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ABSTRACT

Presented is a supplement to three previous collections of expanded abstracts of research with calculators. Twelve 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 INFORMATION CENTER

Investigations with Calculators
Abstracts and Critical Analyses of Research

edited by

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Director, Calculator Information Center

Supplement 3

February 1982

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Introduction to

Investigations with Calculators: Abstracts and Critical Analyses of Research

Supplement 3

The abstracts and critical analyses of research in this document supplement those found in three previous collections (January 1979, June 1979, and February 1981). As has been noted in the previous introductions, these collections were prepared 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

Abdelsamad, Omer Elfaroug. IMPROVED PROBLEM-SOLVING PROCEDURE WITH THE CALCULATOR AS VALIDATED BY MATHEMATICS EXPERTS. (University of Denver, 1980.) Dissertation Abstracts International 41A: 3462-3463; February 1981. [Order No. 8101706]

Expanded abstract and analysis prepared especially for the Calculator Information Center by WALTER SZETELA, The University of British Columbia.

1. Purpose

"The primary purposes of this study were: (1) to develop a plan (the four-step problem-solving procedure) to demonstrate where a calculator can be used in solving secondary school mathematics problems and (2) to substantiate the validity of the study by sending questionnaires to experts in mathematics education." Secondary purposes were to determine if there were significant correlations "between every two of the four major problem-solving strategies."

2. Rationale

The rationale is not clear. The author (?) does suggest that most calculator studies with problem solving involve calculators only as adjuncts to the curriculum with no specific intent to use the calculator expeditiously.

3. Research Design and Procedures

The author states that a "four-step problem solving procedure was developed from the literature." These were (1) understand the problem, (2) devise a plan, (3) carry out the plan, and (4) looking backward. The four steps are decomposed into 14, 32, 4, and 10 problem-solving strategies, respectively. Among multi-step problem-solving procedures, the author chose the stated four-step procedure, stating that "most authors, including Polya, list four major steps to be followed in solving problems." The 60 substrategies among the four steps are listed with little or no explanation. These 60 strategies are included on a Likert-type scale on a questionnaire sent to 53 secondary school teachers. The respondents were asked to rate effectiveness of the calculator for each of the 60 strategies as very effective, effective, somewhat effective, or not effective.

In order to validate each of the 60 problem-solving strategies as calculator-effective with 95% confidence, the author determined that at least 33 of the 53 teachers should give a rating of very effective or effective. One-way analysis of variance was used to determine if there were significant differences in the effectiveness ratings of calculators by junior and senior secondary school teachers and by male and female teachers. Pearson product-moment correlation coefficients were used to determine if there were significant differences between any two of the four steps of the problem-solving procedure with respect to calculator effectiveness.

4. Findings

According to the questionnaire, the following problem-solving strategies were validated under the four problem-solving steps:

STEP I Understand the Problem

1. Use the Calculator to Estimate the Answer

STEP II Devise a Plan

1. Solve a Familiar Problem Having the Same or Similar Unknown
2. Solve a Closely Related Problem
3. Demonstrate the Solution to Part of the Problem
4. Construct Interpolations Regarding the Usefulness of the Given Data
5. Construct Extrapolations Regarding the Usefulness of the Given Data
6. Demonstrate How to Operate the Calculator in Carrying Out the Plan, and Check Its Validity Using a Simple Numerical Example

STEP III Carry Out the Plan

1. Perform the Indicated Mathematics
2. Demonstrate the Checking of Each Step in Carrying Out the Plan for the Solution

STEP IV Looking Backward

1. Check the Result Against the Estimate
2. Check the Result Mathematically
3. Demonstrate the Mathematics Learned, Including Using the Calculator, in This Problem
4. Demonstrate the Use of the Result of the Problem for Some Other Problem

All six pairs of correlations among the four problem-solving steps were significant. These correlations ranged from 0.467 between Understand the Problem and Look Backward to 0.832 between Devise a Plan and Look Backward (critical value at 0.05 level = 0.404). Results were similar when broken down to junior secondary, senior secondary, male, and female teachers, except that correlations between Understand the Problem and Carry Out the Plan were nonsignificant or barely significant. There were no significant differences in effectiveness of the calculator with respect to problem-solving strategies between junior and senior secondary school teachers and between male and female teachers.

5. Interpretations

The author concludes that the calculator is more effective in carrying out the plan than in understanding the problem, but is equally effective in the other five pairs of comparisons among the four steps of the problem-solving procedure. Other "interpretations" are a relisting of findings. He suggests that "future calculator research should extend this study to develop material and sets of problems which incorporate the use of calculators to teach the validated problem-solving strategies." He also suggests the need for curriculum materials to improve rounding and estimating.

Critical Commentary

In addition to major weaknesses in this study, it is very disturbing to note that the literature review on calculator studies is in large part a word-for-word copy of most of the critiques in the Calculator Information Center booklet, Investigations with Calculators (Abstracts and Critical Analyses of Research), edited by Suydam (1979). The author rarely uses quotation marks and cites the investigators rather than the writers of the critiques from whom the material is taken. In study after study, entire paragraphs are copied. Sometimes a word is changed, sometimes sentences are reordered. The duplication is glaring and many of the author's changes only accentuate the travesty. For example, the critiquers universally use letters for lists. Abdelsamad leaves all such lists intact but uses numerals. Groups of words set off by commas in the original critiques frequently appear in the author's text with only the word order changed. While the amount of word-for-word duplication seems incredible, the following single sentence is an obviously blatant example. In Abdelsamad's text we find:

> Some observations and tentative answers to the questions

> stated above are offered, but they are not reported here because they rely completely upon the author's subjective judgment rather than on empirical evidence.

The author cites Lowerre and Colleagues, 1978. However, the words are entirely due to Robert Reys in his critique of the Lowerre et al. study. This situation occurs repeatedly. In another case even a parenthetical remark by Clyde Wiles is retained with no citation. It is somewhat accidental that I discovered the "commonality of text" in the book of critiques and the dissertation. In the reading process of developing my own critique, I had reached a point where I felt that the study was weak, but the literature review was good!. Small wonder! Critiquers whose texts were used by Abdelsamad were no less than George Bright, Marilyn Zweng, Dennis Roberts, Clyde Wiles, Joe Dan Austin, Edward Beardslee, Donald Dessart, Charlotte Wheatley, Grayson Wheatley, Marilyn Suydam, Robert Reys, Fred Weaver, some of these writers with more than one critique.

Aside from the unimaginative text I have the following concerns:

1. The author gives much attention to the general four-step problem-solving procedure and claims to have developed it from the literature. Practically no attention is given to the 60 substrategies under the four steps. They seem to appear suddenly without any explanation. Some attempt should have been made to separate the strategies potentially suitable for calculators from the others, along with a rationale for selection.

2. In the questionnaires used to validate the strategies for calculator suitability the author states that "The term 'use the calculator' was introduced in the wording of most of the problem solving strategies whenever the use of the calculator was felt effective." Such a procedure clearly biases the responses.

3. The sample of 53 secondary school teachers is small for a questionnaire study. The subsample of 10 female teachers is certainly inadequate for generalizing and comparing differences between male and female teachers.

4. It seems ludicrous to determine if there are significant correlations between any two of the four steps of the problem solving procedure. Is it possible to conclude that the calculator is equally effective in Understanding the Problem and Looking Backward on the basis of correlations? It would make more sense to correlate substrategies under the four steps. For example, how strong is the correlation between Estimate the Answer and Compare the Result with the Estimate?

5. It seems odd that under Devise a Plan there should be 32 substrategies while under Carry Out the Plan there are only four. It seems more reasonable that for each strategy under Devise a Plan, there should be a corresponding strategy for Carry Out the Plan. This may be due to inadequate construction and development of substrategies. A proper rationale for the list of strategies should certainly have been provided.

Brey, Rita Kolmesh. EFFECTS OF PROBLEM SOLVING ACTIVITIES AND CALCULATORS ON PROBLEM SOLVING AND COMPUTATION IN GRADE FOUR. (The University of Michigan, 1980.) Dissertation Abstracts International 41A: 1914; November 1980. [Order No. 8025655]

Expanded abstract and analysis prepared especially for the Calculator Information Center by GRAYSON H. WHEATLEY, Purdue University.

1. Purpose

The purposes of this study were

1) to assess the effects of a program designed to improve problem-solving performance, and
2) to determine the effect of calculator use in conjunction with the problem-solving treatment.

2. Rationale

Recognizi. the importance of mathematics in solving real-life problems, the investigator targeted problem solving as an important life skill. The approach to problem solving is quite eclectic but emphasized vocabulary, comprehension, key words, and translation methods. Citing the NIE conference on needed research on calculators, the author endeavored to determine the effects of calculator use on problem solving and computation.

