The impact of hand-held calculators on education is stimulating not only argument, but research.

The hand-held calculator, as if anyone needed reminding, has become part of the American scene. There are calculators all around—in homes, in offices, in stores, in schools. And if the visual evidence isn’t enough, there are the sales figures. One leading newspaper recently reported that worldwide nearly 100 million calculators have been sold since 1971. Other estimates are more conservative, but all agree that the number has been enormous. Projections are for still bigger sales years ahead. About the only thing that has not gone up with calculators are prices. The simpler models, once costing $60 or $70, now can be purchased for less than $10. Some industry observers are predicting that in two years the price will be down to $5.

The proliferation and increased accessibility of calculators is already having an effect on American education. College and advanced high school mathematics students use the machines routinely; few dispute the calculator’s value in that kind of setting. In addition, however, younger students, in elementary and junior high school and those taking standard mathematics courses in high school, are at least playing with the family calculator at home and, if their parents permit, using it to help with homework. And less common, but to a greater extent than most people realize, calculators are being employed—either well or badly—in precollege schoolrooms as part of the formal mathematics curriculum.

The technologies that permit miniaturization of complicated electronics, and increasingly inexpensive calculators, promise (or threaten, depending on one’s perspective) to revolutionize mathematics education. Can (or should) that revolution be prevented; or can it be channeled so that education, and mathematics, and children can benefit from a phenomenon that so far has caught them all disturbingly unawares?

While mathematicians, educators, parents, legislators, administrators and editorial writers, and some in the industry itself, ponder these questions, the makers of calculators are eyeing what might be called the youth market. “One of the most important areas [of sales expansion] is going to be the school market,” predicts Benjamin M. Rosen, a securities analyst for the New York investment firm of Morgan Stanley & Co. One manufacturer has already produced a “Quiz Kid” model, shaped like an owl, and programmed so that the owl’s green eye lights up when the child adds correctly and flashes red when he makes an error. Others are exploring other ways to make their products attractive to this burgeoning market.

The presence or predicted presence of calculators in arithmetic classes unsettles many parents and teachers. They fear that the introduction of the instrument into the curriculum will result in a dependency on the calculator, that students, lacking enforced strength in basic math skills, will be virtually helpless in solving everyday problems without the crutch represented by a functioning calculator. Feelings, understandably, run high. Even what would appear to be cautious and conservative attitudes toward calculators are no assurance against controversy. As Zalman Usiskin and Max Bell of the University of Chicago faculty in mathematics education note, the controversy has turned up the trigger words that seem invariably to emerge in American confrontations over pedagogy: “laziness” encouraged in the young; “pampering” of children; “wasting” of taxpayers’ money; and educational “frills.” When the National Advisory Committee on Mathematical Education
recommended last year, for instance, that by the eighth grade a calculator be available for every student, The Wall Street Journal, echoing the concern of many parents and educators, editorialized: "We don't see how that is going to strengthen the students' ability to do any mathematical operations. Indeed, why should the student bother to learn any mathematics at all, so long as he can get a machine to think for him?"

Because, in part, the confrontation so far has been dominated by emotion rather than by research-based understanding of the implications calculators hold for education, Usiskin and Bell note, many educators have adopted a conservative, defensive consensus reaction. But even so conciliatory a view as that calculators "of course" should not be permitted in elementary and secondary schools until students have mastered calculation on their own could be no more valid than any more forthright position on either side, the Chicago researchers contend. The real point, Usiskin and Bell argue, is that even a conciliatory position is "based on no inquiry whatsoever, and very likely [is] influenced mainly by a wish to minimize controversy."

What is necessary now, they argue, is to avoid battles over "moral assumptions" and to concentrate on the educational pros and cons of the calculator. There are serious points being made by detractors as well as by advocates; what is lacking is a body of knowledge about calculators and education on which to build necessary strategies.

The starting point

To help build this knowledge base, the National Science Foundation last year awarded a grant to Marilyn Suydam, assistant professor of mathematics education at Ohio State University and a research associate in its Educational Resources Information Center. She was asked to marshal a study of the implications for pre-college education of the expanding use of the hand-held calculator. In support of her work, position papers were prepared by a range of specialists, including Usiskin and Bell, as a base from which to begin to think about the role of the calculator in mathematics education.

The unspoken theme of the NSF study might be stated this way: The calculator is a fact of life. Educators and parents are going to have to come to grips with it. It must neither recklessly be embraced nor summarily dismissed. If it is going to have an impact on the teaching and learning processes, we had better be in a position—based on understanding—to control and regulate that impact. For instance: If the calculator turns out not to blend with current mathematics curriculum, can curricula be modified—and strategies devised—to take advantage of opportunities calculators may offer? Or can calculators be modified so they serve the needs of the educational process, for which calculators today are not really designed?

