DOCUMENT RESUME

ED 191 740 SE 032 865

AUTHOR Etlinger, Leonard E.; And Others
TITLE The Calculator in the Classroom: Revolution or Revelation?
INSTITUTION Chicago State Univ., Ill.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE [78]
GRANT NSF-SER-78-11916
NOTE 13p.; Page 3 missing from document prior to its being shipped to EDRS for filming. Best copy available.

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Basic Skills; *Calculators; Computers; Computer Science Education; Educational Technology; *Elementary Secondary Education; Learning Activities; Learning Theories; *Mathematics Curriculum; *Mathematics Education; *Mathematics Instruction; Mathematics Materials; Problem Sets; *Problem Solving; Programing; Student Motivation

ABSTRACT

The use of calculators and computers in the schools is promoted. It is stated that calculators should be used in the mathematics classroom as soon as basic operations are understood. A point is made that calculators are no greater a threat to "learning the fundamentals" than slide rules, which have been available for over 350 years. It is recommended that school districts adopt a policy with guidelines in regard to the use of calculators, and that calculators be used as tools to reinforce the basic skills, not as substitutes. Calculators can be used to facilitate the use of comparison and estimation in problem solving, including real life situations, at all levels, and to teach children critical thinking. The use of the programmable calculator in a creative way is promoted and several example problems that can be quickly explored with the use of the programmable calculator are presented. (MP)

THE CALCULATOR IN THE CLASSROOM: REVOLUTION OR REVELATION?

by Leonard E. Etlinger, Associate Professor of Curriculum and Instruction and Director of Teacher Corps
Chicago State University

Sarah Krull, Director of Teacher Corps
St. Louis University

Jerry Sachs, Past President of
Northeastern Illinois University

Theodore J. Stolarz, Professor of Psychology
Chicago State University

Introductory Comment (Please include - may be a footnote)

This material was prepared with the support of the National Science Foundation Grant Number SER 78-11916. Any opinions, findings, conclusions or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation. In the operation of this and other projects, Chicago State University has not and will not discriminate against any person on the grounds of sex, age, creed, color, or national origin.

THE CALCULATOR IN THE CLASSROOM: REVOLUTION OR REVELATION?

> I was an elementary school student in the late 1930's and attended the Ernest Prussing Elementary School in Chicago's far northwest side. It was a rather new school then. It had an excellent reputation for achievement and, as I recall, it was provided with the best of everything that could be provided during the great depression. We had one of the first "adjustment teachers" in Chicago and I remember taking a lot of tests that ultimately resulted in my skipping a grade. But what I noticed about the adjustment teacher (apart from the fact that she was an attractive young woman) was that she used a stopwatch and a slide rule. It was the first time in my life that I had seen such things. I remember that I had to build up my courage to ask her about them and she demonstrated them to me. I had no use for a stopwatch, but a ruler that could do arithmetic seemed like a miracle. I had to have one.
>
> - Ted Stolarz

The microelectronic revolution is with us and the world will never be the same as it was before it started. That magic ruler that could do arithmetic is now obsolete. The hand-held pocket calculator can do everything the slide-rule could and more. Calculators can do arithmetic, algebraic, trigonometric and statistical computations and do them faster than they can be done by the algorithms most students learn in school. What is more they operate with an amazing degree of accuracy.

There are those who are disturbed by this and who feel that children should not be allowed to use calculators because if they do they will not learn the basic operations of arithmetic. The danger is there, or course, but the calculator when used wisely under the direction of good teachers can

generate interest in learning the facts and skills of mathematics. Once these skills are learned the calculator, especially the programmable one, can take a great deal of the drudgery out of computation.

To illustrate this point consider the "ruler that could do arithmetic." The slide rule, which has been available for over 350 years, makes a number of calculations quite easy. And, until the recent advent of the hand-held calculator, it was always standard equipment for engineering and science students. The same fear that today accompanies the idea of using calculators in the classroom also was prevalent when the slide rule began "taking over" the calculating process.