3. Research Design and Procedures

Twelve schools in Detroit, Michigan were chosen for use in this study. As a group, the children in the sample were performing seven months below grade level on the Iowa Test of Basic Skills. The final sample included 538 fourth-grade pupils drawn from 24 classes. The classes were assigned to one of three groups, Noncalculator, Calculator, or Control in such a way that the ITBS problem-solving scores were equated. The Calculator and Noncalculator groups received a series of 16 lessons designed to improve problem-solving skills through improved reading techniques. The lessons were taught over a two-month period in the spring of 1979. All subjects were pre- and posttested with a 17-item, experimenter-constructed test of two parts, problem solving and computation. Additionally, all subjects took a 14-item problem-solving/computation test on which calculators were available. No reliability data were reported on the tests. Using ITBS-Reading, ITBS-Problem Solving, and the experimenter-developed problem-solving pretest as separate covariates, analyses of covariance were performed on posttest scores.

4. Findings

The conclusions drawn from this study depend on which of the many analyses are considered. For each subtest (problems, computations) and total score, two ANOVAs and five ANCOVAs were computed. Because of the many analyses performed, no definitive statements can be made, but generally the Calculator and Noncalculator groups scored significantly higher than the Control group. On the Calculator test, the Calculator and Control groups had significantly higher scores than the Noncalculator Group (Calculator = 5.53, Control = 5.03, Noncalculator = 3.93), but again the specific conclusions depend on which of the many analyses are considered. There were no significant differences between attitude scores for the three groups. Sex differences were observed on some of the analyses but were not consistent or large.

5. Interpretations

The findings suggest that the fourth-grade students in this study scored higher on a mathematics test as a result of the treatment whether or not calculators were used. Of particular interest is the result that problem-solving experience led to improved computation scores whether or not calculators are available. The calculator was determined to be a motivating factor. Subjects in the Calculator group attempted more problems, especially when the numbers were large.

Critical Commentary

This study provides much information about pupil performance with and without calculator use. The sample size and treatment length are reasonable. Since this study purports to investigate problem solving, the reader should study carefully the treatment materials. The lessons grew out of an existing reading program and attempts have been made to relate the approach to advocated approaches to teaching problem solving. The approach can be characterized as word translation of straightforward story problems as found in fourth-grade textbooks using word clues. Efforts were made to improve the reading comprehension. This approach is in contrast to the heuristic method described by Krulik and Rudnick (1980). The data analysis procedures make interpretations difficult. If analysis of covariance is to be used, then criteria should be established for identifying the covariates. Performing separate ANCOVAs with each covariate confuses the issues; at most one ANCOVA should be performed for each test. It also seems that either ANCOVA or gain score analysis should be used, not both. Additionally, post hoc comparisons, while performed, are often ignored, resulting in false impressions about mean differences.

Reference

Krulik, S. and Rudnick, J. Problem Solving: A Handbook for Teachers. Boston: Allyn and Bacon, 1980.

Conner, Totsye J. AN INVESTIGATION OF THE USE OF HAND-HELD CALCULATORS BY STUDENTS IN ELEMENTARY SCHOOL. Research Monograph #32. Gainesville: P. K. Yonge Laboratory School, University of Florida, Winter 1980.

Expanded abstract and analysis prepared especially for the Calculator Information Center by GRAYSON H. WHEATLEY, Purdue University.

1. Purpose

The purpose was to determine the effect of calculator use on the mathematics achievement of elementary school pupils. A secondary purpose was to examine the attitude of parents toward calculator use in schools.

2. Rationale

Because of wide-spread availability and use of calculators at home and work, the need to study their use in schools was felt. Further, the researchers indicate they were responding to the call for calculator research made by organizations such as the National Council of Teachers of Mathematics.

3. Research Design and Procedures

The subjects for this study were kindergarten, second-grade, and fourth-grade pupils at the P. K. Yonge Laboratory School. It should be noted that admission criteria at the school are designed to provide a cross-section of ability and socioeconomic level to match that found in the state of Florida. Two classes of approximately 30 students each were assigned to the experimental group at each of the three grade levels. The students at these respective grades during the previous year served as control students. The experimental classes each had 15 calculators available and calculator activities were provided by the project director. Calculators were used approximately two days per week during the school year. Using analysis of variance, scores on the Metropolitan Achievement Test (May administration) of the two groups were compared. Additionally, a 21-item parent questionnaire was distributed to 281 families at the school in August and again in May after the treatment phase.

4. Findings

At the kindergarten level, only the total mathematics score was available from the MAT. The scores of the experimental and control groups were found to be significantly different ($p < 0.04$). The means and standard deviations for the two groups were: experimental, $\bar{X} = 26.3$, $s = 5.31$; control, $\bar{X} = 23.9$, $s = 5.90$. At the second- and fourth-grade levels, the subtest scores (Concepts, Computations, Problem Solving) were analyzed separately. The results of the univariate analyses of variance revealed that there were no significant differences between the experimental and control groups on any subtest at either grade level. On the parent questionnaire, there were no significant differences between the responses of the parents in August and May. Several interesting observations about the responses to particular items are reported.

5. Interpretations

The finding of significant differences at the kindergarten level suggest that calculators may be facilitative for very young children. The lack of differences at the other grade levels suggests that the treatment was not powerful enough to show an effect. However, it is important to note that the teachers and researcher were very positive about the experience and plan to continue using calculators. Longer-term effects will be studied in subsequent years.

Critical Commentary

This study should be viewed as one school's attempt to evaluate the implementation of calculator activities in the elementary school mathematics program rather than as a carefully controlled test of hypotheses. The strength of the study lies in the careful planning and implementation over an entire school year. The differences at the kindergarten level, while statistically significant, are probably not large enough to be educationally significant. Further, the possible confounding of factors other than the treatment must be considered. The control classes were from a different year. Thus, random assignment of classes to treatment was not possible.

The nature of the treatment in a study of this type is critical. Judging from the sample activities shown in the report, especially at the kindergarten level, the calculator was not used to its fullest capacity. Further, the implementation varied from teacher to teacher. In order to answer the research questions posed, a more careful prescription and monitoring of calculator use would be necessary.

Dean, David Keller. THE EFFECTIVENESS OF USING A HAND-HELD CALCULATOR AS AN INSTRUCTIONAL AID IN TEACHING THE BASIC MULTIPLICATION FACTS TO FOURTH GRADERS. (Michigan State University, 1980.) Dissertation Abstracts International 41A: 3939; March 1981. [Order No. 8106366]

Expanded abstract and analysis prepared especially for the Calculator Information Center by E. GLENADINE GIBB, The University of Texas at Austin.

1. Purpose

The study was designed (1) to compare the effectiveness of learning the basic multiplication facts with the aid of hand-held calculators with that of using the conventional paper-and-pencil approach; and (2) to examine potential interaction between prior mathematics achievement and the influence of various degrees of calculator use (unlimited, controlled, no use) on achievement.

2. Rationale

Various teaching methods have been examined for teaching the multiplication facts. The use of some drill is a widely recognized and accepted feature of most instruction on facts. Furthermore, the learning of the multiplication facts is an important prerequisite to future mathematics achievement. A review of the related research with respect to learning the multiplication facts supported developing meaning before drill. The related research which is reviewed supports the ideas that using calculators results in increased computational ability, that using calculators to check completed problems produces best results, that low achievers tend to be aided more than average or high achievers, and that skills remain consistent with initial posttests on retention skills. Two studies were cited that had used calculators in teaching multiplication. One study was similar to the present study but at the fifth-grade level, where it was found that significant differences favored the calculator-practice group over the pencil-practice group on both acquisition and short-term retention but not on long-term retention. In the second study a wide range of multiplication topics at various grade levels was explored using the calculator to check problems done by pencil and paper. No adverse effects were found. Also noted was that the previous research treated calculators and content as a supplement to the regular curriculum. Hence, the intent of this study was to use a basic curriculum component and a normal classroom setting including the content of the school's adopted textbook.

3. Research Design and Procedures

The population for the study was fourth-grade students in a primarily rural middle-class Caucasian school district in a large midwestern state. From the population, a sample of all seven intact fourth-grade classrooms (with from 20 to 25 students in each class) from the district's three elementary schools in Fall 1979 was selected. Five weeks prior to the treatments all students (n = 137) were given the California Achievement Test, Level 14, Form C Mathematics Computation and Mathematics Concepts and Application subtests. Special education students were eliminated from the sample. Scores from this test were used to compute the class mean and to assign each student within a class to one of three achievement-level groups according to national percentile score. Students at the 67th percentile and above were assigned to the high achievement group; students at the 34th to 66th percentile range were assigned to the average group; and students at the 33rd percentile and below were assigned to the low achievement group.