If the rate at which Americans are buying calculators means anything, decisionmaking time is running short. Hard sales figures are still closely held trade secrets. But Usiskin and Bell cite a survey, conducted for the industry, that placed cumulative U.S. sales from 1973 through 1975 at 31.6 million. The same survey predicted that 1976 sales would reach a record annual high of 14.7 million. Electronics, a trade magazine, meanwhile has estimated that 1976 sales would approach 21 million—a figure that is regarded as conservative by others in the industry. Perhaps most significant was a finding by Richard K. Shumway, a faculty associate of Suydam's, who found that more than half the calculator sales in the United States are being made to housewives and students for use in home and school.

The Suydam study found that a significant portion—though still less than half—of American schools today are utilizing calculators in some educational context. A 1975 survey of Ohio public schools, for example disclosed that the calculator had found its way into 18 percent of the schools in that State, with most of the use occurring in the 11th and 12th grades. At the moment, according to the study, the utilization of calculators in elementary and secondary schools follows certain general patterns. Sometimes a few machines are given to teachers for "exploratory activities." In other instances they are supplied to classes for use by pupils who have never attained computation skills. At the other end of the spectrum are examples of calculators being made available in high school only to advanced science and mathematics classes.

In 34 percent of the user schools, the survey disclosed prohibitions of one sort or another are imposed on the calculator's use; it is banned from use either in particular classes or on tests.

But uncertainties about where and how calculators ought to be introduced do not seem to be slowing down the overall growth trend. "Given the data on prices," Suydam notes, "the data on the number sold and the fact that in the project survey teacher educators, State supervisors, and textbook publishers appear to be 'sold' on the desirability of the use of calculators in schools, school use of calculators is likely to increase."

She also predicts that the forces that might tend to slow the trend—parent and teacher reluctance to allow the calculator in the classroom—are likely to decrease as individuals in these two groups themselves become more familiar with calculators. "By 1977," she concludes, "there could be widespread use of calculators in schools; by 1979 this will almost certainly be true."

Johnny can add, but . . .

The hand-held calculator looms before the American school system at a time when the American public is hearing disquieting reports about the mathematical capabilities of its young. A widespread view is that "Johnny can't add." And if Johnny can't add, as The Wall Street Journal asked, how in the world will the calculator improve his ability to do so? The question is a fair one. But the researchers say it should be answered in context.

Contrary to what we might assume, mathematics proficiency was not always accorded status in this country. It wasn't until 1807 that Harvard required applicants for admission to be able to add, subtract, multiply, and divide. (Yale had established such a condition in 1745, becoming the first American college to do so.) Later in the 19th century, the pendulum swung to the other extreme; mathematics educators stressed what became known as the "faculty psychology" theory of arithmetic, and textbooks came to contain problems that we would consider very difficult. (Try, for instance, to compute a cube root by hand.) The 20th century brought about a shift toward the center, as educators pretty much abandoned the philosophy of confronting pupils with hard problems simply for the sake of having them do hard problems.

Nevertheless, despite the extensive standard testing that has been undertaken in this country, it is still unclear how today's students perform in math when stacked up against their predeces-
rors. In its 1975 report, the National Advisory Committee on Mathematical Education noted declining computation test scores. But it cautioned against reading too much into the scores because of weaknesses in assessment and evaluation techniques. In any event, the Committee concluded that the lower test scores "paralleled, and in some cases resisted, declining performance in all school subjects."

Usiskin and Bell aren't willing to concede even that. They reviewed test scores going back to 1916, observed trends going in both directions, and observed that "at any given time people appear to feel that students are not as skillful as their parents." In 1940 one researcher, for example, found that the 1938 median scores of students in grades three through eight were lower than those posted by the same age group in 1916. Yet a 1965 study in Nebraska found that students entering the ninth grade in that State were "much more mathematically literate today than they were 15 years ago." In general, the Committee analysts concluded that differences in geography, curriculum emphasis, and lack of a long-term effort to measure the effectiveness of mathematics education had rendered test results of dubious value. And in the view of Usiskin and Bell, research studies show no consistent pattern of declining achievement over the last 20 years.

Then there is the question of just what does demonstrated computational proficiency tell us. There is a fundamental distinction, say Usiskin and Bell, between an ability to calculate accurately and an ability to use those calculations. The 1972-73 National Assessment of Mathematics, part of a nationwide educational testing program conducted every five years, found that 92 percent of 17-year-olds and 86 percent of adults could correctly add a series of dollar-and-cents figures. At the same time, a three-digit decimal subtraction problem was computed correctly by 78 percent of the teenagers and 74 percent of the adults. Yet only 1 percent of the 17-year-olds and 16 percent of the adults could solve a moderately complicated checkbook balancing problem.

