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ABSTRACT

Presented is the third and fourth state-of-the-art reviews on the use of calculators in education, prepared in August 1980 and August 1981. Each presents information concerning the National Council of Teachers of Mathematics (NCTM) "An Agenda for Action: Recommendations for School Mathematics in the 1980's" position on calculator and computer technology. Sections of the reviews report on research on calculator effects, evidence on availability and uses of calculators, surveys on beliefs and attitudes, development of instructional materials, and continuing concerns that need research and development effort. References are included. (MP)

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The Use of Calculators in Pre-College Education: Third Annual State-of-the-Art Review*

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Over the past several years, the cost of calculators has declined to a relatively stable level. Concurrently, calculator availability has become less and less an issue. Technology has provided prolonged battery life, and some calculators are so small and light they can be carried or worn easily, nullifying additional arguments about their availability. While resistance to their use in schools is still apparent, awareness of potential instructional applications has slowly continued to increase. Heightening this awareness is a significant recommendation from a national association.

A Recommendation for the 1980s

In April 1980, the National Council of Teachers of Mathematics released An Agenda for Action: Recommendations for School Mathematics of the 1980s. One of the eight recommendations addresses concerns presented by computing technology: "Mathematics programs must take full advantage of the power of calculators and computers at all grade levels." The introductory comments present a rationale for this stance:

> Beyond an acquaintance with the role of computers and calculators in society, most students must obtain a working knowledge of how to use them . . .
>
> The availability of computing aids, including computers and calculators, requires a reexamination of the computational skills needed by every citizen. Some of these computational skills will no longer retain their same importance, whereas others will become more important.
>
> It is recognized that a significant portion of instruction in the early grades must be devoted to the direct acquisition of number

* The first annual review was prepared in April 1978; the second appeared in May 1979.

concepts and skills without the use of calculators. However, when the burden of lengthy computations outweighs the educational contribution of the process, the calculator should become readily available. (p. 8)

Recommended actions to accomplish the goal include the following:

3.1 All students should have access to calculators and increasingly to computers throughout their school mathematics program. (p. 9)

3.2 The use of electronic tools such as calculators and computers should be integrated into the core mathematics curriculum. (p. 9)

- Calculators should be available for appropriate use in all mathematics classrooms, and instructional objectives should include the ability to determine sensible and appropriate uses. (p. 9)

- Calculators and computers should be used in imaginative ways for exploring, discovering, and developing mathematical concepts and not merely for checking computational values or for drill and practice. (p. 9)

3.3 Curriculum materials that integrate and require the use of the calculator and computer in diverse and imaginative ways should be developed and made available. (p. 9)

- Schools should insist that materials truly take full advantage of the immense and vastly diverse potential of the new media . . . (p. 9)

- Educators should take care to choose software that fits the goals or objectives of the program and not twist the goals and developmental sequence to fit the technology and available software. (p. 9)

Teachers of other subjects in which mathematics is applied "should make appropriate use of calculators and computers" (p. 11). Furthermore, teachers and administrators are urged to "initiate interaction with the home to achieve maximum benefit to the student from coordinated home and school use of computers and calculators" (p. 10).

Other recommended actions address the needs of teachers, pointing out that colleges need to offer courses on instructional uses of calculators for both preservice and in-service teachers and that certification standards should require such preparation. Professional organizations should provide information through media and meetings of various types.

Thus, the NCTM acknowledges that computational skills are still necessary, but stresses the need to integrate calculator use at all levels, reinforces

their usefulness in problem solving, notes the need for imaginative materials, and emphasizes the key component of teacher education.

Evidence on Availability and Uses of Calculators

The NCTM recommendation accepts the reality of the existence of calculators and computers. Data from the Second Mathematics Assessment of the National Assessment of Educational Progress (reported in Reys et al., 1980) support the fact that many children have access to calculators outside of the classroom: 75% of 9-year-olds, 80% of 13-year-olds, and 85% of 17-year-olds either own their own calculators or have one available to use. Other studies indicate that in some locations this percentage may be even higher; for instance, over 90% of the 220 households surveyed in Florida had at least one calculator (Conner, 1980), and in Indiana a survey of 417 students indicated that ownership or access ranged from 79% for first graders to 100% for sixth graders (Ewbank, 1979). Naturally, however, some studies report lower percentages; for example, only 68% of the Missouri children queried by Reys et al. (1980) had access to calculators.

Data from the many studies* still seeking an answer to the question, "Does use of calculators hurt achievement scores?", continue to support the fact that students who use calculators for instruction achieve at least as high or higher scores than students not using calculators, even though the calculator is not used on the test. (In the majority of studies during the past year, no significant differences were reported.) The decrease in time spent on paper-and-pencil practice did not appear to harm the achievement of students who used calculators.

