Letters

Robert Frost on Thinking

Readers intrigued by "Causality, structure, and common sense" by M. Mitchell Waldrop (Research News, 11 Sept., p. 1297) may be interested in knowing that the role of analogy in reasoning has been discussed eloquently by poet Robert Frost in an essay called "Education by poetry" (*1*). The following excerpts are among his most relevant comments:

> I have wanted in late years to go further and further in making metaphor the whole of thinking. I find some one now and then to agree with me that all thinking, except mathematical thinking, is metaphorical, or all thinking except scientific thinking. The mathematical might be difficult for me to bring in, but the scientific is easy enough. . . .
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> What I am pointing out is that unless you are at home in the metaphor, unless you have had your proper poetical education in the metaphor, you are not safe anywhere. Because you are not at ease with figurative values: you don't know the metaphor in its strength and its weakness. You don't know how far you may expect to ride it and when it may break down with you. You are not safe in science; you are not safe in history. . . .
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> . . . All metaphor breaks down somewhere. That is the beauty of it. It is touch and go with the metaphor, and until you have lived with it long enough you don't know when it is going. You don't know how much you can get out of it and when it will cease to yield. It is a very living thing. It is as life itself. . . .
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> We still ask boys in college to think, as in the nineties, but we seldom tell them what thinking means; we seldom tell them it is just putting this and that together; it is just saying one thing in terms of another. To tell them is to set their feet on the first rung of a ladder the top of which sticks through the sky.

Perhaps researchers in artificial intelligence who are teaching computers to reason by analogy should include in their curriculum a course in poetry. If so, I suggest they start with Frost. His poems have become an important feature of my own ecology courses because they contain much insight into cause and effect in nature, rather than mere appearance.

DAN M. JOHNSON
Department of Biological Sciences, East Tennessee State University, Johnson City, TN 37614

REFERENCES

1. H. Cox and E. C. Lathem, Eds., *Selected Prose of Robert Frost* (Collier, New York, 1968), pp. 33–46.

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, nondogmatic 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.

JAMES D. STEIN JR.
Department of Mathematics, California State University, Long Beach, CA 90840, and
Department of Mathematics, University of California, Los Angeles, CA 90024

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.

NEIL W. RICKERT
Department of Computer Science, Northern Illinois University, DeKalb, IL 60115

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