The three classrooms with the lowest class mean based on the above test were randomly assigned to one of the three treatment groups:

1. To use the calculator for all calculations;
2. To use the calculator to check problems previously done without the benefit of the calculator; and
3. To do all work by conventional means without any calculator use.

A similar technique was used in assigning the classrooms with highest class means to treatments. The remaining class was randomly assigned to a treatment group.

Three 50-item tests of the 100 basic multiplication facts were generated by the researcher. Selection and order were established using a system based on a table of random numbers. These tests formed the pretest, posttest, and retention test. There was no time limit for this test. Reliability using the Kuder-Richardson formula 20 resulted in a reliability of 0.95, 0.93, and 0.88 for the pretest, posttest, and retention test, respectively.

Based on a comparison of growth shown by students in each teacher's two previous classes, the assumption was made that the teachers were of comparable competence. The researcher had two meetings with the participating teachers in order to (1) describe the intent of the proposed research and

(2) outline the instructional sequence and procedures. The teachers were provided with no special training or materials before and/or during the study.

The treatment consisted of all groups using the 32-page multiplication unit in the student's fourth-grade mathematics textbook, Mathematics Around Us (Scott, Foresman and Co.), beginning on page 84. Approximately 20 instructional sessions were allowed. For the most part teachers taught their entire class as one group. Any supplementary materials and techniques were those that teachers had found useful in the past. Also, teachers were discouraged from requiring homework.

The researcher made frequent observations in the seven classrooms to monitor the adherence to instructional procedures and assigned treatment conditions. Also, teachers were required to keep a daily log of their multiplication activities which included a record of time spent teaching the facts, opinions of students' attitudes, and work habits.

The multiplication facts pretest was administered to 145 students at the beginning of the study. The posttest was administered six weeks later to 139 students and six weeks after the posttest 137 students took the retention test. (Absences were caused by moving and illness.) The researcher administered all tests.

4. Findings

Data were analyzed using analysis of covariance tests with the pretest multiplication fact test scores as the covariate. More specifically, analysis of covariance tests were made for treatment and treatment-by-achievement-group interaction, with posttest scores and with long-term retention scores as the dependent variables. Classrooms rather than individuals served as the unit of analysis.

The results of the ANCOVA test of posttest scores showed no significant differences between the three treatment conditions. Although adjusted posttest means for treatment groups suggested interaction between achievement level and degree of calculator use, interaction between treatments and ability levels was found to be not significant. Also, adjusted retention test scores did not differ significantly among treatment groups.

Based on anecdotal findings from logs, observations, and interviews, an enthusiasm for the use of calculators was found among the students. This enthusiasm seemed sustained throughout the six-week treatment period.

Teachers, however, reported a certain discomfort in not knowing how well their students were progressing and did not have as great an understanding of their students' learning. Thus, they felt that the calculator was interfering with their teaching.

5. Interpretations

Based on the findings of this study, calculators, as used in this study, do not contribute to improved achievement nor do they appear to be a significant detriment to the learning of the facts. Also, no support was found for any interaction between degree of calculator use and level of achievement; that is, it was not found that students at low achievement levels can be expected to gain as much or more than students at higher achievement levels nor that calculators significantly reflect retention.

This study does support much of the previous research of calculator use concerning motivation.

Critical Commentary

This study seemed well-designed and conducted. The high scores on the pretest may well have been a contributing factor on the results, for it placed a low ceiling on achievement as measured by the posttest and retention test. Although the researcher made an effort to focus on an aspect of basic curriculum, no specific activities seemed to be designed with the intent on learning the facts. Seemingly if we are to assess the contributions to learning effected by calculator usage, conscious consideration must be given to thought processing and relational thinking instead of using calculators for the purpose of getting or checking answers. One must ask what kind of thinking does the student bring to the results obtained by using a calculator.

Furthermore, for the purpose f studying alternatives for learning multiplication facts, it is suggested that a study of this process at third-grade level might be more insightful, including a rethinking of each treatment and optimal sensitivity to thoughtful interactions of the learner with the calculator.

Elliott, James William. THE EFFECT OF USING HAND-HELD CALCULATORS ON VERBAL PROBLEM SOLVING ABILITY OF SIXTH-GRADE STUDENTS. (University of Oregon, 1980.) Dissertation Abstracts International 41A: 3464; February 1981. [Order No. 8101829]

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

1. Purpose

This study was designed to investigate the effect of calculator use on sixth graders' verbal problem-solving ability.

2. Rationale

Previous research has indicated that computational errors are a major reason for students' incorrect solutions to problems. Calculator use was proposed as a way to reduce computational errors and thus improve students' problem-solving ability.

3. Research Design and Procedures

A three-week pilot study was conducted to field-test materials and procedures with two sixth-grade classrooms. Changes were then made to address the "ceiling effect" for high-ability problem solvers and to lengthen the calculator orientation session for teachers and students.

In the actual study, six classes of sixth-grade students were randomly assigned to treatment groups. The six classes were from three schools, each in a different district. Lane County (Oregon) Math Project materials were the source of the problem-solving activities used by all classes for six weeks. In one treatment group in each school the calculator was used and in the other only paper and pencil were used.

Students' problem-solving ability was pretested without the use of a calculator by the Metropolitan Achievement Tests (MAT) and the scores used to define high-, average-, or low-ability students. Different forms of the MATs were used to posttest problem-solving ability with and without the use of a calculator.

4. Findings

There was no significant difference between treatment groups (calculator or paper-and-pencil) on the posttest. However, students, regardless of which treatment group they were in, achieved significantly higher test scores using calculators than when using paper and pencil. Ability-by-treatment interactions were not significant; however, district-by-ability interactions were significant on the paper-and-pencil posttest. And a significant district-by-ability-by-treatment was detected on the calculator version of the posttest. In ~~summary, no~~ significant differences were found for learning verbal problem solving with a calculator or without a calculator (paper and pencil).

5. Interpretations

Instruction and practice in verbal problem solving with the use of a calculator seems to provide no special advantage or disadvantage to sixth-grade students in learning verbal problem solving. Calculator use on the posttest improved performance of both groups (calculator treatment and paper-and-pencil treatment). In addition, student performance was affected by setting (district) and prior ability. Low-ability problem solvers seemed to perform less well with the calculator than with paper and pencil; average-ability problem solvers appeared to perform substantially the same when using calculators or paper and pencil, and high-ability problem solvers seem to perform best with the aid of a calculator.

Critical Commentary

In general, this research substantiates the previous research that indicates no particular advantage or disadvantage to student use of calculators in their instructional program. However, the district differences obtained were dismissed with a caveat that the "basic program" was implemented differently in the different districts. It would be helpful to know what these differences were, since the reality of what happened in those classrooms is the basis for the "treatments." Two observations per classroom by the investigator over a six-week period of time is insufficient to document or describe with confidence what was happening in the treatment classrooms.

The interpretation of the results for the different ability groups does not seem warranted. The small number of students in each group and the acknowledged district differences make these observations misleading. The observed combined means for ability groups (Figure 4 in the study) indicate a higher posttest score with the use of the calculator for all groups, in any case.

Calculator use for classroom instruction continues to be debated and continues as an area for additional research. This study should help to assure us somewhat that student learning in the verbal problem-solving area is not diminished by the use of a calculator.

Gross, Ena. AN EXPLORATORY STUDY ON THE USE OF CALCULATORS AND PROBLEM SOLVING HEURISTICS WITH IN-SERVICE ELEMENTARY SCHOOL TEACHERS. (Georgia State University-College of Education, 1980.) Dissertation Abstracts International 41A: 1451-1452; October 1980. [Order No. 8022871]

Expanded abstract and analysis prepared especially for the Calculator Information Center by JOHN A. DOSSEY, Illinois State University.

1. Purpose

The purposes of the study were to: develop and evaluate a heuristically-oriented problem-solving component for an elementary mathematics methods course, develop and evaluate a set of nonroutine problems which might be used in such a component, and study the relationship of heuristic or calculator usage as elicited by these problems.

2. Rationale

The study was constructed as an outgrowth of the problem-solving process work pioneered by Kilpatrick (1967) and Kantowski (1974). In particular, the focus was on the development and evaluation of a unit to teach heuristic methods to in-service elementary teachers and then to examine the effects of that instruction on the teachers involved. This, combined with the calculator availability for one of the groups, was tied to the general interest in problem solving, hand calculators, and student attitudes toward mathematics.

