Mathematics Education

I would like to commend *Science* for the attention it pays to mathematics and for its emphasis on the importance of mathematics instruction. The excellent Policy Forum by Lynn Arthur Steen (17 July, p. 257) is a fine example.

Steen appears to say that neither "new math" nor "back to basics" can supply a quick fix for this critical problem. It is heartening to see such an intelligent, non-dogmatic approach to mathematics education. However, I have some reservations, which I believe are shared by others, that I would like to express.

I am extremely concerned by the current emphasis on calculators in the elementary and secondary mathematics curriculum. The vast majority of my students, to borrow Hofstadter's phrase, are woefully innumerate, a condition I believe has been exacerbated by the reliance on calculators.

The "higher order thinking skills" that Steen would like to see emphasized arise, in part, from the ability to recognize patterns. In order to recognize patterns, one must have had some experience observing patterns. Many of the patterns one can initially observe arise from integer arithmetic. The increasing reliance on calculators to do arithmetic thwarts much of this pattern recognition. As a result, the development of the process of pattern recognition is impeded as well.

I also disagree with Steen's contention that mathematics teaching must be based on both contemporary mathematics and modern pedagogy. A thorough knowledge of the properties of the real numbers and Euclidean space provides both the basis and the point of departure for much of the mathematics of the last two centuries. A curriculum that weaves the ideas of arithmetic, algebra, geometry, trigonometry, and calculus into a coherent tapestry can close the mathematics gap by increasing the student's understanding of these basic concepts. In biology, one does not teach DNA before cells.

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In the introduction to their well known book *What Is Mathematics?* (*1*), Courant and Robbins warned against the "danger in the prevailing overemphasis on the deductive-postulational character of mathematics." Today's high school curriculum is a clear demonstration that we have not heeded their warning. A generation ago students learned proofs in geometry classes. There they discovered they could prove surprising and unexpected properties, such as the Pythagorian theorem and the concurrence of medians. Today students are asked to recite the axioms of a field and to use them to produce meticulously detailed deductions of the obvious. Although the curriculum a generation ago was far from ideal, at least the students learned that mathematics provided a powerful tool for solving interesting and difficult problems. Today mathematically strong students are leaving high school convinced that mathematics is a boring and sterile subject, overloaded with pedantry.

Steen approaches this point when he wrote "Only tests that measure higher order thinking skills should be used to assess mathematics." However he does not define "higher order thinking skills." Although deduction is an essential part of mathematics, the true higher order thinking skills, in mathematics as in other sciences, involve inductive reasoning. Until the mathematical community recognizes this, there is faint hope that the current situation can be reversed.

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REFERENCES

1. R. Courant and H. Robbins, *What Is Mathematics? An Elementary Approach to Ideas and Methods* (Oxford Univ. Press, New York, 1978).

Response: Stein and Rickart call attention to three very important issues in the revitalization of mathematics education: using tools of technology wisely, teaching mathematics in a contemporary style, and encouraging effective problem solving.

Certainly blind substitution of calculator methods for paper and pencil methods would not lead to any improvement in mathematics education. But the calculator makes possible precisely the exploration of arithmetic patterns that Stein seeks. To translate this possibility into reality will require greater emphasis on quality teaching so that calculators can be used effectively.

A contemporary curriculum is more a psychological than a logical necessity for learning. Biology students do not need to study DNA before learning about cells, but their motivation for studying cells is enhanced by knowledge that cells contain the mechanisms that make possible genetic engineering, with all its benefits and controversies. Mathematics too should have such a contemporary "hook" to grab student interest. One does not teach advanced ideas before basic concepts, but teachers should know enough about current events in their field to relate their classroom agenda to student interests. Mathematics should be no exception.

The need to move students from lower, rote skills to complex problem-solving has been recognized in virtually every report on education during the last decade. It is calculation rather than deduction (as Rickert states) that improperly dominates today's school curriculum. Higher order problem-solving involves a variety of approaches and skills—not just calculation or deduction. Estimation of reasonable answers, identification of relevent issues, hypothetical "what if" approaches, structured approaches to isolate problem components, wise choice of tools and resources—all these and more must supplement the traditional diet of calculation and rote skills.

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