Use of Electronic Calculators by Students In Examinations and for Course Assignments

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Abstract

Potential benefits and problems associated with the use of electronic "pocket" calculators for course assignments and examinations are discussed and illustrated. Conditions necessary for effective use of electronic calculators in learning situations, requiring the solution of new types of problems involving arithmetic, are suggested.

> "The age of chivalry is gone; that of sophisters, economists, and calculators has succeeded."
>
> — Edmund Burke (1729-97)

Burke was not pleased with developments in his time regarding the types of persons he described. However, **part** of his statement is appropriate to the present day — the age of electronic "pocket" calculators is upon us.

The merits of college students' using calculators in courses that include problems involving arithmetic are apparently not appraised equally by all instructors. Discussions with other instructors and conversations with students reveal that some instructors do not allow use of electronic calculators in the classroom but others encourage their use.

My purpose in this paper is to share some observations about potential benefits and problems, based on experience in working with students using electronic calculators for assigned problems and for examinations and quizzes.

Questions to be Answered

Does use of electronic calculators enhance or inhibit the thought process in learning subject matter in courses such as applied statistics, farm management, and agricultural marketing, where problems involving arithmetic are a usual part of the material to be mastered? Should calculators be allowed for use in examinations? How can a teacher check a student's methods if the work was done on a calculator rather than written out on the paper? Does the student really understand an answer obtained by using a calculator?

These are questions you may have resolved but which are worth consideration again now that we have experience as a guide.

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Availability

The first request I received from a student to use an electronic calculator in class was for a final examination in agricultural economic statistics in 1972. At the time, the percentage of students having access to such calculators was extremely low — the cost was prohibitive for most students. Reasonably simple models of the electronic slide rule cost over $100. Similar models today sell for less than $40. Four-basic-function models now often cost less than many textbooks and can potentially be used in several classes and beyond, if properly cared for and secured against theft. My response in 1972 was "no" because allowing use of the calculator would give an unfair advantage to the student. This reasoning was accepted.

By the next year prices of electronic calculators had started to decline and/or more students were acquiring them despite their cost, so I allowed use of them on quizzes and examinations. Many students who did not own one could borrow one for use in the class, or share one during the class. However, if a calculator was to be shared in class, it had to be turned "off" and held up so that I could see that it was "off" in passing. I also brought my calculator for short use by those not having a calculator and not sitting near someone who had one to share.

In my judgment, this system worked tolerably well in classes of 40 to 50 students. By 1975, practically all students in the class either owned a calculator or had access to one they could borrow to bring to class on quiz and examination days. The only problem of availability at this point was an occasional need to borrow a different calculator for taking a square root, or to replace one that had lost its charge during the class period.

Potentials

Students are using electronic calculators for doing assigned problems outside the classroom. This use has made the arithmetic of problems assigned less burdensome and thereby enhances the probability that subject-matter will be grasped more easily. Because students are using calculators on homework, not allowing their use in classroom examinations and quizzes may present a psychological block, in addition to eliminating other potential advantages.

The obvious benefit to the student from using an electronic calculator is that accurate arithmetic computations can be done much more quickly and work can be checked by the student, if used appropriately. A corollary is, of course, that mistakes can also be made more rapidly if one is used inappropriately. I will return to this potential problem as I relate the use of calculators to mathematical understanding below.

Probably the main benefit from the standpoint of the learning process is that use of the electronic calculator frees time for the student to work on new subject matter concepts that problems are related to in the course and for the **interpretation** of answers. More realistic problems can be assigned for laboratory exercises, homework, and on quizzes and examinations, because now neither the instructor nor the students need worry so much about answers coming out "nice and even," as they seldom do in "real world" problems. This has always constituted a potential burden under manual (pencil and paper only) approaches.