But the slide rule did not destroy students' ability to do fundamental operations longhand. It did not destroy their ability to do computation without it because to use the instrument skillfully, one had to know the process. The slide rule simply gave an approximation to the answer without some of the long computation.

Just as the slide rule did not destroy computational ability, the calculator will not do so either if used properly. Many facets of mathematics can be enhanced and supported by the use of calculators, especially the processes of estimation and approximation (for which the slide rule was often used).

For example, a good teacher of small children, or older children, or adults will make certain that students understand

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Once this process is understood, a calculator can be used to perform all those dreary, time-consuming calculations. This testing then becomes easy and quick and the method needs nothing except an understanding of what one is looking for. It makes the complicated arithmetic algorithm useless and gives the added advantage of keeping before the person doing the work, the meaning of square root.

Thus, the calculator should be used in the classroom for mathemtatics as soon as basic operations are understood. It is useless and discouraging to forbid the use of them. What the teacher should try to do is to make use of them in a helpful manner. When a child does a computation, ask him to check it by using the calculator. Stress the idea that the calculator is only as good as the person running it so that to use it skillfully the child must be able to tell it what to do. This in itself requires that he understand what must be done.

The fact is, calculators are here to stay and children of all ages now take them for granted. The question is not "will we make use of calculators in the schools?". It is, "How will we do so?". Perhaps the key here is not in the ordinary calculator that performs operations that most people can perform by hand. Of greater significance is the programmable calculator. The programmable calculator introduces a new mental process and provides the opportunity to develop in students a method of thinking that will prove to be of great value as they face the world of the future.

A programmable calculator is an instrument which can be taught to do more than a single operation. It can "learn" to do a sequence of operations and it can "learn" to do a single operation or a sequence of operations over and over again indefinitely or a set number of times. It can "learn" a complicated sequence in which it does one part over and over a set number of times or until a predetermined value has been reached and then goes on to do other things. It can store information in what are called memories and recall whatever is needed for use whenever it is needed. This means that the programmable calculator, unlike the ordinary calculator, can do sophisticated operations without needing the operator to initiate each step.

However, it does these things only if one can "teach" it to do so. One must make the calculator "learn" the separate steps in a sequence. Every mathematical step is possible on a non-programmable calculator. But the advantage of the programmable calculator is its ability to "learn" to do many operations with processes not possible on a non-programmable calculator. It is important to note that if one does not understand the process he is trying to program, the programming is a hopeless task. The programmer must identify and plan sequential steps for solving the problem as well as plan the order of arithmetic operations. Thus with the programmable calculator, even more than with an ordinary calculator, the thinking process of the user is primary if he is to build his own program.

Most of the applications of mathematics to real problems involve several operations. The programmable calculator permits us to address many different real problems without spending hours and hours in longhand computation. In addition, the use of the programmable calculator helps to develop skills in designing algorithms for the solution of problems which recur with different inputs. These skills will be as essential in the twenty-first century as basic arithmetic.

The programmable calculator or computer can also enable a person to use a special program (prepared by experts in a certain field) to do a complex operation he cannot do longhand. For example, there are statistical packages which can be very useful in providing results which are meaningful to the user even though he does not have the statistical training to do the computation or program the calculator.

The use of the programmable calculator in a creative way (i.e., having the user develop his own programs) is preferred over using the calculator or computer to run existing programs. Several examples of creative uses of the programmable calculator can be made. For instance, students can gain several geometric insights by using a programmable calculator. Suppose there are youngsters at the level of using basic geometric formulae for lengths, areas and volumes.

Consider these problems for the student to explore:

1. How does the area of a circle of diameter d compare with the area of a square of side d? Try several cases and see if you can get a generalization. Look at the formulae and see if the generalization makes sense.