Data from studies on learning mathematics with calculators, as well as evidence from the practical experiences of teachers, are slowly accumulating, indi-

* This type of study on achievement comprises about two-thirds of all studies reported. Studies focusing on the development of specific mathematical ideas account for about one-sixth of the studies, while the remainder are surveys. While doctoral students continue to produce at least 50% of the research, ongoing investigations are being conducted by researchers in schools and colleges.

cating that calculators are useful in teaching a variety of mathematical ideas. Reports from Conner (1980) and Moser (1979), for instance, detail some specific ways in which calculators are useful instructional tools.

Surveys on Beliefs and Attitudes

When beliefs and attitudes are surveyed, however, it becomes obvious that many persons ignore the evidence from research on achievement and learning. Perceptions of the uses and importance of calculators in the mathematics curriculum depend primarily on the audience surveyed. The Priorities in School Mathematics Project (PRISM), conducted in 1979, devoted about 20% of its items to ascertain ways in which educators at all levels from primary through college, parents, and school board members feel about the use of calculators. Educators were much more supportive of increased use of calculators than were lay persons: 54% of the professional samples but only 36% of the lay samples would increase emphasis on them during the 1980s. Strongest support came from supervisors and teacher educators (85% and 74%, respectively); teachers at all levels had more reservationa (support averaged 50%); and parents and school board members gave weak support to increased emphasis -- and to almost all uses of calculators except checking answers. The percentage agreeing with various uses of calculators were:

	Professional Samples	Lay Samples
checking answers	93%	89%
doing a chain of calculations	89%	-
computing area	78%	-
making graphs	71%	-
solving word problems	70%	38%
solving equations	70%	-
learning why algorithms work	68%	-
doing homework	66%	37%
developing ideas and concepts	59%	49%
learning basic facts	51%	-
taking a test	50%	22%

Over 70% of the teachers at all levels endorsed having four-function calculators available. However, 67% of the professional samples and 88% of the lay samples believe that calculator use should be postponed until after paper-and-pencil algorithms are learned. Only 40% of the professional samples and 19% of the lay samples would let slower students use calculators, and putting students who have not learned paper-and-pencil computation by grade 8 into a calculator course was supported by only 34% (45% of the professional samples and 30% of the lay samples).

Other studies provide data which both compare and contrast with the PRISM data. Cohen and Fliess (1979) reported that over 63% of the teachers they queried favored the use of calculators. In a survey conducted in 1979, Reys and some colleagues interviewed a random sample of 194 classroom teachers in ten school districts in Missouri. The researchers reported that:

> The overwhelming feeling was that calculators exist, that there are many appropriate places for using them at all levels of the mathematics curriculum, and that the type and extent of this usage should be left up to the discretion of the individual classroom teacher. (Reys et al., 1980, p. 41)

While 84% of the teachers said that calculators should be available to children in school, only 35% had actually used calculators in mathematics classes (the data ranged from 14% at the primary level to 62% at the senior high level). Another 42% said they would like to use calculators. Teachers who had used them commented that:

> not only could they work more problems if a calculator was available, but also they actually covered more topics. They also reported dealing more with concept development and less with computation during their mathematics class. (Reys et al., 1980, p. 41)

It was also reported that

> most of the teachers who had not used a calculator in the classroom seemed aware of primarily two uses. One was as a computational device which they saw as defeating the major goals of school mathematics and the other as a tool for students to check the paper-and-pencil computations. . . . the majority of the teachers were unaware of the instructional potential of the calculator. (Wyatt et al., 1979, p. 218)

An average of 80% of the teachers felt children should master the four basic arithmetic operations before using calculators. (Interestingly, 76% of the primary teachers held this view, while 89% of the senior high school teachers did.) Indeed, 43% felt that using a calculator would cause students' ability to compute to decline. Teachers generally agreed, however, that slow students or senior high students who had never learned to compute should use a calculator because they would probably never be able to compute otherwise.

Slightly over 50% of the teachers wanted textbooks with activities using calculators. Forty-three percent favored use of calculators on problem-solving portions of standardized tests.

Four implications were drawn from the study (Wyatt et al., 1979):

(1) There is a need for leadership and direction for teachers regarding calculator use in schools.

(2) Training in the use of calculators as an instructional tool is needed.

(3) Dissemination of current information about calculator usage is needed to dispel many false conceptions.

(4) Materials which integrate calculators into the regular mathematics curriculum should be developed and disseminated.

