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.

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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.

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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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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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Peer Review at the Agricultural Research Service

As administrator of the Agricultural Research Service (ARS), I was surprised and mildly disconcerted to see Colin Norman's briefing (News & Comment, 7 Aug., p. 597) on the recent report (*1*) by a committee of the National Research Council's Board on Agriculture. The report evaluates the ARS project peer-review system. Had Norman contacted me first, I would have told him that ARS requested and paid for this study, that we welcome the Board's objective evaluation of our research processes, and that we are finding the report highly constructive and helpful to agency management.

The report states correctly that ARS uses peer review to improve the quality of our research. Unlike the National Institutes of Health and the National Science Foundation, ARS is not a granting agency. Our funds are appropriated by Congress for specific research programs. We therefore use peer reviewers, including outside scientists, to answer two questions about each proposed research project: Will it help solve the problem? Is it good research from a scientific standpoint?

Also, there seems to be some confusion about the relation between project peer review and position classification review. These are two different review systems, the former deals with the scientific aims of specific projects, and the latter deals with a scientist's work performance. They are related to the extent that the scientist's achievements on a research project can result in awards, increased peer recognition, merit pay increases, and upgrading of their position by means of the Office of Personnel Management classification system.

In summary, we in ARS did not find the committee's report "by implication highly critical of current practices," as Norman states. The committee report was straightforward, positive, and constructive. It implied nothing to the contrary. We have already taken steps to implement the justified recommendations made in the report. The agency's official response to the report is a 30 July letter from me to Charles M. Benbrook, executive director of the National Research Council's Board on Agriculture. I will be glad to share that letter with anyone.

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REFERENCES

1. Board on Agriculture, National Research Council, *Improving Research Through Peer Review* (National Academy Press, Washington, DC, 1987).

Response: The first paragraph in the section of the report headed "principal conclusions" states: "The committee finds a lack of understanding and agreement among ARS staff regarding the purpose, use, and effect of the project peer-review system. Many staff members also believe the system has no real impact on ARS research. As a result, some view it more as busy work than a substantive review of real or potential value to ARS scientists and, ultimately, to the ARS. This view seems logical because it appears the results of project peer review have no direct bearing on decisions affecting project funding, staff promotion, and merit pay increases."

I am surprised that Kinney does not find the report highly critical of current practices.

—COLIN NORMAN

International Science Foundation

Marjorie Sun's article "Strains in U.S.–Japan exchanges (News & Comment, 31 July, p. 476) addresses the fact that Japan is riding free on the knowledge developed out of basic research done in the United States and discusses the search for means to compensate for this. However, the arguments presented from various experts do not address the most crucial issue, inherent to basic research in both countries.

The goal of basic research is to produce new knowledge, with creativity serving as the base. Japanese society, which emphasizes conformity, harmony, and consensus and suppresses individualism and uniqueness is inherently unsuitable for carrying out creative research; it does, however, match perfectly with the development of commercial products. The opposite holds for American society, where individualism is emphasized. Americans are thus more suitable for performing creative research, but less so for developing commercial products, where coordinated teamwork is required.

Because of the sharp contrast in the social backgrounds between the United States and Japan, even if Japan increases basic research funding by a significant factor, the trend of Japanese industries having a free ride on the output of American basic research will continue. The output of basic research is new knowledge that cannot be sold or patented, but is crucially needed by humankind. It is wealth that human beings should share, without the restrictions of national borders. Clearly the most efficient way of supporting basic research is to fund the most productive laboratories or individuals in the world.

In view of these realities, I propose that we set up an International Science Foundation (ISF) to which interested nations would contribute funding, perhaps in proportion to their gross national products. The ISF would fund basic research in member nations on the basis of proposals and peer review by scientists in the member nations.

The system would work on the basis of merit and the fairness of the scientists who review the proposals. The foundation could be started by the United States and Japan. In this case, funding would flow from Japan to the United States for the conceivable future, because basic research activity in the United States is much stronger. The trend would continue until Japan revolutionizes her educational and merit systems. However, it would resolve the current strain between the two nations in a most effective way.

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Erratum: In the map accompanying the article "War on cattle disease divides the troops" by John Walsh (News & Comment, 11 Sept., p. 1289), the name Upper Volta was incorrectly given for the country now called Burkina Faso. The country is correctly identified in the text.

Erratum: The Louisville Twin Study, referred to on page 600 (column 2) of "The genetics of personality" by Constance Holden (Research News, 7 Aug., p. 598), was started in 1957 by Frank Falkner, a pediatrician at the University of Louisville, not by Ronald Wilson, as stated in the article.