   $A_c = \pi d^2/4$ and $A_s = d^2$

   $\pi/4 < 1$, therefore, A_c is a little more than 3/4 of A_s

2. What happens to the perimeter and area of a square, rectangle, circle if all basic dimensions are doubled? Tripled? Do the same for volume formulae.

3. If we have a rectangular box of fixed volume made out of sheet metal, what dimensions will make the area of the sheet metal a minimum?

4. You have a can in the shape of a cylinder made of sheet metal. If the volume is fixed, what radius and height will made the amount of sheet metal a minimum?

These problems can be quickly explored with the use of a programmable calculator. First, the student must know how to use the formulae required. Next he must tell the calculator how to use the formulae--that is, what sequence

of steps it must take to arrive at a solution. Once this is achieved, the student experiments with different inputs to arrive at the final conclusion.

The programmable calculator should be introduced as soon as the child is faced with problems which occur frequently or which require more than a single step. This will happen not only in the computation but also in the application of mathematics to real problems such as interest, installment buying, cost comparisons, etc.

The use of the programmable calculator will not only make computation less tiresome, it will also allow the child to learn simple programming at an early date. Computers and their programs affect everyone in many ways. In the near future it will be as natural for one to understand how to use programming as it is now to understand spoken and written language. In the secondary schools it will become essential to give many if not most students some hands-on experience with microprocessors. The present generation of professional men and women, business people and skilled workers has a handicap because the computer, its uses and its languages were not a part of their early experience. Those who have had to learn this later have not had the advantage of an early introduction. Even more serious is the problem of those who must blindly use the results without any understanding of how they came about or, in the case of managment, make

decisions affecting computer operations with only a smattering of knowledge about what they do and how they do it. This generation, those in school now, must be given some background on this tool which they find everywhere in their lives.

It is obvious that the calculator, especially the programmable calculator, has much to offer mathematics students of any age. The following recommendations are made to promote and encourage the use of the calculator in the classroom.

It is recommended that:

1. Calculators be used in our schools.
2. School districts adopt a policy with guidelines in in regard to the use of calculators.
3. Calculators be used as tools to reinforce the basic skills, not as substitutes for teaching the basics.
4. Calculators be used:

   to facilitate the learning of basic arithmetic skills at all levels.

   to facilitate the use of comparison in problem solving at all levels.

   to facilitate the use of estimation in problem solving at all levels.

   to facilitate problem solving in real life situations at all levels.

5. Emphasis in calculator programs should be to teach children critical thinking. Calculators enhance critical thinking by:

reinforcing the basic skills.
helping in the basic skills of reasoning.
reinforcing the thinking process.
reinforcing problem solving ability.
promoting logical thinking.
encouraging creative usage.
providing stimulation and motivation.
helping to develop number sequencing concepts.
aiding in discovering mathematical concepts.

All of this has important implications for teacher education. It is essential that those who will teach future citizens be prepared to introduce them to the tools which they will use and which will affect their lives in so many ways. It is suggested that elementary school teachers be required to learn how to use a calculator and be urged to learn how to use a programmable one. Secondary school teachers should understand how to employ the programmable calculator as well as the microprocessor or minicomputer.

The responsibility for this training will have to be assumed by the universities. Although there will be specialists who can teach the advanced material, most if not all teachers will have to have some background knowledge. At the moment it looks as though the universities will have

to be sure that experience in the use of hand calculators, programmable and otherwise, plus experience in the use of microprocessors and main-frame computers is available to all who desire it. Further, it will be the responsibility of the universities to encourage all students to get at least minimal training with such equipment.

It is difficult to predict what the future will bring. The revolution in miniaturization, along with decreasing costs, will undoubtedly produce new wonders in the next few years. Whatever is made available in schools and colleges should reflect what is available on the market and in general use. The equipment purchased in the present should be minimal and consistent with good usage so that schools can take advantage of new developments. In short we are entering a new age. It is hoped that in education we will enter it with enthusiasm and not be dragged into it reluctantly.