Mathematics for 21st Century Citizens

STEPHEN S. WILLOUGHBY

Commission reports and political pronouncements on the state of education in the United States have become legion during the past year. These various statements have in common their negative evaluation of the present condition of education and their firm conviction that the situation should be improved.

Because mathematics and science are important for the defense and economy of the nation and for solutions to the world's ecological and human problems, and because there is a shortage of teachers of mathematics and the quantitative sciences, education in mathematics, science, and technology has played a central role in many of the statements.

How bad is mathematics education in the United States today? What happened to the "reforms" of the past 25 years? Where do we stand today compared with other nations and with our own past? What can we do to achieve our future potential?

Present Status

Today the schools of our nation are doing more for more children with fewer resources than has ever been the case for any nation in the history of the world. Our underpaid, overworked, underprepared teachers provide the moral and psychic support that should be provided by families and religious groups. They provide the services of police officers, secretaries, baby sitters, psychologists and social workers, janitors, and many others, with fewer resources,

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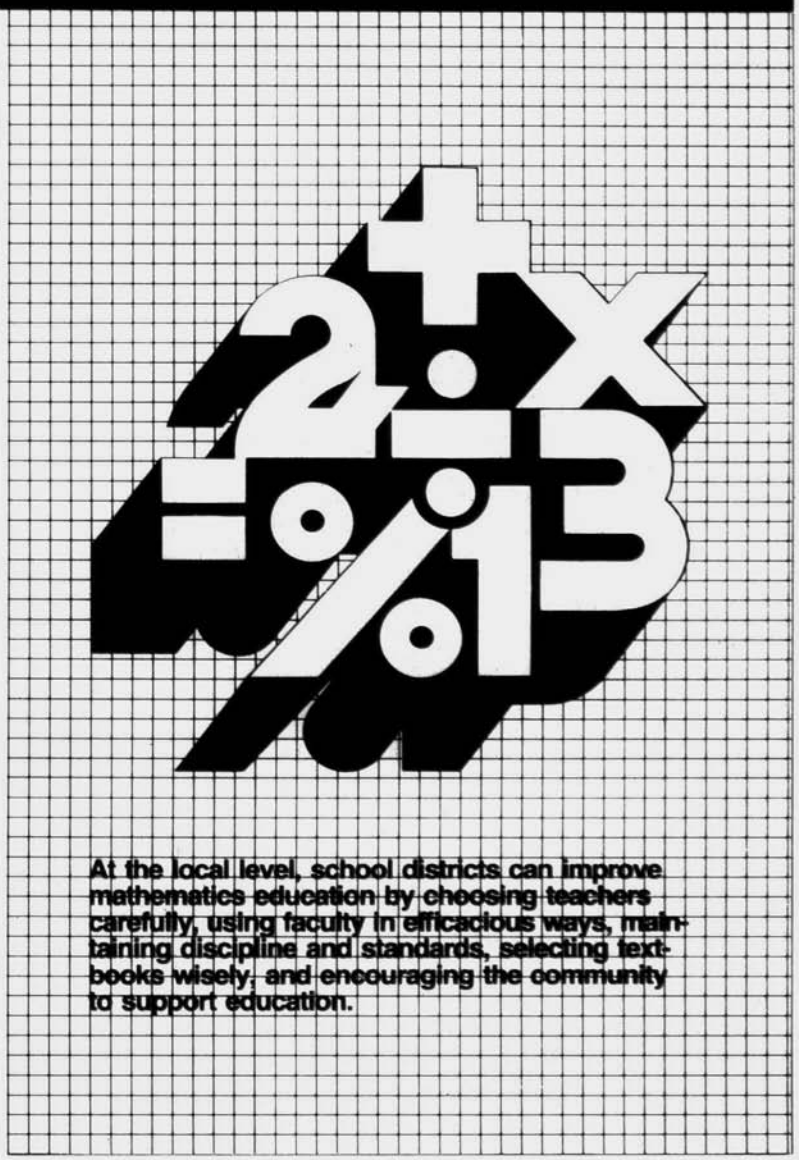

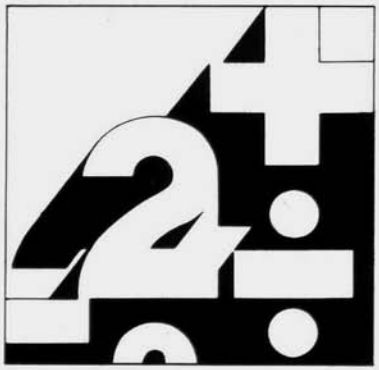

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worse conditions, and less recognition than would be expected by full-time workers in any of these trades.

