Using 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 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.

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.

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

> Calculators should be available for appropriate use in all mathematics classrooms, and instructional objectives should include

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

the ability to determine sensible and appropriate uses.

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.

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.

Schools should insist that materials truly take full advantage of the immense and vastly diverse potential of the new media...

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.

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

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 (Reys et al., 1980) support the fact that many children have access to calculators outside of the classroom: 75 per cent of 9-year-olds, 80 per cent of 13-year-olds, and 85 per cent 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 per cent 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 per cent for first graders to 100 per cent for sixth graders (Ewbank, 1979). Naturally, however, some studies report lower percentages; for example, only 68 per cent 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

*This type of study on achievement comprises about two-thirds of all studies reported. Studies focussing 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 per cent of the research, ongoing investigations are being conducted by researchers in schools and colleges.

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, indicating 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 per cent 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 per cent of the professional samples, but only 36 per cent of the lay samples would increase emphasis on them during the 1980s. Strongest support came from supervisors and teacher educators (85 per cent and 74 per cent, respectively); teachers at all levels had more reservations (support averaged 50 per cent); 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 per cent of the teachers at all levels endorsed having four-function calculators available. However, 67 per cent of the professional samples and 88 per cent of the lay samples believe that calculator use should be postponed until after paper-and-pencil algorithms are learned. Only 40 per cent of the professional samples and 19 per cent 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 per cent (45 per cent of the professional samples and 30 per cent 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 per cent 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 10 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)

While 84 per cent of the teachers said that calculators should be available to children in school, only 35 per cent had actually used calculators in mathematics classes (the data ranged from 14 per cent at the primary level to 62 per cent at the senior high level). Another 42 per cent 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)

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)

An average of 80 per cent of the teachers felt children should master the four basic arithmetic operations before using calculators. (Interestingly, 76 per cent of the primary teachers held this view, while 89 per cent of the senior high school teachers did.) Indeed, 43 per cent 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 per cent of the teachers wanted textbooks with activities using calculators. Forty-three per cent 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 per cent for the elementary level and 16 per cent for the middle school level to 29 per cent for the high school level. When she asked about "regulated" use, the percentages rose to 83 per cent for the elementary level, 80 per cent for the middle school level, and 81 per cent 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 focussed solely on games, and an increase in the number of books which could be used to supplement ongoing 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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