The benefits from using an electronic calculator must become more apparent with use, as many students decide to buy them during the course of a semester, even though they can always borrow a friend's calculator. Several students have told me that they have decided after the end of the semester to buy their own calculators based on their experiences in the course. I do not require students to have their own calculators and continue to make one available for use during quizzes and examinations. If answer methods are set up properly, as discussed below, the amount of time actually spent using the calculator is usually relatively short.

Relation to Mathematical Understanding

Is the calculator a poor substitute for understanding mathematical computations, as some have suggested? It is true that one does not have to go through the manual details of adding, subtracting, dividing and multiplying; and operations such as taking square roots and squares and reciprocals can easily be accomplished on an electronic calculator. However, the key to using an electronic calculator to get an answer that is both accurate and amenable to interpretation is in setting up the problem on paper. This allows the student to check work done and allows the instructor to verify that correct methods were used, to identify sources of errors, and to give partial credit for wrong answers. This approach is useful for both assigned work and for quizzes and examinations.

A calculator has the peculiar trait of doing what it is asked to do, within its capacity, when its buttons are pressed. Speed in calculation will not compensate for errors either in the logic of how the buttons are pressed or in the logic of how the problem is set up. Two simple examples, each involving weighted averages and errors actually made by students last semester, will illustrate this point:

1. An investor has \$30,000 in 9 percent bonds, \$20,000 in 6 percent certificates of deposit, and \$10,000 in 5 percent pass-book savings. What is the weighted average rate of return on these investments?

Answer set-up: $$\frac{9(3) + 6(2) + 5(1)}{6} = \underline{\underline{7\ 1/3\%}}$$

One student did this problem as follows:

$$\frac{9 \times 3 + 6 \times 2 + 5 \times 1}{6} = \underline{\underline{11.83\%}}$$

That is, he pressed the above numbers and functions on his calculator in exactly the order given. Unfortunately he did not observe that his answer was outside the range of 5 to 9 percent and was therefore unreasonable. His faith in his calculator was shaken somewhat when he checked his answer and got the same result **after** the corrected examination paper was returned. An office conference clarified the problem in pressing the buttons in this manner:

$$\frac{9 \times 3 + 6 \times 2 + 5 \times 1}{6} \neq \frac{(9 \times 3) + (6 \times 2) + (5 \times 1)}{6}$$

For this problem, it seems likely that the calculator actually increased this student's chance of error. This problem also illustrates the fact that effective use of a pocket calculator requires one more competency of the student — how to use this labor saving device!

2. Use the data given here to compute a Paasch price index for 1975 on a 1965 base.

Product	Price ($)		Quantity (mil)	
	1965	1975	1965	1975
A	.50	.60	20	25
B	.40	.30	10	20
C	.20	.50	100	80

Answer set-up:

$$P = \frac{\Sigma p_t\ q_t}{\Sigma p_o\ q_t} \times 100$$

$$= \frac{.60(25) + .30(20) + .50(80)}{.50(25) + .40(20) + .20(80)} \times 100$$

$$= \underline{\underline{167}}$$

Some students made the following error in setting up this problem:

$$P = \left[\frac{.60(25)}{.50(25)} + \frac{.30(20)}{.40(20)} + \frac{.50(80)}{.20(80)}\right] 100$$

$$= \left[\frac{.60}{.50} + \frac{.30}{.40} + \frac{.50}{.20}\right] 100 = \underline{\underline{445}}$$

In this case, the unweighted average of price relatives used because the problem is set up incorrectly gives an answer which is wrong by a large margin. This answer is not, by inspection of the data, as clearly unreasonable as in the case of the first problem.

These errors did not occur **only** because an electronic calculator was used. However, some false sense of security may result from use of a calculator, particularly when an error in method is duplicated by the student in checking a problem. The set-up of the method for obtaining the answer will help avoid many, but not all, such errors.

Accuracy and Interpretation

The rules for significant digits are no less important than in the past, particularly since electronic calculators usually give answers with more digits than are significant. It is a pleasure, however, to observe the now nearly complete elimination of the phrase "slide-rule accuracy" which used to appear often on assignment and examination answers. That "accuracy" often left much to be desired!