But serious problems face education generally, and mathematics education in particular. People preparing to be teachers have the third lowest college entrance exam scores and secondary school standings of all possible majors. Since 1972 there has been a 77 percent decline in the number of high school mathematics teachers prepared, and only 55 percent of those who are prepared choose to teach. Of those who do teach, almost five times as many leave teaching for employment in nonteaching fields as leave to retire. Those who leave teaching for other employment tend to be the better qualified ones. Even if we could say that mathematics education is excellent in this country today, the prognosis for the future would not be good.

Holding Our Own Not Sufficient

Unfortunately, mathematics education is not now excellent. Large numbers of students graduate from high school with extreme disability in and distaste for mathematics, making them neither able nor willing to use quantitative reasoning to solve everyday problems or to help earn a living. College entrance examination scores are only the tip of the iceberg. National Assessment of Educational Progress (NAEP) scores are more indicative of the general population. Some of the recent NAEP scores suggest that we are "holding our own" in mathematics, but holding our own is hardly sufficient.

Productive citizens of the future will have to be able to deal with a quantitative world. Even more disturbing than our apparent lack of substantial progress in mathematics are the skills in which students appear to be making progress—lower-order skills such as fact recall and multidigit computation—the very activities that a $10 calculator will always be able to do more efficiently. The back-to-basics movement, having misidentified what is really basic, is producing youngsters who are slightly better at skills that were of questionable value in the 19th century and will be of little value in the 21st century.

Apparently, in becoming responsible for replacing the family, the church, and society in matters of proper nutrition, reproduction, driver training, and so on, our schools have not managed substantial improvement in teaching mathematics and other subjects that were once thought to be the major province of the schools.

Are other countries doing better? Possibly, but almost certainly not as much better as is reported. Our very best students are as good in the International Mathematical Olympiad as the students from any nation. In 1983 our team took second place (behind West Germany, with Hungary, the Soviet Union, and Romania taking third, fourth, and fifth places, respectively). Japanese educators have complained that their colleges are an intellectual wasteland, and that even their precollege students are less creative than they ought to be because of the rigid nature of instruction. Reports from the Soviet Union are impressive, but emigrants from the Soviet Union seem convinced that mathematics instruction in that country simply is not as good or effective as some reports suggest.

Our best teachers and our best students are second to none. And there are surprising numbers of outstanding educators still working in our schools. But still, all too many students are exposed to unprepared teachers using uninspiring textbooks, and are demonstrating minimal competency on outmoded standardized tests. At a time when the need for a mathematically literate population is increasing, we are becoming less able to satisfy the need.

New Math

How did we get here? Did the purveyors of "new math" lead us down a blind alley? With all the time and money spent on "reform" in the 1950s and 1960s, why aren't we in better shape?

The answer is: we *are* in better shape in mathematics than we would have been without a reform movement. Over the past 20 years, the decreases in verbal skills have been greater than those for quantitative skills. One reason for this difference is the commitment that was made to mathematics and science education in the 50s and 60s. Certainly, there were some unfortunate activities carried on under the rubric of new math. A lot of unnecessary formalism (set theory, proofs based on commutative, associative, and distributive laws in the elementary schools, and so on) was forced on children in the name of rigor. Claims were made that if students understood, they wouldn't need practice. And numerous other strange mathematical and pedagogical procedures were called "new math" by their perpetrators. But generally, the reform movements did more good than harm. They called attention to the need for a good education in mathematics; many of them placed great emphasis on understanding (though not always at the learner's level); and they called attention to the fact that new mathematics is being created every day—the subject is not set in Precambrian stone.

One important benefit of the activities in mathematics education during the 50s and 60s was the recruitment and education of mathematics and science teachers. During that time, many people who became very fine teachers were attracted to the profession, and many of those who were already teaching went back to school to strengthen their mathematical knowledge. Unfortunately, many of those who upgraded their

knowledge discovered that conditions, respect, and remuneration were better in other occupations and left the classroom.

The more recent back-to-basics movement has less to recommend it. Using psychological theories of the 1920s to teach skills thought useful in the 1890s is hardly appropriate in the 1980s. In order to "update" such programs for the problem solving that is advocated by most mathematics educators today, some textbook companies have added sections or chapters on the topic. Indeed, some have even produced separate booklets on problem solving that are correlated with the main textbook. Needless to say, such cosmetic attempts do not fulfill the National Council of Teachers of Mathematics recommendation that "problem solving be the focus of school mathematics in the 1980s"; they simply make it easy for publisher, teacher, and student to appear to be doing what is expected of them. There is need for substantial improvement in the content and pedagogy of mathematics to which children are exposed in this country, and slick, easy solutions will do more damage than good if they detract from the serious attempts to make real improvements.

