CALCULATORS — A REVIEW

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INTRODUCTION

For at least the past two decades, educators have been investigating the potential of using calculating machines as instructional aids in elementary school mathematics. More recently, the availability and increasingly lower cost of the hand-held calculator prompted most teachers and mathematics educators to ask if it should be used in the classroom. The past few years have seen dramatic progress. Mini-calculators are widely available now for less than 10 dollars. Many adults are buying them for everyday use. Children are using them at home and bringing them to school. Today, the question no longer seems to be whether or not calculators should be used in school but, rather, how they can be used most effectively.

Hopkins cites an historical analogy to the present situation. In one of Plato's dialogues, *Phaedrus*, concern was expressed that written materials would cause decay of the oral tradition of memorization and recitation. Hopkins concedes such a loss, but points to the greatly increased amount of literature which can be appreciated through reading. In the same vein, he says that widespread use of calculators in mathematics education, like any technological advance, will not be easily accepted. He refutes the argument that calculators should not be used because they do not carry understanding of basic operations by asserting that algorithms can also be done mechanically without meaning. He says that using a calculator does not mean that understanding is not a goal. It is merely a faster and more accurate replacement for pencil and paper algorithms. Gains will be greater than losses because more time can be spent doing more complicated word problems and studying the theory of mathematics.

Hawthorne says that the anticipation of inexpensive calculators influenced the lack of drill in modern arithmetic programs. Few jobs require lengthy calculations with paper and pencil, but basic operations must still be understood.

Etlinger distinguishes between using the calculator as a functional device for tedious computation and using it as a manipulative device to facilitate learning. Gawronski says that the type of use could be good or bad, depending on the task and age of the student: both views can be rationalized in the curriculum. If used as a functional tool for all computation, current objectives would be changed from using algorithms to using a calculator.

Rogers warns that the calculator, like other teaching aids in the past, could become obsolete. She presents features of enduring teaching aids, for which the calculator has potential. It must be inexpensive and durable enough to be used anywhere that mathematics questions might arise. It must be controllable by the learner in terms of starting, stopping, and rate of working;

and be adaptable to a variety of physical positions. It must satisfy individual needs and be self-contained to prevent planned obsolescence.

Sullivan reports on classroom trials carried out in two Grade VI classes in New York during the 1973-74 school year. The major goal was to try to find if and how the calculator could enrich, supplement, support, and motivate the regular mathematics program. The calculator proved to be a successful motivator. It led to more sophisticated calculations, was useful in checking answers and intermediate steps of algorithms, facilitated verbal problem-solving, encouraged exploration of topics requiring complex computation, and supported regular topics. Sullivan feels that the outstanding impact of the calculator may have been its power to motivate increased attention to decimal fractions, and interest in their relation to common fractions.

Bell reports that the initial motivation of using calculators is high and persists for a long time, providing that interesting activities are available. In fact, he found that children 'demand' such activities. Even kindergarten children can benefit by using calculators for number readiness activities, as reported by Scandura. For this age level, desk model calculators seemed more suitable than hand-held models because the keys and display are larger, making them easier to use and read. While specific instructions on calculator operation appeared preferable to open-ended exploration, all the kindergarten children observed were motivated to learn mathematics, and their attention spans were greatly increased.

The National Council of Teachers of Mathematics Instructional Affairs Committee identified the following nine justifications for using the hand-held calculator in the schools:

1. to encourage students to be inquisitive and creative as they experiment with mathematical ideas;

2. to assist the individual to become a wise consumer;

3. to reinforce the learning of basic number facts and properties in addition, subtraction, multiplication, and division;

4. to develop the understanding of computational algorithms by repeated operations;

5. to serve as a flexible "answer key" to verify the results of computation;

6. as a resource tool that promotes student independence in problem-solving;

7. to solve problems that previously have been too time-consuming or impractical using pencil and paper;

8. to formulate generalizations from patterns of numbers that are displayed; and

9. to decrease the time needed to solve difficult computations.

We have at our disposal a small, inexpensive calculator that computes quickly and accurately. Its inevitable impact on the elementary school mathematics curriculum has concerned educators warning against its wholesale use in the classroom until the large problem of how it should be used has been rigorously examined. Many pros and cons have been raised concerning this issue. While formal research is really just beginning, many informal studies and observations have been and will continue to be made.

COMPUTATION

One of the biggest concerns regarding the use of calculators in school is that children will become dependent on them and lose, or not develop, mental computational skills. These concerns are legitimate, but both formal and informal studies are showing that calculator use does not undermine meaning. It can, in fact, facilitate understanding.

Many educators including Bruni, Ockenga, Gibb, and Immerzeel have pointed out the necessity for sharpening estimation skills when using the calculator. Bell reports that while children do tend to accept the results shown on the calculator, they also accept the results of paper and pencil algorithms. In fact, poor judgment of significant figures is revealed by calculator use. Calculator errors tend to be large, and estimation skills, which are important in any case, must be learned. Bell also found that children seem to quickly gain good judgment in deciding when to use their heads or the calculator.

Bruni has found the calculator to be useful in developing standard algorithms and in discovering alternative ones. Ockenga advocates use of sequenced calculator exercises which can be effective with hard-to-teach ideas. An example of this is the placement of the decimal point in the division algorithm.

