's ability to dissect exercises into essentially discrete sub-problems in order to effect a simulation. This would seem worth pursuing in additional research efforts in this area.

In summary, the study is a technically good exercise, but contributes little to our knowledge level in this area.

West, Tommie A. THE EFFECTIVENESS OF TWO DRILL STRATEGIES (PAPER AND PENCIL, ELECTRONIC CALCULATOR) IN FACILITATING THE LEARNING OF BASIC MULTIPLICATION COMBINATIONS WITH FACTORS OF 7, 8 or 9. School Science and Mathematics 80: 97-102; February 1980.

Expanded abstract and analysis prepared especially for the Calculator Information Center by RALPH A. LIGUORI, University of Texas at El Paso.

1. Purpose

An experiment was reported that was designed to compare the effectiveness of two feedback strategies in facilitating the learning of basic multiplication facts. One strategy used an electronic calculator designed specifically for teaching facts through reinforcement; the other was a fairly typical paper-and-pencil drill strategy.

2. Rationale

Calculators in the elementary classroom can be used as a pedagogical tool, but little empirical evidence exists in the literature to indicate how to include the calculator in the curriculum. Using the calculator to provide immediate feedback was one way cited in the literature as a potential contribution of the calculator.

3. Research Design and Procedures

Students in three ungraded classes composed of fourth-, fifth-, and sixth-grade children were randomly assigned to one of three treatment groups.

One group, the electronic calculator group, received regular classroom instruction and additionally used an electronic calculator called the Matheputer for ten school days. Students in this group were given fifty basic multiplication facts to work and check with the Matheputer, for a maximum of 20 minutes daily with the machine.

A second group, the paper-and-pencil group, was given regular classroom instruction and also received drill in basic multiplication combinations using paper-and-pencil problems. Each child was given fifty problems to solve.

The third group was the control group, which received all regular classroom mathematics instruction but did not engage in any additional drill or reinforcement activities.

A 7-minute timed test of 100 basic multiplication combinations with factors of 7, 8, or 9 (called Tables Test) was one dependent measure and a 6-

minute timed test of one-by-three-digit multiplication problems with the one-digit factors being 7, 8, or 9 (called Transfer Test) was a second dependent measure. Each test was administered on a pre-post basis.

4. Findings

The Tables Test was analyzed using a analysis of covariance with the pretest score as the covariate. A significant difference was established at the .01 level. In planned comparisons the paper-and-pencil group scored significantly higher than the control group, while the electronic calculator group and the control group exhibited no significant difference.

The Transfer Test was similarly analyzed using the analysis of covariance with the pretest score as the covariate. A nonsignificant F was found at the .05 level.

The two experimental groups made significant gains from pre- to posttest on both dependent measures. The control group showed a significant improvement from pre- to posttest on the Tables Test, but there was no significant difference on the Transfer Test.

5. Interpretations

The author claims that the paper-and-pencil drill was more effective than the electronic calculator for teaching basic multiplication combinations as measured by the Tables Test. However, no such advantages appeared on the Transfer Test. The fact that fourth graders who had not yet mastered the multiplication algorithm and sixth graders who previously had mastered that algorithm were included in the same groups might have clouded the Transfer Test issue. The author concludes that paper-and-pencil techniques for drill and reinforcement is a viable methodological tool!

Critical Commentary

The choice of ungraded fourth- to sixth-grade classes appears to introduce unnecessary variability in the experimental design which might have been avoided had the groups been at a single grade level. However, the most severe problem with the report is in the statistical analysis. Although the author was interested in comparing the paper-and-pencil technique to the electronic calculator technique, no direct statistical comparison of these two groups is reported. The author reports that only comparisons between each technique and a control group were planned and, in fact, performed.

On this basis it is concluded that the two experimental groups differ. The use of an indirect indicator when a direct one is available is certainly a serious analytical flaw. Additionally, it appears that the author used simple t-tests on the observed means to compare the groups, rather than comparisons appropriate to analysis of covariance techniques.

Whether the electronic calculator is most effectively used as a feedback device to provide young students with immediate reinforcement is open to question. It appears that the calculator might best be used to enhance children's problem-solving capabilities by reducing the computational load on a child and permitting that child to try alternate solutions in an inductive approach. In any case, the serious analytical flaws in the report of this study destroy an interpretation of the reported results.

Wheatley, Grayson H. and Shumway, Richard J. IMPACT OF CALCULATORS IN ELEMENTARY SCHOOL MATHEMATICS, Final Report, National Science Foundation Grant No. SED77-18077, July 1979. ERIC: ED 175 720.

Expanded abstract and analysis prepared especially for the Calculator Information Center by JANE D. GAWRONSKI, Department of Education, San Diego County.