"Schools react to charges that students can't use mathematics by increasing skill and drill work aimed at calculation," observe Usiskin and Bell, "but the probability is that Johnny can add—he just can't use addition."

If Usiskin and Bell's suspicion is sound, then training in computation becomes less focal an issue than understanding concepts, a job to which the calculator, as an eliminator of drudgery, is seen as addressing itself. Usiskin and Bell suspect that the threat the calculator poses to a "conventional wisdom" regarding computational techniques may be behind the intense skepticism about proposals to bring calculators more deliberately into the classroom.

How, not whether

Suydam feels that the observation that "they exist," that calculators are turning up in the hands of an increasing number of students, is the most compelling of all the arguments against a refusal to think Designed to sell. Part of the impetus for the employment of hand-held calculators in elementary education comes from the manufacturers. Early simple efforts to adapt the calculators to the new market have been followed by more complete, school-oriented packages.
constructively about the calculator as a phenomenon. But it is an argument that carries with it considerable responsibility. The educational community is faced, rather than with the problem of whether calculators will be used, with the question of how they can be used. “Few educators believe that children should use calculators in place of learning basic mathematical skills,” she states. “Rather, there is a strong belief that calculators can help children to develop and learn more mathematical skills and ideas than is possible without the use of calculators.”

One way to find out whether the calculator would enhance or retard the teaching and learning of mathematics is through research. (Many educators and researchers in the field attended a joint National Science Foundation/National Institute of Education-sponsored conference this June in Washington, D. C., specifically to assess R&D needs in the field and follow up the Suydam study.) Unfortunately, according to Suydam, so little quality research has been conducted on the subject so far that even reviewing it is of questionable merit. Most of the studies undertaken have been exploratory in nature; some of the “hardest” data come from studies conducted by calculator manufacturers. “Not surprisingly,” says Suydam, “these indicate that students (a) can use the calculator with a variety of content; and (b) achieve well when using the calculator.” Suydam, as do other educators, cautions school officials against rushing into a calculator purchasing decision until they have examined what is available—and what is being developed—in the way of both machine and curriculum design.

Some promising avenues of research into the use of the calculator as a teaching aid have been proposed by, among others, J. F. Weaver of the University of Wisconsin, a researcher on mathematics learning. And the National Advisory Committee on Mathematical Education included in its 1975 report a number of questions on calculator use that it felt should be investigated by “thorough research.” The areas being identified for future research emphasis include:

- What kind of algorithms would be effective on a calculator?
- What are the long-range effects on students who have used calculator algorithms?
- What need will remain for pencil-and-paper algorithms?
- What will be the effect of calculator use on curriculum design, and what will be the effect on the learning process of changes made in mathematics curricula as the result of calculator use?
- What educational relationship might exist between calculators and computers?
- What changes should be made in teacher training?
- What are the best calculator designs for school use?

A glimpse of what might be learned through research was seen in the responses that Bell collected from 20 teachers who cooperated with him in a year-long trial use of calculators in elementary schools near the University of Chicago. Bell emphasizes that his project did not qualify as bona fide research, and that the trial was “quite informal.” But he found the teacher comments useful.

The most significant pedagogical question raised was whether children became overly dependent on the calculator. Although Bell concedes that it might become a long-range problem, he believes it was not a significant problem during the one-year trial period. After an early phase of doing virtually everything on the calculator, children rather quickly exhibited the good judgment to perform easy calculations in their heads, leaving pencil-and-paper processes to the calculator. To make sure that calculator usage did not become habitual, most teachers periodically demanded pencil-and-paper calculations.

On detecting errors, Bell received mixed reports. While some children with good “number sense” questioned obviously wrong answers, others readily accepted whatever the calculators produced. But many of these children also accepted the answers to which any form of calculation led, revealing perhaps a neglect on the part of schools in teaching approximation skills. This weakness, noted Bell, should be remedied whether calculators are introduced or not.

But while Bell did not detect a tendency to overrely on the calculator, he was disturbed by the lack of information on an area of mathematics education that could bear significantly on the central issue raised by the Suydam study: Just how do children learn mathematical concepts? While a calculator may indeed free a youngster’s mind from the computational obstacles that interfere with his grasping of concepts, isn’t it also possible that the manipulation that he now goes through contributes to the concept-learning process?

“It is easy to imagine that the very intricacy of the manipulation plus the patterns and rules that make them work may sometimes result in important, even if unspecified learnings,” Bell writes.