As part of an investigation in which calculators were used in elementary school mathematics instruction, Conner (1980) surveyed parents of children in kindergarten through grade 5. Percentages favoring what she called "unrestricted" use of calculators as an instructional aid ranged from 13% for the elementary level and 16% for the middle school level to 29% for the high school level. When she asked about "regulated" use, the percentages rose to 83% for the elementary level, 80% for the middle school level, and 81% for the high school level.

Balka (1979) also found that parents were skeptical about the use of calculators in elementary grades. They agreed that calculators could be used along with paper-and-pencil computation, but strongly objected to using calculators in place of paper-and-pencil computation.

Successful integration of calculator uses in the mathematics curriculum will

require careful and thorough communication among all concerned groups. Efforts to provide information on how calculators can be used successfully in teaching mathematics without harm to achievement must continue. And parents and other members of the public must receive assurance that necessary computational skills will still be taught. This point is clearly made in the NCTM Agenda for Action.

Development of Instructional Materials

Materials which integrate the use of calculators to teach mathematical ideas are still comparatively scarce. Most of the published articles, however, do present ideas for using calculators to promote learning on specific topics, including work with operations, functions, exponents, polynomials, square roots, and problem solving. There appears to be a decrease in the number of books focused solely on games, and an increase in the number of books which could be used to supplement on-going instruction.

Two compilations of materials may prove useful to teachers. One is a collection of articles from the Arithmetic Teacher and the Mathematics Teacher (Burt, 1979); the other is a categorized listing of references on calculators (Suydam, 1979). As has been true ever since calculators appeared in schools, however, there is a continuing need for materials which develop mathematical ideas.

Concluding Comment

While support from some groups for the use of calculators in schools is low, it is nevertheless changing as people accept the existence of calculators in their lives and in their children's lives. Concern continues to revolve around the issue of when the calculator should be used in relation to instruction on basic facts and algorithms: there is fear that paper-and-pencil computational skills will be lost and achievement scores will decline, despite the continuing reassuring research evidence on this point. Educators need to consider carefully ways of assuring parents that calculators can be used in developing a wide range of mathematical ideas which will promote mathematical achievement.

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The Use of Calculators in Pre-College Education: Fourth Annual State-of-the-Art Review*

Marilyn N. Suydam

The technological tool that has captured the attention and imagination of educators during this past year is the microcomputer -- but calculators are still in schools, quietly being put to use. Their continuing use is not usally a contentious issue, as it was in the mid-1970s; rather, they are an increasingly accepted tool.

Effect of the NCTM Recommendations

In An Agenda for Action: Recommendations for School Mathematics of the 1980s, the National Council of Teachers of Mathematics recommended that "Mathematics programs must take full advantage of the power of calculators and computers at all grade levels." Some people expected that this would lead to a renewal of the earlier antagonistic attitude toward calculators, feeling that the phrase "at all grade levels" would be rejected. It appears, however, that the recommendation has not served to rally those who do not favor the use of calculators in schools. It may be that the recognition given in the Agenda that "a significant portion of instruction in the early grades must be devoted to the direct acquisition of number concepts and skills without the use of calculators" calmed the fears of those who believe that calculator use threatens the acquisition of computational skills. It may be that the fears have been dampened by research that computational skill achievement is not lowered by calculator use. Or, it may be that time has simply defused the issue.

* The first annual review was prepared in April 1978; the second, in May 1979; and the third, in August 1980.

On the other hand, the NCTM recommendation has not served to rally those who believe that calculators should be used throughout the school mathematics program. They merely go on using calculators. However, articles and books of activities using calculators continue to appear with frequency, while articles decrying their use have faded away. While all children do not use calculators in schools, and while those who do use calculators may not be using them in an integrated fashion, nevertheless it would appear that whether or not calculators should be used is no longer the foremost issue on the educational scene.

Research on Calculator Effects

In the Second Mathematics Assessment conducted by the National Assessment of Educational Progress (NAEP), an attempt was made to ascertain how well students in a testing situation solved different types of exercises and problems using a simple, four-function calculator. After brief instruction on how to operate the calculator, students aged 9, 13, and 17 were each given about 25 calculator exercises, many of which were also presented to other students in a paper-and-pencil format.

Students performed routine computation better with the aid of a calculator. Thus:

- The calculator aided every age group for subtraction, multiplication, and division with calculators. In several cases, performance was nearly 50 percentage points higher when a calculator was available. In fact, the performance of 9-year-olds with a calculator was only slightly lower than that of 13- and 17-year-olds without a calculator. On addition exercises, 9-year-olds did as well with a calculator as without one. For students aged 13 and 17, scores were slightly better when a calculator was available.
- Students aged 13 and 17 performed better with calculators than without calculators on exercises involving decimals.
- Students in all age groups were more likely to make no response when using calculators than when not using calculators. On the other hand, fewer students responded "I don't know" when using calculators.

