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1 + 1 = 0: New Math for a New Age

One year ago America read with alarm *A Nation at Risk*, the indictment of public education by the Commission on Excellence in Education. Shortly afterward, the National Science Board issued a parallel, bleak report on education in mathematics, science, and technology. Both reports make the same points: test scores are low, academic requirements are inadequate, and teaching is no longer a prestigious profession.

Slowly, but with gathering momentum, the states are responding. California, Florida, Ohio, Texas, and others are increasing requirements: longer school hours here and more required courses there. Some states are even requiring competency tests—for teachers as well as for students.

As the political momentum of our educational crisis peaks, legislators often gravitate to the quick fix, to a nostalgic return to the good old days of stern requirements and no-nonsense exams. It seems that the new regime in education is committed to the basics, even if it means going backward to get there. But today's students need the science and mathematics of the future, not of the past. The world of today's student is dominated by genetic engineering and computer modeling, by new tools used to solve new problems. Yet the world of school tests and texts, too often, is full of old tools applied to old problems.

Mathematics provides a good example. Traditional school mathematics aims to perfect arithmetic skills (such as percentage calculations and long division) as a basis for algebra, which itself becomes the cornerstone of trigonometry, analytic geometry, and calculus. America was built with these tools, applied by generations of engineers and scientists to the physical environment in which we live.

But today's growth industries are dominated by information, which is abstract and immaterial. Whereas the material world is modeled by calculus, the language of continuous change, the immaterial world of information requires discontinuous, discrete mathematics. Both genetic codes and computer codes are intrinsically discrete. Discrete mathematics basically deals with fancy ways of arranging and counting. It can be used to enumerate genetic patterns and to count the branches in computer algorithms; it can be used to analyze the treelike branching of arteries and nerves, as well as the cascading options in a succession of either-or decisions. It can tell us how many things are there as well as help us find what we want among a bewildering morass of possibilities.

Courses and seminars in discrete mathematics are being introduced in colleges across the land. Many computer scientists are urging beginning students to study discrete mathematics before they study calculus. Recent recommendations for preparation of secondary school teachers of mathematics add both discrete mathematics and computer science to the list of required courses.

Reform of school mathematics must reflect this new mathematics. Requiring more tests is of no use if the tests examine only the old mathematics; increasing time in class is of no benefit if it only reinforces old traditions. Standardized tests must be changed, new textbooks must be written, and teachers must be provided with opportunities in substantive workshops to learn this discrete, computer-oriented mathematics.

In mobilizing for excellence in mathematics education, we must create a new curriculum founded on the principle that mental arithmetic is more valuable than mechanical calculation, that solving problems is more important than solving equations. Mathematics in the computer age must comprehend and supplement the computer, not merely imitate it. Arithmetic in the computer age relies as much on the concept of "bit" as on the concept of number. But inside a computer, bits do not add up, they just flip on and off. The verity of nostalgic arithmetic is that $1 + 1 = 2$; but in the new mathematics of the computer age, we must also teach that $1 + 1 = 0$.
—LYNN ARTHUR STEEN, *Department of Mathematics, St. Olaf College, Northfield, Minnesota 55057*