3. Research Design and Procedures

The study was built around a set of 21 nonroutine problems selected by the investigator. These problems had multiple solution paths, required minimal prerequisite knowledge, and were solvable through use of a hand calculator. Nine of the problems were incorporated into an instructional unit and used with the students enrolled in two sections (21 Ss/section) of a graduate mathematics methods course for in-service teachers during a six-week summer session. The remaining 12 problems were reserved for testing purposes at the end of the study.

In addition to the heuristic methods presented to both sections, one of the sections (HCL) was given instruction on the use of a hand calculator (4 functions, $\sqrt{\ }$, %, and memory) in problem solving. The teachers in this section were allowed to use the calculators in all remaining phases of the study.

The teachers in the two sections spent the first week of the course discussing Kilpatrick's modification of Polya's four-step method for solving problems (Understanding, Planning, Executing the Plan, and Looking Back) and the heuristics that fit under each stage. During the next 4½ weeks, four 75-minute periods were spent applying these methods to the solution of the nine nonroutine problems. The teachers were given 20 minutes to work on a problem. Then the problem's solution was discussed, alternate methods of solution shown, and, in the case of the HCL section, how a hand calculator might have been used in the solution of the problem. This pattern was then repeated with another nonroutine problem in each of the sessions. All students in both sections were asked to keep logs showing their solution attempts and the methods they employed.

During the last week of the term, six students were selected from each of the sections for further study. Three of the students from each section were given four additional problems to solve and sent home to solve them. The other three students from each section were given the same problems in an interview session and then observed during their work on the problems. The sessions were audio-recorded and the students were asked to "think aloud' during their work on the problems. All twelve of these students had hand calculators available for use at any point in the problem solving process.

The final eight nonroutine problems were given to all students on an in-class test during the final week of the summer term. They were asked to solve the problems and record their processes and findings along with the solutions.

The written records of problem attempts and processes used were analyzed, along with the recordings of the interviews, in an attempt to categorize the heuristics employed, the sequence of their use, and other information. The researcher employed Kilpatrick's process sequence code (1967) and Kantowski's process-product scoring scale (1974). These results were then presented by problem by section of the study.

4. Findings

The analysis of the data from the instructional phase showed that students who used the heuristics "draws a diagram," "uses successive approximations," "uses a related problem," or "uses a pattern search" were more successful than students who did not apply these heuristics in the first nine problem sets. This analysis also showed that the students in the hand calculator group used their calculators very sparingly and then only a few students on any given problem. These usages of the hand calculators were limited to the problems with long or tedious calculations. The usages were generally tied to the use of the heuristic "uses successive approximations."

The analysis of the interview/take-home problem recordings and logs indicated that students who were able initially to restate and plan attacks for problems were the more successful problem solvers. The study of the heuristics employed showed very similar patterns for each individual problem across students--indicating that problem characteristics seem to be related to heuristics needed or elicited. Again, there was minimal hand calculator usage. The few who did use the calculators were all from the HCL section.

The anlaysis of the results from the eight items on the final examination showed that the heuristics employed by the students having above median product-process scores were very similar for individual problems. Hand calculator usage was minimal among the students in the HCL section and then only for long calculations. The most commonly used heuristic was "uses pattern search."

5. Interpretations

The researcher felt that the foregoing results indicated that the problem solving component was successful. However, if the problems are to elicit hand calculator usage, they will have to be written in such a manner as to demand difficult computations.

In addition, the analysis of heuristic sequences indicated that successful problem solvers tended to plan their attack and then be able to employ a wide variety of heuristics in facing a given problem. The investigator suggested that there be additional work done on the relationship of problem types to heuristics elicited.

Critical Commentary

While the study was exploratory in nature, the execution involved too many subjective-based decisions. The importance and interpretability of the findings would have been greatly increased if more attention had been given to the details of reporting (time line, content of class, periods, ...), nature of the content on problem solving contained in the hand calculator group's instruction, and having another person score the logs and interviews for reliability.

While the investigator gathered some initial information on the mathematical background and attitudes of the subjects involved, no information was gathered either to test the subjects' intact knowledge of heuristics at the beginning of the session or to test the subjects' attitude changes over the experimental period. The lack of the former severely limits the generalizations that can be made about the success of the problem-solving component. The lack of the second makes the section on attitudes in the review of research seem tangential to the study that followed.

An analysis of the data presented on the equivalence of the two sections and the resulting scoring of the outcomes seemed strongly to favor the HCL group. A recheck of the equivalence section showed that while there was no significant difference at the 0.05 level, there was one at the 0.10 level. This, combined with the added instruction on problem solving included with the calculator, may account for the differences in performance of the two groups.

There was one error noted in the problem set. On the Street Problem, the word "west" was used when the diagram called for the word "east." This error was consistent at each mention of the problem, thus probably also in the experimental materials used. This error would account for the different level of performance by the students on this problem.

Thus the results, while interesting and suggestive of several hypotheses, must be treated with extreme caution until the study is repeated with greater care and stronger controls. The repetition might wish to block students by the factors calculator-noncalculator and heuristic instruction-nonheuristic instruction. Such a 2 x 2 design might more closely answer the questions the researcher seemed to be after.

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Kolpas, Sidney J. THE USE OF ELECTRONIC CALCULATORS AS IN-CLASS INSTRUCTIONAL AIDS IN A NINTH-GRADE ARITHMETIC PROGRAM. (University of Southern California, 1979.) Dissertation Abstracts International 39A: 5293; March 1979. [--]

Expanded abstract and analysis prepared especially for the Calculator Information Center by CLYDE A. WILES, Indiana University Northwest.

1. Purpose

To investigate how two schedules of use of electronic calculators as integrated "in-class instructional aids" affect the computation, concept, and application scores of ninth-grade arithmetic students.

2. Rationale

The general availability of electronic calculators and the sparsity of information about their effects upon present curricula with students of these age and ability levels provided the primary justification for this study. The author's review of the research of the 20th century, with particular attention to that reported in the 1970's, gave rise to several features of this study. A summary of these features follows:

1. The use of intact curricula. It should be noted, though, that the calculator groups were informally introduced to a variety of topics earlier than usual because of their use of the machines.
2. A stress on estimation with the calculator groups.
3. The use of calculators for diagnosis of conceptual problems.
4. The use of calculators to teach concepts.
5. The use of calculators on the posttest.
6. The use of two schedules of calculator usage.
7. The involvement of low-ability or low-achieving ninth-grade students.
8. The use of joint instructional planning by the two teachers throughout the course of the study.

The general rationale for expecting calculator-induced, superior performance was stated in terms of reinforcement theory. However, there was no discussion of a theoretical basis for predicting effects attributable to the two schedules of calculator use.

3. Research Design and Procedures

The basic design was a pretest-posttest, non-equivalent control group design with two levels of experimental treatment.

Subjects

The students involved in this study were ninth-grade low or underachievers assigned to general mathematics classes in a Los Angeles County school district. The district was characterized as suburban-industrial, having a majority of white students with some minority Latin students. Classes were selected from two of three junior high schools in the district. Two of the classes in one building were designated as experimental (E1, and E2); the two classes in the other building were designed as control (C1, and C2). The numbers of students involved by group were E1, 24; E2, 20; C1, 17; and C2, 19.

The control classes were taught by the wife of the investigator, who in turn taught the experimental groups. The students in the control groups received "the regular math 9 curriculum" while the experimental groups received "the regular 9 curriculum with use of electronic calculators as in-class instructional aids." The author notes:

> All classes used the same basic instructional scheduling, lessons, and in-class assignments...they received identical practice-sheets, extra credit, and exams. ...instructor variables (were controlled) through daily discussions of assignments and methods. However, the styles of teaching, amount of examples covered, time for independent work, and nature-and-scope of in-class assignments were necessarily different in the experimental groups because of calculator usage. (p. 139)

Hence, while not part of the textbook program that all students used, concepts, methods, and emphasis were present in the experimental groups that were not touched on in the control groups. The calculator groups differed from each other in that group E1 was permitted to use calculators as the sole source of answers for in-class assignments 50% of the time, and as checking devices 50% of the time. Group E2 was allowed to use them 75% of the time as the sole source of answers. No students of any group were issued books, the calculators were kept at school, and all work had to be done during the regular class period.

Tests

The Comprehensive Tests of Basic Skills (CTBS, McGraw-Hill, 1970) were administered as pre- and posttests. Two forms of the test were used. Pretest scores for reading comprehension, computation, arithmetic concepts, and applications were used as possible covariates. A 50-item final examination dealing only with computational skills taught or reviewed during the semester was constructed by the investigator and administered twice at the end of the semester. The first time all work had to be done by hand. Each test was scored, but not marked, and returned to the student. Students were then asked to rework the unmarked finals using the calculators as aids, and to correct any problems they wished.

