Making Mathematics Meaningful

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The organizers of this Forum picked an opportune time to bring mathematics education to wider attention. Congress has mandated third- to eighth-grade tests in the new Elementary and Secondary Education Act, Leave No Child Behind. Students in a number of states already are facing high school exit examinations, and other states are likely to follow suit. Students who fail will be denied their high school diplomas. Unless the situation changes quickly, the failure rate and the number of denied diplomas will be too high. As a result, the entire standards movement will be put in jeopardy.

If history is any guide, many of those denied will have failed their mathematics examination. Even today, many students interested in college programs leading to degrees in a technology field are denied entrance because of weakness in mathematics. Results of the National Assessment of Educational Progress (NAEP) document the difficulty American students—especially black and Hispanic students—have in learning mathematics. Results of the National Adult Literacy Survey (NALS) document continuing difficulty beyond adolescence.

As indicated by the NAEP, the test likely to be used to calibrate state standards, current practices in mathematics education are clearly failing at least half of our students, including a majority of blacks and Hispanics. An examination of the tests and textbooks clearly shows why: they are too abstract. Moreover, when the test questions are put in context, the context is often so odd that it may make matters worse. The book *Humble Pi* (Smith 1994) lays out some of the contexts that make up the majority of algebra word problems: trains or planes crossing in the night, mixes of two different-colored jelly beans at two different prices, the age of a relative or pet as an algebraic function of another (“Aunt Jo is twice as old as Uncle John’s dog. . .) and, of course, rowing a canoe upstream or downstream.

No wonder a majority of college students need extra help in mathematics and take only the easiest and required course, proclaiming after the final “Thank God I’ll never have to take another math course in my life.” No wonder few students, even very good ones, can apply mathematics to real problems. No wonder gatekeepers establish mathematics as the screen to engineering and medical school, and that calculus serves as an effective screen for many. It is, however, a greater wonder that mathematics educators tolerate this state of affairs and resist change with so much vehemence.

Quantitative literacy, in my judgment, can save the day, not by being added to the curriculum but by altering *required* mathematics. National Science Foundation (NSF) director Rita Colwell makes the analogy of understanding a clock (Colwell, see p. 247). Some people need to know how to make a good timepiece and some need to understand how a clock’s mechanism keeps time. But everyone needs to know how to read a clock’s face and tell time.

Similarly, a few—a very few—need to know mathematics well enough to be researchers in the field. A much larger number—but still only a small percentage of the nation’s labor force—need to know enough mathematics to be research scientists and engineers. But the majority of those who are going

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to have successful careers need to have quantitative literacy, as does everyone who is going to be a participating citizen.

"How will students know whether they want to be mathematicians or research engineers unless they are exposed to abstract mathematics early?" some will say. "Yeah," replies the quantitatively literate after looking at some data, "as if students—especially minorities and women—are beating down the doors to graduate from mathematics departments now." The current system clearly needs to be radically improved.

Adding courses in quantitative literacy will not do; formal schooling already takes too long. Instead, we must change basic mathematics education, at least until grade 14. What does that mean in practical terms? Replacing trigonometry with data analysis and statistics as the first post-algebra course is one step. De-emphasizing calculus is another.

Even more radically, eliminate the use of *x*'s and *y*'s as variable names until the junior year in college. Eliminate *x* and *y* in the NAEP exams. Move understanding the transferability power of mathematics to the end of the chapter—where the applied problems now languish—to be learned *after* students see how mathematics can solve relevant problems. "See, now that you understand how rates of change apply to prices to produce measures of inflation, you can use similar equations to determine the speed of tennis serves or changes in the incidence of AIDS." The hallmark of quantitative literacy (QL), in my judgment, is its emphasis on learning in a *meaningful* context. The *Humble Pi* algebra examples are not meaningful contexts, and neither are most "consumer math" problems.

I do not mean to denigrate the importance of "transferability" and the power of mathematics in this regard. The issue of transferability is quite complex but data clearly indicate that the majority of students do not transfer what they learn in mathematics class to problems in the outside world. A full conversation would bring us into the field of learning theory, which I hardly understand. I do, however, suggest *How People Learn: Brain, Mind, Experience, and School* by the Committee on Developments in the Science of Learning of the National Research Council, which reviews recent developments (Bransford et al. 2001). The authors make the following pertinent points:

1. Learners build on what they know and unfamiliar principles are difficult to learn in unfamiliar contexts.

2. What learners already know may get in the way of new learning (for example, in ordering fractions).

3. The only reason for schooling is to transfer the lessons beyond the classroom.

4. Transfer rarely occurs unless explicitly shown and too narrow a context inhibits transfer.

Our work at the Secretary's Commission on Achieving Necessary Skills (SCANS) 2000 Center at Johns Hopkins University tends to focus on education for careers. For us, meaningful contexts are jobs paying more than the median wage. Thus, Algebra I students develop marketing plans for a tourist agency. This requires that they deal with a line whose slope changes when the printing price changes from 25 cents per 100 (for quantities under 1,000) to 10 cents per 100 (for greater quantities). Algebra II students develop a business plan for a mall and deal with trade-offs through spreadsheet simulations and probability through developing an inventory strategy. It is not rocket science (where they *may* need calculus) but it is plenty rigorous, certainly more rigorous than trying to find out where the two trains meet, or than lightweight consumer mathematics.

More important, students in our programs learn the stuff, at least as compared to their peers. In schools that have graduation rates under 25 percent, students taking our courses are graduating at about a 90 percent rate. Compared with other non-dropouts, their mathematics grades are one-half grade point higher (although still only a "C"). Even more significantly, students in these programs are one-third more likely to take and pass Algebra II.

The background essay I prepared for this Forum (see p. 33) describes a "canon" of issues in mathematics education that I will not discuss at length here. But I will mention a few issues in career education that come from SCANS. The commission listed five broad problem domains; career success is likely to require competence in a few of them. One of the SCANS problem domains, for example, is planning or resource allocation. This leads to budget problems as illustrated by the business plan project mentioned above. The planning domain also includes space problems, staff assignments, and scheduling. In addition to converting from English to metric measure (still, unfortunately, rare for Americans), a quantitatively literate person should be able to convert hours and days into minutes (for example, to determine when a heat-treated part should be removed from an oven). This is a career-relevant problem using a number system based on 60 rather than 10.

Let me reiterate five points:

1. Too many students—especially minority students and young women—are poorly served by the current practices in mathematics education.

2. The standards movement, especially the adoption of high school exit examinations, makes change in this situation imperative.

3. Quantitative literacy is a way out of the current dilemma. This implies more data analysis and statistics and less trigonometry.

4. Mathematics needs to be taught in relevant contexts of real-life problems that productive workers and engaged citizens need to be able to solve.

5. One way to achieve this is to eliminate *x*'s and *y*'s from mathematics until the junior year in college and from the NAEP and other high school exit examinations.

The aim of the first 13 years of mathematics education should be to equip students with the tools and desire to continue learning mathematics. By this criterion, current programs clearly fail many students. There is some evidence that quantitative literacy will succeed.

References

Bransford, John D., Ann L. Brown, and Rodney R. Cocking, eds. 1999. *How People Learn: Brain, Mind, Experience, and School*. National Research Council. Washington, DC: National Academy Press.

Smith, Michael K. 1994. *Humble Pi: The Role Mathematics Should Play in American Education*. Amherst, NY: Prometheus Books.