Until the answer is in, says Bell, “a conservative (but not immovable) posture toward the learning of calculation in schools seems warranted.” Good multiplication and addition “reflexes,” he goes on to say, remain essential. “With or without a calculator, it is crippling not to have such reflexes.”

The Chicago trial produced some useful practical information as well about the use of calculators in elementary schools. For instance, schools that furnish calculators to students would probably be wise to figure on replacing or repairing perhaps 20 percent of their machines annually. While theft and loss of calculators were not major problems, enough difficulties along this line were reported to persuade Bell that direct ownership or rental of calculators by students was preferable to their being furnished by schools.

Somewhat surprisingly, one of the greatest deterrents to using calculators in the classroom may be the powering of them. Teachers told Bell that they and the kids loved the calculators, but that the instruments were often out of service because of worn-out batteries. Few classrooms had enough outlets into which to plug the machines, and even if they did there would be the problem of curtailed mobility. Batteries are expensive and schools may be unwilling to buy them; one possible solution, suggests Bell, are rechargeable nine-volt transistor batteries, if they can be obtained inexpensively.

The implications

What could be called the crux of the overall NSF study was the identification of the potential implications for education in the widespread use of calculators in elementary and secondary schools.
The issues include:

Curriculum. The sequence of mathematics learning can be altered. Children, for example, now learn whole numbers before decimals because they must learn the addition of whole numbers before they can handle decimals. On the calculator the procedure for decimals is the same as that for whole numbers. The same button is pushed for both computations. It may no longer be necessary or desirable to delay decimals until the fifth grade. Similarly, the calculator and the advent in the United States of the metric system could sharply diminish the importance of fractions, leaving them pretty much the exclusive tool of the stock market. Negative numbers, a concept that is not easy to teach students with the assistance of a calculator.

Computational Skills. Calculators will enable very young children to perform square roots, trigonometric functions, and logarithms as well as all of the basic operations of arithmetic. “Decisions regarding curriculum,” notes Suydam, “need no longer be based on whether or not children can perform the calculations, but rather on whether they understand the concepts involved.” Children will no longer have to avoid interesting problems because the computation is too lengthy or complicated. A nine-year-old may find the question: “How many seconds have I been living?” intriguing and challenging. With a calculator it is a problem that can easily be solved; without one the thought of extended calculations might be enough to discourage the child from trying. The same can be said of a real life problem in which a class is asked to ascertain the per gram cost of five different candy bars.

“At the minimum,” says Suydam, “one would expect some deemphasis of the paper-and-pencil algorithms. Most calculations, in reality, will not be carried out by paper and pencil. It is likely that schools will begin teaching paper-and-pencil algorithms as another way to do calculations, but not the principal way.”

Remedial math. For the remedial student, on the other hand, the calculator may serve as the only means of acquiring mathematical skills. Many American students have spent eight years trying to learn arithmetic, without becoming sufficiently adept to take on bank accounts, no less algebra. More remedial training is given, and they still cannot master the necessary skills. “So, at present, such people are condemned never to have arithmetic to use in their lives,” note Usiskin and Bell. “For such people the calculator is not a crutch but provides the only way to get a right answer.” The crucial issue, they maintain, is not how calculation is accomplished but solving problems and answering questions that matter in the lives of people.

Teacher Education. At the moment it is a considerable problem. Aside from dealing with parents who object to the use of calculators in the schools, teachers today must use the machine within the framework of a curriculum that is not designed for its use and without the benefit of special teaching techniques gained through tradition or research. As the use of calculators takes hold, teachers must become adept at exploiting their potential, rather than permitting them merely to be present, exerting what might be inappropriate pressures on the educational process.

Budget. The impact need not be as great as it might seem. A typical elementary school with 360 students (two classes at each grade level) might want to purchase one basic four-function calculator for every two pupils. At today’s cost of $10 per machine the total expense would amount to $1,800, an amount equivalent to the cost of 30 filmstrips or 120 minutes of 16 millimeter film. For a school that routinely buys film materials, the calculator expense may not be a financial burden. The cost will be lowered, of course, as students bring their own machines to school and the cost of calculators drops even further.

How, when, and where the calculator should be integrated into the school system are questions that cannot be answered definitively until there exists much more information than is now available. Some general guidelines, however, are offered by mathematicians closest to the subject. Calculators may achieve the same status, they say. Just as spelling is still taught, they observe, students will continue to learn basic mathematical skills. But pupils will not be able to perform all types of computation, just as few people can spell all the words they need.

All of this may require some rethinking of the nature and purposes of mathematics education. But the educators and mathematicians closest to the subject appear to believe that what is required, if we are ever going to come to terms with what is rapidly becoming—if it hasn’t already become—a fact of educational and mathematical life.

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