Performance on all nonroutine computation exercises was poor, with no improvement shown when a calculator was available. Similarly, performance on all calculator exercises assessing concepts and understanding was poor, as it also was when calculators were not used.

It was evident from the data that problem solving requires more than computational skills:

- In general, the problem-solving performance of both 9- and 13-year-olds with a calculator was poorer than that of students without a calculator. For 17-year-olds, performance was better on 9 of 14 exercises when calculators were available. The lowest performance for all groups was found on problems involving division.
- The no-response rate ranged from 3 to 14 percentage points higher for those having calculators available than for those without calculators.

Assessing the effect of calculators on problem solving was also the focus of many of the other 19 studies on calculator uses reported in the United States since January 1980. This interest in problem solving was heightened by the first NCTM Agenda recommendation that "Problem solving must be the focus of school mathematics in the 1980s."

Among the findings of the studies on problem solving are:

- Calculators are useful for problem solving if the problems are within the range of students' paper-and-pencil computational ability. (grade 4, Brey, 1980)
- Students are less afraid to tackle difficult problems when using calculators. (grade 4, Brey, 1980)
- Students use more varied problem-solving strategies when using calculators. (grade 6, Wheatley, 1980)
- There is no significant difference in the number of problems completed with or without calculators. (grade 8, Miles, 1980)
- The use of calculators probably does not affect problem-solving scores significantly. (grade 6, Elliott, 1981; grade 8, Miles, 1980; grade 6, Shult, 1980; grades 4-6, Stewart, 1981; grades 3-8, Szetela, 1981)

For six studies comparing the use or nonuse of calculators on achievement on various mathematics topics, results were mixed: two favored the calculator-using groups, three indicated no significant differences between groups, and one favored the non-calculator-using group. Another study provided additional evidence that first graders learned addition and subtraction facts equally well with calculators as without, as has been indicated in previous studies. And it was reported that those using a four-function calculator had better computation scores than those using a programmed-feedback device.

Thus, the evidence continues to be amassed about calculator uses in schools. Most of it indicates that calculators do not harm achievement; some of it indicates topics with which calculators can be successfully used to teach mathematical ideas. Furthermore, the use of calculators makes it obvious that the difficulty children have with problem solving does not lie primarily with computational difficulty.

Surveys on Beliefs and Attitudes

Few studies surveyed attitudes toward the use of calculators in the past year, possibly another sign of the shift of attention from the calculator as an issue. In a study on minimum competency testing, Kasten (1981) asked samples of teachers and principals in four states if they believed that using calculators should be included as a topic on high school competency tests. The data were relatively similar across the states:

	total group	elementary teachers	secondary teachers	elementary principals	secondary principals
Florida	42%	44%	43%	30%	44%
Missouri	44	42	41	43	52
Ohio	50	49	55	50	45
Oregon	54	51	49	42	66

Thus, 40 to 66 percent of the teachers and principals (with one exception), or an average of 47%, indicated that using calculators is something with which all

students should be familiar. These percentages are slightly lower than in some other surveys (see Suydam, 1980), but perhaps higher than one might expect when the use of calculators is suggested as an item for competency tests.

Development of Instructional Materials

The publication of materials containing activities involving the use of calculators with topics in the existing curriculum continues; indeed, the production of ditto masters or worksheets has grown. Activities for using calculators in the primary grades continue to appear at a much reduced level from the number for middle and secondary school grades. An increasing number of publications focus not on activities for the four-function or scientific calculator, but on materials or techniques for the programmable calculator. This is presumably a result of the decrease in price of programmable calculators, plus their usefulness when a computer may not be available.

The biggest disappointment to many people is the scarcity of published materials in which the use of calculators is integrated throughout the curriculum. Instead, most materials suggest supplementary modules. Interest in microcomputers seems to be drawing att[illegible] and funding) away from the development of more extensive materials involving calculators.

In few instances have calculators affected methodology -- how mathematics is taught remains the same whether calculators are used or not, although the calculator can lead to differing teaching patterns and strategies. Instances of content change -- where content has been added or dropped because calculators are available -- are similarly slow in occurring.

Concluding Comment

In 1976, participants at the Conference on Needed Research and Development on Hand-Held Calculators in School Mathematics believed that there would be a "five-year interim period, while new calculator-oriented curricular materials are

being developed" (p. 28). The five years are up -- but the "interim materials" are still needed, for very little attention has been given to developing that new calculator-oriented curriculum.

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