The largest potential gain from the use of an electronic calculator, in my opinion, is that it frees the student from grinding through arithmetic manually and thus allows more time for interpretation of answers. An accurate answer is necessary but clearly not sufficient without an interpretation of the answer's meaning, including the unit of measure. This statement holds regardless of how the answer is obtained.

The first requirement in interpretation of an answer should be "is the answer reasonable?" In the example on interest rates given above, the student should have suspected something was wrong. If time does not permit working the problem through again to obtain a reasonable answer, at least an indication of the basis for this suspicion would be appropriate. Of course, it is not always easy to judge whether an answer is reasonable, but without interpretation there is little basis for judgment.

A third example will illustrate more clearly what I mean by interpretation:

> 3. In 1974, Illinois farmers produced 54 million bushels of wheat. The average market price of wheat in Illinois for the crop year was \$3.85 per bushel. What was the value of the Illinois wheat crop for 1974? Express your answer to the correct number of significant digits and indicate the unit of measure.
>
> Answer set-up: 54 mil bu × \$3.85 per bu = \$207.9 mil

There are two significant digits in bushels and three in the price per bushel. Thus the answer to two significant figures is \$210 mil. An answer of 207.9 with no interpretation should not be accepted for full credit because 207.9 might be interpreted as 207.9 billion bushels, \$207.90, etc., with an obvious lack of comprehension on the part of the student. I base these illustrations on actual answers.

Before electronic calculators were widely available, to save time to get what I considered an adequate coverage of realistic problems on an examination, I often had students set up the method for answering the problem so that someone who could follow instructions could finish the work. This often precluded the possibility of interpretation of the answer. I find that I can now put much more stress on interpretation of answers that can reasonably be completed.

Summary

Ways an electronic calculator can and cannot help in problem-solving involving arithmetic computations can be summed up as follows:

It Can	It Cannot
1. Do arithmetic computations quickly.	1. Set up the method for obtaining the answer.
2. Provide accurate answers, if used properly.	2. Provide evidence by itself of what was done.
3. Allow the use of more realistic problems.	3. Decide how many digits in an answer are significant.
4. Give a psychological boost (and perhaps a false sense of security).	4. Give the correct unit of measure and interpret the meaning of answers.

The instructor must insist that all details of method be indicated by showing the problem set-up clearly **and** that a concise and complete interpretation be given. This approach allows the student to check work done and allows the instructor to verify that correct methods were used, to identify sources of errors, and to give partial credit for wrong answers. These conclusions hold regardless of whether a calculator is used or not. Under these conditions, however, use of electronic calculators for assignments and examination problems involving arithmetic has the potential for allowing greater concentration on the subject matter being studied and more progress toward the goals of the course.

LETTERS TO THE EDITOR

Dr. Jack C. Everly, Editor
NACTA Journal
608 W. Vermont
Urbana, IL 61801
Re: "The Quality of Rural America"

Now is the time, Mr. Everly, to get involved in the future. The Conference on Rural America is involved in helping plan Rural America's future. We want to make you a part of it.

The Conference on Rural America is a three-day forum (July 15-17) for rural residents and everyone else concerned with the future of Rural America. It will be a chance for educators and others to talk and learn from each other.

Featured speakers include Dr. Harold Shane, professor of education at Indiana University; Dr. George Donahue, University of Minnesota, Minneapolis; and noted author and consultant Robert Theobald, Northwest Regional Commission, Spokane.

Representatives of many different educational organizations are assisting the conference. These include Stanley Sahlstrom, provost, and Ervie Glick, chairman of the General Education Division, University of Minnesota Technical College, Crookston; Del Roelofs, superintendent of the Crookston Public School District; and Audrey Eickhof of the American Association of University Women, Crookston.

For further information write: Conference on Rural America, Box 94, Crookston, Minn. USA 56716; or call: (218) 281-3663.

Thank you for helping us plan the future.

Dorothy Eckert
Conference on Rural America