Fehr, in 1955, conducted a two-week controlled experiment which tested the effect of hand-operated computing machines as an aid in learning both the meaning and pencil and paper skills of multiplying by two-digit multipliers. Though he found no significant difference in favor of either the control or experimental group, there were factors which indicated that prolonged use could be advantageous. Both students and teachers enjoyed using the machines, but the teachers had to simultaneously learn how to use them and teach with them. Though the experimental groups had to learn pencil and paper as well as machine methods at the same time, they still made normal gains in pencil and paper achievement.

Fehr followed up with a half-year experiment involving Grade V children. He tested the hypothesis that pupils who use computing machines to learn arithmetic will gain significantly in both pencil and paper computations, and in arithmetic reasoning compared to a control group not using machines. The experimental group gained 4.4 more months in reasoning and three more months in computational ability than the control group. There was, however, no statistically significant difference in the final achievement standing between the two groups. Again, the experimental group had learned both methods in the same time, and they enjoyed the experience.

Rudnick reports preliminary findings from a study in progress. It was designed to measure the effect of the availability and use of a mini-calculator on students' total math achievement and their ability to perform pencil and paper skills. It is a full-year study involving 600 seventh graders in two schools. Classes were randomly assigned to experimental and control groups. The curriculum was not changed for either group. Calculators were not used on pre- or post-tests, but the experimental groups used them on the second post-test. At the time of writing, no statistical differences in achievement were found between the two groups, but slight differences favored the experimental group. A survey of parental attitudes revealed that parents were evenly divided on whether or not calculators should be used in school, but most parents felt that the students should learn how to use calculators.

Schnur reports on a controlled experiment conducted with a summer compensatory education program where most students were bicultural. Both groups received the same instruction on the four basic operations. The experimental group used calculators to verify or do some problems, but neither group used them on pre- and post-tests. Analysis of these tests revealed significant differences in the computational ability of the two groups, favoring the experimental group. There was no significant interaction between ethnic background and calculator usage. Neither was there significant interaction between sex and calculator usage, but there was a slight trend to favor females.

Schafer, Bell, and Crown reported on a study conducted with fifth-grade children at the University of Chicago Laboratory School. About 120 children were divided into an experimental and a control group. Following a computational pre-test, on which the two groups showed no significant mean differences, the control group was given calculators to experiment with and solve problems. A parallel form of the pre-test administered one week later again revealed no overall significant mean differences between the two groups. The calculator group scored significantly better on examples which could be worked by simple calculator manipulation, but did not score as well on examples requiring additional information or more than one operation. Concern was raised that the control group might have become dependent on the calculator, using it inappropriately. The authors suggest that more experience may lead to better judgment in this respect. Also, as the children involved, overall, tended to score above national norms on standardized computational tests, the authors question whether lower achievers may produce different results. General impressions from the study were that the calculator necessitates sharper estimation skills, and has great potential for motivating children to learn mathematics and discover new concepts.

CONCEPTS

Concept learning is proving to be an area where the calculator has great potential. Immerzeel describes the calculator as a "portable, hand-held math lab" providing a source of experience with numbers in a fast, efficient manner. Topics not pursued previously because of the computation they require can be introduced earlier and developed further.

The calculator itself seems to promote discovery. Bell reports that, in learning to use the calculator, children tend to ignore unfamiliar keys, but their presence eventually sparks curiosity and interest in exploring new ideas. Gibb says that the decimal solutions of calculators will cause the study of rational numbers in decimal form to appear earlier in the curriculum - a change already anticipated by the shift to the metric system. Similar changes have been predicted by Elder and Scandura, who have found that children are eager to use large numbers because the calculator handles them so easily, and they discover negative numbers by experimenting with the subtraction function.

Van Atta suggests using the calculator in an intuitive approach to learning laws of exponents, Pythagoras' theorem, square roots and logarithms. Such an approach is only marginally possible without a calculator. The large amount of paper and pencil work required is prone to error and mistaken conclusions. Patterns in mathematics have long intrigued children, but interest quickly wanes when the computation becomes tedious and boring, and undetected errors cause frustration. The immediate feedback of the calculator lends itself well to trial and error procedures involved in the discovery of number patterns. Number properties and relationships can also be formulated faster and inductively with the use of a calculator.

PROBLEM-SOLVING

The calculator's greatest potential may well be in the realm of problem-solving. Many educators, in advocating use of the calculator as a problem-solving tool, have quickly pointed out that the nature of the operations must still be understood.

Gawronski says the calculator should not be used for problems which can and should be done mentally. If handled properly, the calculator will save time and relieve computational drudgery. More time can be spent on problem-solving skills, and the curriculum can be expanded in a problem-solving direction.

Another advantage recognized by Immerzeel, Gibb, and Schumway is that problems can be more realistic. Numbers do not have to be chosen to have integer or 'smooth' answers. Children can generate their own problems from their own experiences. Immerzeel says that the calculator enables students to tackle more complex problems, and solve verbal ones much faster.

CONCLUSIONS

The issue of calculator use in schools continues to be debated and the questions arising are being investigated by educational researchers. Lewis expresses the thoughts of those who support calculator usage by predicting that the calculator "may revolutionize mathematics teaching." But curriculum changes will not appear overnight; they will only occur if and when teachers are convinced of the calculator's potential.

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