Analysis

Five hypotheses were tested.

H1 The post computational scores are the same.

H2 The post concepts scores are the same.

H3 The post applications scores are the same.

H4 The final exam scores (without calculators) are the same.

H5 The final exam scores (with the calculators) are the same.

Each hypothesis was tested by analysis of variance, analysis of covariance (with a variety of covariates), and t-test. Groups E1, E2, and C1 + C2 were treated as three independent groups using individuals as the unit of analysis. An alpha level of .10 on any test was taken as indicating significance. The reason advanced for this level was that the study is viewed as exploratory and type I errors are preferred to type II errors.

4. Findings

The analysis of the pretest data indicated significant differences in favor of the experimental groups for pre-concepts as measured by the CTBS scale. However, a variety of analyses using either reading or pre-concepts as covariates, using no covariates, and using simple t-tests on combined groups were used to test for significant differences. The author reports:

> The computer analysis of the data related to each null hypothesis was done through a number of approaches; analysis of variance, *t* test, and two different runs of analysis of covariance. .... However, each of these was done on postscores as well as gain scores. However, with each hypothesis only the approach that yielded the most statistically sensitive and relevant results was reported. (p. 122).

On this basis the findings were as follows. Hypotheses one through three were not rejected. Hypothesis four was rejected by the t-test data analysis. The mean of combined experimental groups and the mean of group E1 by itself were found to be greater than the mean of the combined control groups. Hypothesis five was rejected by covariate analysis. The experimental groups, combined and singly, were found to have greater means than that of the combined control groups.

5. Interpretations

1. Hand-held calculators as in-class instructional aids neither impair nor improve ninth-grade students' arithmetic computational, conceptual, and application abilities.
2. The value of calculator instructional aids for improving ninth-grade students' computational abilities is more readily apparent on teacher-constructed exams. However, the value diminished with excessive calculator use.
3. Formal instruction in hand-held calculator usage markedly improves abilities to use calculators. An apparent improvement in student attitude as evidenced by the number of semester absences and extra-credit points was noted. An apparent though unmeasured motivational impact due to calculator availability was also reported.

Further research was called for dealing with a) calculators and low achievers, b) varying amounts of calculator-aided instruction time, c) the impact of calculators upon the amount and distribution of instructional time, and d) the effect of calculators on student attitudes. Inquiry should be made to determine the most appropriate calculator activities for different grade and ability levels, and further research should be attempted using researcher/teacher-constructed tests.

Critical Commentary

We have here a good piece of action research that undoubtedly contributed to the broader understanding of all involved and that could have a salutary effect upon the local situation. It strongly suggests, as have so many other studies, that no harm can come from integrating calculators into existing curricula in any reasonable way. Furthermore, all involved value this use.

The question of "How much of a good thing can you stand?" is novel. Apparently, a 75% requirement led to problems. In this study low-level ninth-grade students are reported to have complained about the lack of computational practice apart from the calculators.

The strength of the study is to be found in the detailed thoroughness of its execution. The author has left no stone unturned. The report too was detailed, except for the presentation of the data. A table of means is not reported, and only those tests judged to be "most sensitive" are reported although a multitude of statistical tests were made. While they are not enumerated, it is clear that more than enough tests were made to insure type I errors. Quite apart from the fact that the groups were known to be different by virtue of choosing intact classes in different schools, and by virtue of pretest data, there can be no justification for this kind of significance testing. It is simply meaningless.

It is clear on the face of it, however, that students who have been taught to use calculators will surely use them more effectively than students who have not. This is the only undisputable finding. It seems likely as well that there were no significant differences on other criterion variables. The three interpretations do seem to be defensible.

An analysis of the teacher-made test raised some interesting questions. How did students who had been given no instruction in calculator usage solve the problems 42 - (7 + 5) and 6(9 + 8) + 7 using the machines that do not observe order of operations or have parenthesis keys? Why were no problems included that would "tax" the power of the calculator? Only two problems, 859 x 985 and $68/\overline{26.52}$, were on the face of it "tedious" without the use of a machine. Of ten such problems, the only fraction problem that obviously favored calculator usage was "change 7/8 to a decimal." One wonders what problems the control groups missed with greater frequency than the experimental groups.

The call for curricula that optimize the use of the calculator and for tests that measure outcomes that should be so optimized is important. This study, along with many others, seems to have assured us that the question before us is not should we integrate these machines into our mathematics program, but rather, how should we do so.

Miles, Marion Moss. A STUDY OF THE INTERRELATIONSHIP OF THE HAND-HELD CALCULATOR, ACHIEVEMENT IN MATHEMATICAL COMPUTATION AND PROBLEM-SOLVING, AND ATTITUDE TOWARD MATHEMATICS OF EIGHTH GRADE STUDENTS. (The University of Mississippi, 1980.) Dissertation Abstracts International 41A: 931: September 1980. [Order No. 8018831]

Expanded abstract and analysis prepared especially for the Calculator Information Center by WALTER SZETELA, The University of British Columbia.

1. Purpose

The purpose of the study was to determine if grade 8 students do as well in computation and better in problem solving on paper-and-pencil tests after using calculators during instruction than students who used only paper and pencil during instruction. An additional purpose was to determine changes in attitude toward mathematics through experience with calculators.

2. Rationale

There is a resistance to the use of calculators in elementary and junior secondary schools because of the traditional emphasis on computational skills with pencil and paper. If calculators are used for lengthy computations, more time may be spent on learning how to solve problems.

3. Research Design and Procedures

From an original sample of 132 grade 8 students pre-registered in a southern junior high school, 82 students completed all tests. Two experienced teachers, one of whom was the investigator, each taught a calculator group and a control group. Students were randomly assigned to treatment. In the year prior to this study, a preliminary study was made in one grade eight class to identify calculator activities that were "considered to be fun, informative, and interesting." Five sets of activities designed to "teach use of the calculator" were used for the "Introduction to the Calculator" unit. The main study consisted of this one-week introductory unit, a three-week percent unit, and, presumably, a seven-week problem-solving unit. The problem-solving unit consisted of guess-and-check strategies, patterns, chain problems, and money problems. The 1978 California Achievement Test Development Scale was given as a pretest.

After one week of calculator familiarization including use of the memory and constant features, three weeks were spent on the percent unit, mainly on interest, tax, and discount problems, with additional problems for enrichment from various books. In the problem-solving unit, the "Guess and Check" and "Patterns" sections began with a teacher-led activity, followed by a group activity, and then an individual activity. For the "Applications" part of problem-solving, instruction was individualized. Subjects who passed three diagnostic tests involving word problems with whole numbers, fractions, and decimals at an 80 percent performance level, moved on to problems obtained from the literature which required lengthy computation. There were four sets of such problems, and students were allowed to work these problems in pairs.

In addition to hypotheses comparing experimental and control groups on computation, problem solving, and attitude toward mathematics, the investigator examined comparisons between males and females, whites and blacks, and three ability levels. Posttests included the California Achievement Test (Form A, Level 4, 1970) with computation, problem-solving, and concept subsections; tests on percent and on problem-solving designed by the two teachers; and a seven-item Likert-type attitude scale with a range of 7 for each response, designed by the investigator. The hypotheses involving the main experimental and control groups were analyzed by analysis of covariance with the pretest score as covariate. Hypotheses involving males vs. females, whites vs. blacks, and high- vs. medium- vs. low-ability groups were analyzed by repeated measures analyses of variance. The attitude test was analyzed by a t-test.

4. <u>Findings</u>

The reported findings were as follows:

a. There were no significant differences between the main experimental and control groups on any of the measures of computation and problem-solving performance or on attitude toward mathematics.
b. Females performed significantly better than males on the computation subtest of the California Achievement Test, but no other significant differences were obtained on the other four measures.
c. On all four achievement measures, the white groups performed significantly better than the black groups.
d. Significant differences between ability groups followed expected patterns. When comparisons were made at particular ability levels, all differences were non-significant except the following:
   1. The experimental medium-ability group scored significantly

higher than the corresponding control group on both the computation and problem-solving subtests of the California Achievement Test.

ii. On the teacher-designed test of problem-solving, the low-ability experimental group scored significantly lower than the corresponding control group.