1. Purpose

This year-long study was conducted to determine the impact of calculator use for teaching elementary school mathematics (grades 2-6) on the achievement and attitudes of students.

2. Rationale

Three major factors were identified as providing a rationale or need for this study. They were:

1. Calculators are readily available.
2. The public has expressed great concern about debilitating effects.
3. Adequate research regarding the effects of calculator use is not available.

3. Research Design and Procedures

Five schools from five midwestern states were selected by the site directors from schools in the area surrounding their location. The schools represented a spectrum from large urban schools, to suburban schools, to rural consolidated attendance area schools. Two teachers and their classes were selected at each grade level 2 through 6 at each of the five schools. At each grade level at each site, teachers and their classes were randomly assigned to either the calculator treatment or the no-calculator treatment. A researcher-designed instrument was used to obtain descriptive data on teacher characteristics in October. In summary, a total of 50 classes, 10 at each grade level or 5 per treatment at each grade level, participated in this study.

The calculator treatment consisted of classroom use of simple four-function calculators, teacher attendance at two workshops on teaching with calculators, and availability of reference copies of supplementary classroom materials at each school. Regular textbooks were also used and teachers were encouraged to select calculator activities and use calculators with their mathematics classes. However, no attempt was made to prescribe calculator activities or a specific level of calculator use.

Classes in both treatments were observed almost daily by a researcher.

A two-phase treatment plan was used in case debilitating effects were found. After 15 weeks of instruction and subsequent testing, the calculators were moved from calculator classes to no-calculator classes and a revised calculator treatment was conducted for 9 weeks.

Pre-, mid-, and post-testing included both attitude and achievement measures. Attitude tests were 6-item semantic differential instruments designed by the researchers. The four basic facts tests consisted of 20 randomly selected items in addition, subtraction, multiplication, and division. A researcher-designed 12-item estimation test and a Special Topics test were used in the February and May testing. The Mathematics Tests of the Stanford Achievement Tests were used to test Concepts, Computations, and Applications in the October and February testing. In addition, computation was tested with the use of the calculator in February and with no calculator in May.

The October pretests were used to check comparability of groups, the midtests (February) were used to detect the effects for the phase and treatments, and the posttests (May) were used to detect the cumulative effects of the Phase I and Phase II treatments. The primary statistical analysis was a two-factor fixed effects multivariate analysis of variance. The independent variables were treatment (calculator and no-calculator) and grade level (primary grades 2, 3 and intermediate grades 4, 5, 6).

Dependent variables were defined by the attitude and achievement tests. Other analyses included summary statistics for student and teacher background characteristics and for observational data taken during the experiment.

4. Findings

Pretest analyses indicated expected grade level differences on basic facts and mathematics achievement, but no differences were found by grade level on attitudes. No evidence of treatment group differences was indicated by the multivariate and univariate analysis of variance for group equivalence on pretests, so no covariance procedures were used in subsequent analysis.

Midtests given in February indicated that across all achievement measures grade 3 scores were significantly higher than grade 2 ($p \leq .01$), an expected difference. No evidence was found of a treatment effect in the primary grades at even the $p \leq .1$ level except on the Special Topics test, when the calculator group had higher scores ($p \leq .091$). Expected grade-level differences were found for grades 4-6.

Observational data indicate that games were more prevalent in calculator classes than in no-calculator classes; when calculators were used by a class, approximately 60% of the students used them; and calculators were used for instruction, on the average, about 40% of the class time.

Children were asked at pre-, mid-, and posttesting times if there was a calculator at their homes, if they were allowed to use it, and if they owned a calculator themselves. There was a definite increase in the number of students who had their own calculator between the pre- and midtesting times. This increase was no different for calculator and no-calculator groups.

The Phase II test results showed continued grade-level effects but no evidence of treatment effects.

Children were also asked to respond to questions on calculator use. Their unedited quotes reflected a variety of feelings. Some felt they learned more, some felt they learned less, some felt the calculator aided in computation. This last contention was supported by testing. Children performed 2 to 3 grade levels higher on advanced computational tests when allowed to use the calculator.

Attitude tests indicated very positive results throughout the study, and observations at all schools support this.

5. Interpretations

The authors conclude very succinctly that:

1. There are no measurable detrimental effects for the first-year use of calculators for teaching mathematics in grades 2-6.
2. Children have a high, positive attitude toward using calculators in mathematics.
3. Children learn to use calculators for computation with 30 minutes of instruction and can perform computations much more successfully than children not using calculators.

Curriculum implications for elementary school mathematics could be dramatic. However, testing for possible effects should be investigated over a longer period of time and with more intensive calculator use.