5. Interpretations

The investigator concluded that eighth grade students who used calculators during instruction but not on tests did as well in computation as students who used only paper and pencil during instruction, that girls benefited more from experience with calculators than boys, that the effects of calculator use were nonsignificant when controlling for race, that low-ability groups did not benefit as much from use of calculators as did medium- and high-ability groups, and that use of calculators did not serve to motivate. It was recommended that calculators be used to save time in problem-solving, that calculators not be used when teaching new material to low-ability students, and that further studies be made to investigate the relationship between the use of calculators and types of problems.

Critical Commentary

This is a carefully designed and executed study. It is well-written, making it easy for the reader to comprehend what was planned and what was done. The preliminary study was useful to clarify and expedite the design of the main study as well as to select appropriate materials. The length of the study, ten weeks, compares favorably with the many short, shotgun-style studies. Although only 82 out of an original 132 grade 8 students had both completed instruction and taken all tests, the attrition rate for students in the study was approximately equal to the attrition rate for the entire school. Nearly half of the attrition was due to students who had preregistered for the school in the spring when random assignment to treatment was made, and who did not enroll for fall classes. The use of both standardized and teacher-designed tests is commended. However, these positive aspects are tempered by the following questions or flaws:

a. The major weakness is that, as with so many calculator studies, all posttests are with paper and pencil. It seems that researchers are still so anxious to show that calculators will not reduce computational skill with paper and pencil that they are afraid to allow calculators in situations where calculator benefits might be more apparent. There is nothing sinful about allowing students who have used calculators during instruction to use calculators on problem-solving tests. When such students take problem-solving tests with paper and pencil only, it is not surprising if they do not perform significantly better than control groups.

b. The pretest scores were not significantly different for any of the comparison groups. In fact they were remarkably similar. I do not understand why analysis of covariance was used to test the hypotheses involving the main comparison groups, while repeated measures analysis of variance was used to test hypotheses for male-female, white-black, and high- to low-ability groups. In view of the pretest scores, simple analysis of variance seems more appropriate.

c. No reliability estimates are given for the posttests. There were 25 items on each of the teacher-designed tests on percent and on problem-solving. Normally, this number is large enough to provide a satisfactory reliability coefficient if indeed the test is stable. One is left wondering just how valid are the results in the absence of reliability measures?

d. The set of hypotheses involving high-, medium-, and low-ability groups is inappropriately focused. Certainly one expects that high-ability students will perform better than low-ability students. What is more important is how experimental and control groups perform <u>within each</u> ability level. In fairness to the investigator, these results are given, but these are the comparisons which should have been stated in the hypotheses, not the obvious and less interesting ones.

e. The investigator's conclusions are somewhat unjustified. Only on the computation test did girls exceed boys. On three other tests there were no significant differences. This evidence is not sufficient to generalize that girls benefit from calculators more than boys. Only in one measure out of four did low-ability students perform significantly less well with calculator instruction. Again, this evidence is insufficient to generalize that low-ability groups do not benefit as much from calculators as do higher-ability groups.

Despite these concerns, the investigator is commended for care and thoroughness. One further example of interest is the analysis of data for 42 students who did not complete the study. Data for these students on two subtests of the California Achievement Test were analyzed and indicated that the sample of students who failed to complete the study were from the same population as those who did complete the study. Thus attrition appears not to have biased the final sample of students who completed all tests.

Shult, Douglas Lee. THE EFFECT OF THE HAND-HELD CALCULATOR ON ARITHMETIC PROBLEM-SOLVING ABILITIES OF SIXTH-GRADE STUDENTS. (University of Oregon, 1979.) Dissertation Abstracts International 40A: 6179-6180; June 1980. [Order No. 8012320]

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

1. Purpose

The two purposes of this study were to determine the effect of calculator use on the problem-solving abilities of average sixth-grade mathematics students and to study differences in problem-solving processes of calculator users and non-users.

2. Rationale

Calculator use should allow students to concentrate on strategies for problem solving rather than on computation needed to find a solution. Previous research has indicated that computational facility does not seem to be impaired or improved by calculator use, but little definitive research has studied the effect of calculator usage on problem-solving effectiveness or processes. This research was an attempt to address these issues concerning problem solving.

3. Research Design and Procedures

A pilot study was conducted with seven above-average fifth-grade mathematics students. Interview guidelines and techniques, coding variables and scoring schemes, and appropriateness of instructional materials were considered in the field test. All students participating in the pilot and actual study were students at the International School of Kenya (I.S.K).

The I.S.K. is a private coeducational school near Nairobi and is owned by the United States and Canadian embassies. Students in the study represented 12 different countries and were in a program that "was basically North American and college preparatory in nature."

As a result of the pilot, the audio recording of interviews was abandoned in favor of directly coding subjects' responses during interviews. Direct coding indicated strategies that did not appear on audio tapes, such as re-reading of the problem. In addition, problems which were too difficult for students were either eliminated or modified.

Subjects were 30 sixth-grade students who scored nearest the mean on the Science Research Associates Assessment Survey in Mathematics. The 30 were selected from the total group of 44. A stratified random sampling technique to account for equal representation of high-, medium-, and low-ability students was used to assign 15 students to an experimental group and 15 students to a control group.

Two interviewers were selected and trained to collect both pre-intervie and post-interview data on subjects' problem-solving thought processes. One interviewer collected all pre-interview data and the other interviewer ducted all post-interview data. During the interviews, subjects' problem-solving process and product data were recorded as subjects worked arithmetic word problems.

Experimental and control group pre-interviews and post-interviews were conducted without calculators and a post-interview with calculators was conducted with the experimental group. All subjects completed an investigator-constructed Calculator Familiarity Questionnaire, which indicated all subjects had some knowledge of calculators.

Investigator-written problem booklets were used during the interviews. The form for coding problem-solving behaviors was adapted from those used by other researchers (Kilpatrick, 1967 and Days, 1977) in this area. Approximately six weeks of instruction in problem-solving constituted the treatment phase of the study. The experimental group used calculators during this time and the control group did not. However, all 44 students in the I.S.K. participated in the instructional phase. Students completed activity sheets individually. The highest numbers completed were from 30 to 35 and the lowest were 10 to 15, with an average completed of 22.7 for the experimental group and 24.4 for the control group.

4. Findings

The group comparisons of pretest and posttest data did not reveal any significant differences. However, some patterns of interest were indicated. Subjects using calculators tended to require more time to solve problems, to make more errors in logical problem-solving strategy development, and to demonstrate a greater tendency to check solutions than control students.

5. Interpretations

Calculator usage does not appear to affect adversely the problem-solving process nor cause students to become dependent on them or less proficient in paper-and-pencil problem-solving skills.

Critical Commentary

A phenomenal amount of time and energy and creative thinking obviously went into the design and data analysis of this study. Modifications of existing coding schemes for interviews, as well as operational definitions for variables such as accuracy, logical strategies development, and evaluation were developed. This tedious examination of data and strategies, in newly defined ways, contributed little. The bottom line seemed to be little or no contribution to what we know about the effects of calculator usage in learning.

The design and implementation of the study had definite limitations. The population of students was very small and would also appear to have the potential of being uniquely different from the usual cross-section of sixth-graders In addition, the use of one interviewer for all pre-interviews and a different interviewer for all post-interviews might have introduced systematic error.

The number of variables scored also seemed inordinately high -- 26 variables for each problem. This contributed to the complexity of analysis without adding to the clarity of the intent. In spite of this flaw, the study does confirm earlier work indicating calculator usage does not seem to inhibit learning of selected skills in mathematics.

Ward, Dennis Elliott. THE EFFECT OF THE ELECTRONIC CALCULATOR ON PROBLEM-SOLVING ACHIEVEMENT AND ATTITUDES TOWARD MATHEMATICS OF GENERAL MATHEMATICS STUDENTS. (University of Southern California, 1978.) Dissertation Abstracts International 39A: 4038; January 1979. [--]

Expanded abstract and analysis prepared especially for the Calculator Information Center by CLYDE A. WILES, Indiana University Northwest.

1. Purpose

The purpose of this study was to investigate the effects of use of an electronic calculator upon problem-solving achievement and upon student attitudes toward mathematics. Differential effects attributable to sex and reading ability were also examined.

2. Rationale

The use of calculators in the normal program of school instruction has been widely advocated, although not without resistance. The lists of anticipated gains to be realized from this introduction commonly include the expectation that this can greatly facilitate problem solving. A great deal of research was reviewed that had the primary focus of investigating the effects of calculator usage on computational skills and student attitudes. This research was summarized by the conclusion that calculators have no negative impact on either of these two variables. While the studies that were reviewed did not have problem solving as a criterion variable, the reports abounded with confident statements that calculators provided students with increased ability and confidence in problem solving. Only one study was found that directly related calculator usage and problem solving, and no study was found that "investigated the effects that the use of an electronic calculator [may have] on problem-solving ability." This study was therefore undertaken with the purposes described above.

A review of the more general problem-solving literature indicated that the performance of boys may well be different from that of girls, and that reading ability can influence problem-solving achievement. These two factors were therefore entered into the design as independent variables.

Definitions used were generally taken from Good (1973). In brief, problem-solving achievement is a score for a written problem test, which in turn is a set of problems stated in words rather than symbols. Reading ability, too, is a score on a test. Attitude, taken abstractly as a predisposition or tendency to react, is operationally defined as a test score on a set of 5-choice, Likert-type items.

3. Research Design and Procedures

Involved in this study were the students assigned to ninth-grade general mathematics classes at a Department of Defense American High School in Okinawa during the 1977-78 school year. This group had been screened to remove a remedial group. The students were primarily dependents of U.S. military personnel. Included, however, were dependents of non-military Americans, native Okinawans, and other non-Americans. While 92 students were chosen for the study and randomly assigned to four groups, 20 subjects were lost to the study due to major changes in the military situation at that time. The remaining 72 students ended up in four classes each containing 18 boys and 18 girls, taught by four teachers randomly chosen by matched pairs from a staff of six teachers.

The study involved essentially all of the first semester. The first two weeks were spent in reviewing basic computation, pretesting, and introducing the calculator groups to the calculator. The instructional materials for both the experimental and control classes were problem-solving units selected from A Workbook to Accompany Essential Mathematics (Coburn, 1975) and from The Mathematics of Personal Finance (MacKenzie and Kreutzer, 1974). The only planned instructional difference was that the students of the calculator classes were given calculators to use in school. No homework was given throughout the period and the calculators were kept in the school.

There were both pre and post instruction tests. A standardized reading test was given only as a pretest, while the other tests were given as both pre- and posttests. These consisted of two attitude scales and the Final Exam provided by the publishers of the Essential Mathematics program.

Analysis was by five independent analyses of covariance using the student as the unit of analysis. All computations for this analysis were carried out by using a programmable pocket calculator.

4. Findings

Five hypotheses related to (a) achievement differences by treatment, (b) achievement differences by sex, (c) achievement differences by reading ability, (d) attitude differences by treatment, and (e) attitude differences by sex. The hypothesis of no difference was rejected ($p < .001$) only for reading ability differences, without regard for treatment. Students with reading scores above the class median scored better than those with reading scores below the median. Attitude scores were markedly lower for all groups.

5. Interpretations

a. Since there was no evidence of worse problem solving by the calculator group, (even though adjusted means as well as raw score means were higher for the control group) it was felt that calculators may be introduced without fear of inhibiting problem-solving achievement.

b. Although all students were poor readers, the better readers did better in problem solving than those who read less well. Therefore providing poor readers with a calculator in general mathematics will not improve their problem solving.

c. Mathematics teachers should not expect that calculator usage will necessarily improve a student's attitude toward mathematics.

Critical Commentary

While one can certainly sympathize with the difficulties associated with action-based research, there is little reason to place confidence in the findings of this study.

To begin with, the population is so special that it precludes meaningful generalizations. And worse, even the internal consistency of the study is threatened by the emotional and social adjustments that must have been associated with the transfer of up to 1 of every 5 students during the semester.

The problem-solving test also presents a fundamental difficulty. The validity and reliability of the test is open to much speculation. There exists only the publisher's word that the test matched the content of one of the workbooks used for instruction. Furthermore, on the basis of the data presented there is reason to wonder if anyone learned anything that the test was measuring. While differences between adjusted means of 2.77 were not found to be significant, gain scores between the raw pre- and posttest means were less than 2. The only identifiable subgroup that had a gain score of greater than 2 was the high reading control group.

One could also wonder about the handling of the data, the nature and reliability of the analysis, the interpretations of the data that were presented, and the reporting of the project itself. For example, we are not told if students used the calculators for testing -- but it is vain to do so.

The problem, however, is worthy of investigation. While one desires more sophisticated definitions of problem solving involving such things as complexity, problem settings, novelty, and "realness" of data, the simple question of what effects the mere availability of the calculator may have on problem-solving behavior is interesting. This study provides us with no insight into even the most rudimentary questions. It was a noble attempt carried out in a very special situation too far from adequate counsel and resources.

Wiksten, Sif. CHILDREN'S LEARNING OF ADDITION AND SUBTRACTION FACTS. (Rutgers University The State Universit, of New Jersey (New Brunswick), 1980.) Dissertation Abstracts International 41B: 1550; October 1980. [Order No. 8022602]

Expanded abstract and analysis prepared especially for the Calculator Information Center by E. GLENADINE GIBB, The University of Texas at Austin.

1. Purpose

The intent of this study was to obtain further information (1) on the relative effectiveness of simultaneous versus successive practice in the acquisition of addition and subtraction facts and (2) on the effectiveness of training without or with the supplementary use of a hand-held calculator. Also studied was the relative difficulty of each open sentence and fact before training and the effects of practice on such difficulty.

2. Rationale

Research on mastery of addition and subtraction facts has focused on five issues: (1) relative difficulty of addition and subtraction facts and of particular pairs of addends; (2) form of presentation of facts; (3) simultaneous versus sequential training on addition and subtraction facts; (4) use of supplementary devices and materials; and (5) models of processes presumed to underlie addition and subtraction. Previous research, as reported, supported subtraction facts as being more difficult to learn than addition facts; addition of two numbers in commutative form usually of equal difficulty; size of the addends rather than the sum as the principal indicator of difficulty; and that doubles in addition and subtraction in which 1 is added or subtracted are the easiest facts. The open-sentence format from easiest to most difficult is $a + b = \_\_$, $a + \_\_ = c$ and $\_\_ + b = c$. Also, subtraction sentences are more difficult than addition sentences. Although inconclusive, research suggests that successive teaching of addition facts followed by subtraction facts may be more effective than simultaneous introduction of addition and subtraction. Supplementary materials or devices that are manipulative have been used for developing understanding. Worksheets are a standard way of presenting problems for drill on basic facts. Yet, the delay between a child's answer and information about correctness of answer has been a common disadvantage of worksheets. The calculator was deemed a device to overcome this disadvantage.

3. Research Design and Procedures

Forty-five children from two YMCA's in a northeastern state were tested for the purpose of identifying children with neither too little nor too much initial mastery of the arithmetic facts. Forty children who had not entered second grade qualified to participate in the study. Twenty children came from a working class community; 20 children were from middle-class communities. These children were randomly assigned to four training groups and one control group within the constraints of half boys and half girls and that children from each YMCA were represented equally in each group. Only four black children participated in the study, and were randomly assigned to each of the four training groups.

The four training groups were

(1) Successive, no calculator condition

(2) Successive, calculator condition

(3) Simultaneous, no calculator condition

(4) Simultaneous, calculator condition

A preliminary calculator training session involved each child being shown individually the use of the calculator in solving open sentences. Each type of open sentence (a + b = __; a + __ = c; __ + b = c; c - b = __; c - __ = b; and __ - a = b) was repeated twice. The same problems were used for all children.

Following the preliminary calculator training, the pretest was administered to each child individually. This test consisted of 16 items selected with half the facts being addition and half being subtraction. Each of the six types of open sentences was represented three times, except for a + b = __ and c - a = __, which were used twice. Parallel tests were constructed and used for the intermediate test and the posttest. Facts for these tests were sampled without replacement until the pool was exhausted. Three facts were selected from the category where one addend was 5 or greater and the other less than 5, one fact was selected from each of the other 10 categories.

In the first training session of four phases, each group of four children was given a different training condition -- two children with a calculator and a worksheet and two children only with worksheets. During each session, each child had a worksheet of 25 problems arranged in open-sentence type and was considered finished with the worksheet when all problems were solved correctly. Since only four children were working at the same time, the researcher was able to attend to each child enough to provide any needed information about the answers. Upon completion of the four training phases, the intermediate test was given.

In the second training session a new random arrangement of the basic facts were used. The only procedural change was for the successive group, for which the open sentences were with the subtraction operator instead of addition. Upon completion of the phases of the second training session, a posttest was given. Each child was given a different test and a unique set of facts.

Children of the control condition were tested on the same day as those of the training conditions.

4. Findings

Answers on pretest, intermediate test, and posttest were classified as correct, incorrect because of counting wrong, incorrect because of use of the wrong operation, and no answer. The pattern of analyses using analysis of variance was (1) comparisons of training conditions with sequence and calculator use and (2) comparison of the four training conditions and the control condition treated as a single variable.