Critical Commentary

A year-long study of the effects of calculator use on elementary school students' attitude and achievement in mathematics is commendable. The lack of significant differences in achievement among the treatment groups is intriguing and does help lay to rest the notion that calculator use will be debilitating. The researchers recommend that the effects on calculator use over a longer period of time should be studied. This is certainly true, but in addition some "control" over the nature and extent of the calculator use should be introduced. This effort would build on the work done in this study. It is refreshing to read a study such as this one which makes a state-of-the-art contribution and also identifies either implicitly or explicitly areas in which additional research efforts should be made.

The Phase I and Phase II aspects of this study point out the real difference between strictly controlled laboratory research and school-based educational research. The school-based studies such as this one need to prepare for and include in their protocols strategies to correct "debilitating" effects. This type of research is not conducted in a value-free environment, but rather one in which the public has a vested interest. This interest and the public's trust in school-based research must be maintained. It is noteworthy that these researchers planned and provided for correcting debilitating effects. They also provided in this way for the "have/have-not" symdrome where one class gets the calculator and the other class gets nothing. Aside from the research implication, this could have influenced school climate and morale. The study documents well the effects of calculator use over a period of time on attitude and achievement. It provides a knowledge base and foundation for needed continued research efforts in this area.

Wheatley, Grayson H.; Shumway, Richard J.; Coburn, Terrence G.; Reys, Robert E.; Schoen, Harold L.; Wheatley, Charlotte L.; and White, Arthur L. Calculators in Elementary Schools. Arithmetic Teacher 27: 18-21; September 1979.

Expanded abstract and analysis prepared especially for the Calculator Information Center by JANE D. GAWRONSKI, Department of Education, San Diego County.

1. Purpose

This research, supported by the National Science Foundation, was conducted to determine if there would be any difference for elementary school children in knowledge of basic facts, computational skill, or understanding as a result of calculator use.

2. Rationale

Educators as well as parents have expressed both interest and concern over the effects of calculator use on basic mathematical skills. This research was an attempt to identify these effects.

3. Research Design and Procedures

At a school in each of five states (Indiana, Iowa, Michigan, Missouri, Ohio) two classes at each grade level 2 through 6 were randomly assigned to a calculator or no-calculator treatment. Thus, 1500 pupils, 50 teachers, and 5 schools participated in the study. Students were pretested on mathematics achievement and on attitudes toward mathematics and calculators. Stanford Achievement Tests and a basic facts test, constructed by randomly selecting twenty basic facts from each of the four operations, were used to measure mathematics achievement. A Likert Scale Attitude instrument was developed for measuring attitudes towards mathematics and towards calculators.

A two-hour calculator workshop for participating teachers was held at each school and recommended calculator activities were made available to teachers of the calculator classes. However, teachers themselves made the decision as to when and how calculators were used in their classrooms. Teacher reports and observations were used as the basis for an estimate that 30 percent of class time involved the use of the calculator. A mathematics educator participant-observer was present in each school daily and attempts were made to balance the mathematics educator's time spent with teachers using calculators and teachers not using calculators.

Fourteen weeks after inroduction of calculators in the classes, all pupils were tested (without calculators) on the same topics as before. In addition, tests were administered to measure estimation skills and selected topics not usually taught at the grade level tested.

After this fourteen-week period (October-February), treatments were reversed. This design was planned as a safeguard so compensatory activities could be provided if declines in student achievement were found in the February testing.

In May all pupils were tested on basic facts, computation, and attitudes.

4. Findings

There was no significant difference in the test scores between calculator and no-calculator classes, although scores on basic facts, concepts, computations, and applications increased significantly from October to February, and predictable grade-level differences were observed. Calculator and no-calculator classes scored about the same on each of the attitude and achievement measures. However, when pupils used calculators during a computation test, they scored two or three grade levels above the national grade level norms.

May testing on attitudes, basic facts, and computation showed no significant differences between the groups. For all children, attitudes towards calculators remained high and were much more positive than attitudes towards mathematics.

5. Interpretations

The authors conclude that this research found no evidence of a decline in students' performance in mathematics resulting from a one-year period of calculator use and some evidence that primary pupils' learning of mathematics is enhanced through calculator use. Elementary school children using calculators do continue learning basic facts and mathematical concepts. Calculators can have a positive effect on mathematics learning and their use at the elementary school level should be encouraged. Calculators are helpful in motivating pupils at this level to learn mathematics and activities that involve the use of calculators in grades 2 through 6 are easy to implement.

Critical Commentary

The length of time, a full school year, spent in this study of the effects of calculator use is noteworthy. No significant differences in this study is an encouraging result since some educators, concerned citizens, and parents have raised the possibility that calculator use will inhibit the learning of basic facts and mathematics in general. It's encouraging to have data to support the notion that use of current technology is appropriate and may even be beneficial.