Children in the training conditions improved with learning, while children in the control condition did not improve. Also, children improved equally well without or with the use of the calculator. No significant difference was found between simultaneous and successive presentation of sentences. The addition and subtraction operations were of equal difficulty throughout the experiment. With respect to open sentences, those sentences with the unknown in the last position were easiest. Although children used the operation indicated by the operator on the pretest, they used position-contingent rules after training for problems where the unknown was in the first or middle position. Sentences with the subtraction operator and unknown in the first position were most difficult, since the rule being used was to subtract if the unknown was in the first or middle position.

On the pretest, combinations where one number was 0 were easiest. Facts where both numbers were 5 or greater were hardest. On the posttest the same pattern existed, except that where both numbers were 1, 2, 3, or 4 were solved correctly almost as often as facts in which one number was 0.

5. Interpretations

Implications of these findings support the need for instruction and the need for children to learn to solve addition and subtraction problems presented symbolically as open sentences. No support is found for teaching the facts simultaneously or successively. Furthermore, based on this study, the use of the calculator cannot be expected to enhance learning. Findings also do not indicate that the calculator is a timesaving device in early drill on addition and subtraction facts and may even slow down some students. Findings also suggest that more practice should be provided for larger numbers, including learning basic rules and strategies for problem solving.

Critical Commentary

This study is complex, which may contribute to the difficulty in reporting it with clarity. In fact, some information seems at times in conflict. Classification of basic facts from which the sampling was done for tests and worksheets was not described, although inferences can be made by the reader. Yet, giving attention to basic issues previously studied for purposes of seeking further information seemed to be fulfilled. The need to concentrate practice on the more difficult facts, particularly in grades two and three, should be noted by those planning mathematics curriculums. Relational thinking about the facts would seem to enhance strategies for problem solving, however, rather than training on basic rules used in a mechanistic way.

Zink, Ronald Joseph. THE EFFECTS OF USING A PROGRAMMED PRINTING CALCULATOR TO IMPROVE THE COMPUTATIONAL SKILLS OF REMEDIAL MATHEMATICS STUDENTS IN GRADES 7-12. (Columbia University Teachers College, 1979.) Dissertation Abstracts International 40A: 4942; March 1980. [Order No. 8006870]

Expanded abstract and analysis prepared especially for the Calculator Information Center by JOHN A. DOSSEY, Illinois State University.

1. Purpose

The intent of the study was to determine whether the use of a Monroe Classmate 88 printing calculator would have a different effect on remedial students' mastery of rational number skills than would an approach using textual and supplementary materials for drill.

2. Rationale

Given the large amount of interest in hand calculators in the mathematics curriculum, the growing number of minimal competency tests, and the availability of hard-wired printing calculators for drill usage, the researcher built a case for the present study. Outcome could provide helpful information to school districts having or considering the purchase of similar equipment and/or having similar remedial programs in their middle and senior high schools.

3. Research Design and Procedures

The study revolved about the performance of students using the problem sets generated by the Classmate 88 for a series of rational number objectives compared with the performance of students using problem sets generated from textual and supplementary materials sources. Both groups used similar introductory materials providing the conceptual background for the operations prior to the drill-and-practice phase of the study.

The subjects for the experiment were the students enrolled in remedial mathematics classes in grades 7-12 in a suburban New Jersey community. They had been selected for inclusion in the sections on the basis of their performance on the New Jersey Minimum Basic Skills Test or on the mathematics portion of the California Achievement Test.

A special curriculum was designed for the seventh- and eighth-grade levels to prepare students to meet 35 stated objectives. All students studied the same textbook introduction to the skills, but their drill-and-practice activities differed. While a portion of the students got drill-and-practice from additional textual and supplementary materials, other students had sequences of drill-and-practice problems generated by the Monroe Classmate 88 printing calculator. In either instance, students had to work until they could answer 8 out of 10 sequential problems correctly. A similar curriculum was developed for students at grade levels 9-12 to prepare them to master a set of 36 similar objectives. Students were placed into the sequence of objectives on the basis of their performance on a local Diagnostic Mathematics Inventory. Prior to the study of each of the ten objectives targeted for analysis in this study, the students took a pretest. Following reaching the criterion level, they completed a posttest over the same type of problems. Students were allowed to work at their own pace.

A set of ten objectives, further grouped into six sets, was selected as the base for evaluating the relative performance of the students using the textual drill-and-practice exercises and those using the printing calculator practice exercises. The ten skills of interest and their grouping into sets were:

Set I:	1.	Find all factors of a given number.
	2.	Find the Least Common Multiple of a pair of numbers.
Set II:	3.	Write the prime factorization of a number.
	4.	Find the Greatest Common Factor of a pair of numbers.
Set III:	5.	Find a fraction equivalent to a given fraction.
Set IV:	6.	Simplify a given fractional number.
Set V:	7.	Add fractions with unlike denominators.
	8.	Add mixed numerals with unlike denominators.
Set VI:	9.	Subtract fractions with unlike denominators.
	10.	Subtract mixed numerals with unlike denominators.

The students (45 in grades 7-8, 42 in grade 9, and 71 in grades 10-12) were allowed to work forward from their initial placement. When students reached the first objective in Set I, they were alternately assigned to either Group A or Group B. Students in Group A had drill-and-practice exercises from the Classmate 88 on Objective Sets I, III, and V and from textual materials on Objective Sets II, IV, and VI. The students in Group B had the opposite pattern of drill-and-practice sources.

Data were collected on the students' performances on the pre- and posttests for each of the 10 individual objectives. In addition, the distribution of scores for each of these pre- and posttests was divided into thirds (High, Medium, and Low) for an analysis of possible differential shifts in level from pre- to posttest for students in the two treatments.

4. Findings

A three-way ANOVA (grade level, pretest score group, drill source) was conducted for each of the 10 objectives using the posttest score as a criterion. No main effect differences were reported in the dissertation (see Critical Commentary). It was further reported that significant ($p < 0.05$) two-way interactions were found for objectives 1, 2, 4, 5, 8, 9, and 10 for the Pretest X Grade combination. An analysis of these interactions showed that they were a result of the older students' maturity and greater exposure to the materials. No significant three-way interactions were reported (see Critical Commentary).

An analysis of the net gain scores from pretest to posttest for each objective for each practice treatment showed no significant differences for the practice treatments at grade levels 8, 9, or 10.

An analysis for differential patterns in shifts from pretest score groups (High, Medium, Low) to posttest score groups was made using the SPSS Crosstabs program. While some differences were noted, no regularities were found in the patterns.

5. Interpretations

The researcher concluded that the lack of significant findings either for or against the use of the printing calculators in drill-and-practice work suggests further research in the area. In particular, it was noted that the development of specific instructional materials preceding the calculator drill-and-practice which were correlated with the calculator might lead to significant findings in favor of the calculator drill-and-practice. This would follow significant findings in earlier studies involving the calculator in mathematics classes. It was also noted that teachers intervened in helping students in the calculator groups for the objectives on factoring and writing prime factors, as the calculator would only recognize the factor sets if they were written in increasing order. Had they not intervened, the findings for these objectives might have favored the noncalculator groups for these objectives.

One other possible suggestion was the high criterion level might have washed out differences in the performance levels of the students involved. A lower criterion level might show differences between the two drill-and-practice treatments.

Critical Commentary

There were several disquieting factors about the reporting of this study. The first was the general lack of comments about the equivalence of the problems and activities included in the drill-and-practice sequences for the two treatment groups. Were the problems generated by the Classmate 88 equivalent to those in the supplementary materials in breadth or in difficulty? Further, what about the error rates and time to criterion for the two treatment groups? What about differential student work rates or attitudes as they surfaced in working with the two different drill-and-practice routines?

Secondly, an analysis of the data tables for the ANOVAs, located in Appendix D, indicated that there were three significant findings not reported in the body of the dissertation. The first, a main effect difference, indicated that the textual drill-and-practice approach was judged significantly better in forming the calculational ability to simplify fractions (Objective 6). Further, for adding unlike fractions (Objective 7) the Pretest X Treatment Group interaction and Pretest X Treatment Group X Grade Level interaction were both judged as being statistically significant. Also, the Treatment Group X Grade Level interaction was judged statistically significant for subtracting mixed numerals with unlike denominators (Objective 10). While the analysis of these interactions did not add new information, they did bring into question the thoroughness of the other analyses made in the study.

Third, little attention seems to have been paid to either the effects of the treatments on student attitudes or on retention of the skills beyond an immediate posttest. It is quite possible that one of the drill-and-practice methods might have a greater effect on a long-term skill retention level.