The authors' article is actually a popularized version of their carefully done and statistically controlled study. They comment that additional detail or analysis is available on request. This is appropriate and should be encouraged in reporting research to a nonresearch-oriented audience. Since it is an article and not strictly speaking a rigorous research report, the authors have taken the liberty of making concluding observations that are somewhat philosophical and exhortative. These may be of interest to those searching for suitable classr m strategies and ideas.

In describing the research, the authors note that each teacher decided how much classroom time was spent using the calculator. They report that this appeared to be about 30%. It would be helpful to know what the range of time spent on calculator use was as well as the quality of that time. Recent research and interest in time-on-task makes this time concern particularly relevant.

Williams, David Edward. THE EFFECT OF THE USE OF THE MINI-CALCULATOR AND AN ASSOCIATED CURRICULUM SUPPLEMENT ON COMPUTATIONAL SKILLS AND ATTITUDES TOWARD ARITHMETIC OF NINTH GRADE NON-COLLEGE BOUND STUDENTS. (Temple University, 1979.) Dissertation Abstracts International 39A: 6610-6611; May 1979. [Order No. 7910028]

Expanded abstract and analysis prepared especially for the Calculator Information Center by LEN PIKAART, Ohio University.

1. Purpose

The study was designed to compare the effects on computational skills and student attitude toward arithmetic of using hand-held calculators with and without an associated curriculum supplement to an instructional treatment devoid of these characteristics. The population for the study was ninth-grade non-college-bound students enrolled in general mathematics courses in inner-city schools of Philadelphia.

2. Rationale

The existence of inexpensive hand-held calculators in the first half of the decade of the seventies stimulated a great amount of professional interest in their educational uses. The author cites the NCTM policy statement, the NACOME report, and several articles and conference reports to substantiate the need for and interest in the study. A thorough review of relevant research literature is included in the report.

3. Research Design and Procedures

Five experienced teachers in five different inner-city Philadelphia, Pennsylvania schools volunteered to participate in the study. Each of three intact ninth-grade general mathematics classes taught by the cooperating teacher was randomly assigned to one of the research treatments. Group C, a calculator group, was taught a three-day unit about a NOVUS 850 calculator and later the students were permitted to use their calculators for a full school year. Group CSC used both the NOVUS 850 and an associated curriculum supplement for the full year. Some part of the supplement was studied each week. Group NC served as a control group. "The curriculum and methodology used in the study were the same in all three groups . . ." with the exception of the calculator and supplementary materials in the experimental treatments. The instructional materials consisted both of those developed by the investigator and commercially prepared materials; the complete set is contained in the report as an appendix. A total of 316 subjects on whom complete data were gathered were selected for the study from approximately 500 students in the fifteen research classes.

The same instruments were used as pretests and posttests. The California Achievement Test, Level 4, was selected to measure arithmetic skills. Dutton's Attitude Scale was selected to measure changes in attitudes during the study.

Analysis of covariance was employed on both arithmetic skills and attitudes. The pretest for each served as the covariate. The .01 level of significance was selected for all tests.

4. Findings

The author found that the assumption of homogeneity of variance was unlikely, based on a significant F when comparing pretest variances between groups. Noting that covariance is insensitive to violations of homogeneity of variance, the author conducted the planned analyses. All three groups C, CSC, and NC improved significantly based on posttest scores adjusted for pretest scores. However, there was no significant difference among the groups.

Analyses of covariance of posttest attitudes controlling for pretest attitudes yielded a significant F (40.34). Tukey's HSD Test was employed to make pairwise comparisons. It was found that differences between the control group NC and each of the two experimental groups, C and CSC, were significant. However, differences between Group C and CSC were not significant. The author also examined item statistics on the attitude scale in comparing pretests and postests.

A final analysis found the the two calculator treatment groups used calculators more than ninety percent of the time they were distributed to classes, based on pupil periods used divided by pupil periods distributed. Student calculator logs were the basis for these data.

5. Interpretations

Neither the use of calculators alone nor calculators together with the curriculum supplementary material appeared to have an effect on the computational skills of the students. However, all three groups improved significantly in these skills. Thus, the study serves as further evidence that the use of calculators does not interfere with computational skill development.

On the other hand, both groups who used calculators showed a significant improvement in attitude toward arithmetic, when compared to a control group. The two experimental groups exhibited a significant negative attitude change. One hypothesis, suggested by the author, is that the comparison group students were aware that the other students were permitted to use calculators and this may have influenced their negative attitude change on the posttest. However, the author rightly points out that this hypothesis does not "dilute the significance of the positive attitude gains of the two calculator groups" (p. 79).

Critical Commentary

This study was found to be well-conceived, thoroughly researched, carefully developed, professionally conducted, and succinctly reported. Both the investigator and his major professor, Jesse A. Rudnick, are congratulated for the scholarly quality of the dissertation.