A Plan to Improve Education

One year ago, in testimony for the Committee on Education and Labor of the U.S. House of Representatives, I proposed the following unrealistic four-point plan for addressing the long-term problem facing the nation in education:

1. Improve conditions within schools
2. Increase the number of days in the school year
3. Improve standards for becoming and remaining a teacher
4. Double the salary of every teacher in the country.

All of these unrealistic suggestions have since appeared, in slightly modified form, in various commission reports and other statements. In contrast to the beliefs of large numbers of educators and other citizens, I believe the federal government can and must play a central role in points 2, 3, and 4. From a practical point of view, there is no hope that local property owners and state taxpayers are going to vote the necessary funds to match the major national commitment that has been made by virtually every other developed country in the world—notably the Soviet Union and Japan. If the federal government can provide matching funds for highways, surely it can do so for education. The funds for highways come from taxes on users. The individuals and businesses that pay taxes to the federal government are the main users of the products of our educational system. Individual and corporate income taxes are a most reasonable source of funds for education.

There are two common philosophical arguments against this kind of major federal commitment to education. First, "the Constitution reserves control of education to the states." This statement, of course, is not true. Section 8 of Article I of the Constitution gives Congress the power to collect taxes to "provide for the common defense and general welfare of the United States." Nothing is of more importance to the long-term common defense and general welfare of the United States today than the education of our children. The need for federal involvement in education was recognized in the Northwest Ordinance of 1787, and has continued to be a tradition ever since. There is simply no truth to the contention that either the Constitution or tradition forbids federal involvement in education.

The more serious objection to a substantial federal role in education is the argument that evil or misguided federal officials could control education for the entire nation and thus control the hearts and minds of our youth. The events in Germany during the 1930s make this a particularly frightening prospect. It is possible to protect against this danger, however, by limiting the federal government's role to setting general standards rather than allowing direct influence on the day-to-day curriculum. Of course, such limitations could be abrogated later, but that would be more difficult to do if such regulations were written now by people who understand and avoid the dangers.

If the federal government, in concert with the state and local governments, were to take substantial action on points 2, 3, and 4, it would be easy and natural for local authorities to improve conditions within the schools. For example, if teachers were paid a reasonable wage, it would be as ludicrous to suggest that teachers patrol the parking lots and halls of schools as it now would be to sugggest that physicians and attorneys patrol the parking lots and halls of hospitals and courthouses.

Action to Take at the Local Level

But readers of this article presumably wish to take actions now that will improve local school systems soon—whether or not the federal government acts. Some of the things you can do now are discussed below.

1. *Choose teachers carefully*. The most important decision a school supervisor or administrator makes is the choice of new faculty members. The choice could affect students for 50 years into the future. Choosing new faculty members is not an easy task, and when there is a shortage of candidates, as there is in mathematics and some other subjects at present, the task is even more difficult. Making the school environment more attractive, as discussed below, will help attract good candidates. Some school systems, such as Houston's, have found that making certain teaching jobs slightly more attractive financially produces

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substantial numbers of candidates.

If there are several candidates, how do you choose among them? Any simple set of rules will produce wrong answers when the problem is this complex. Mature human judgment is the most important influence you can bring to bear on the problem. On the other hand, various professional organizations do provide guidelines that can help you evaluate the preparation of a prospective teacher. The guidelines produced by the National Council of Teachers of Mathematics suggest that beyond the usual communication skills, humane ways of dealing with people, and knowledge of the foundations of education, teachers of mathematics should have a knowledge of mathematics "substantially beyond that which they may be expected to teach."[1] For elementary school teachers, the specific knowledge suggested is equivalent to about nine semester hours of special mathematics courses including methods of teaching mathematics to young children. The guidelines suggest that a high school teacher ought to have the equivalent of a good solid major in mathematics plus a course in the methods of teaching senior high school mathematics.

Involving outstanding teachers who are aleady on your faculty in the decision–making process will pay dividends both in producing better decisions and in improving the feeling of collegiality among the faculty.

2. *Use available faculty members in the most effective way possible to enhance the education of students.* If one teacher is outstanding in presenting material to a class and carrying on class discussions and another is particularly good with one–to–one explanations, encourage each to spend as much time as possible doing the things they do well, while reducing other obligations. This will require the cooperation of the teachers involved, and some creative scheduling.

3. *Support teachers strongly in maintaining discipline and standards.* The worst deterrent for good teachers to remain in teaching today is the lack of discipline and the lack of respect for knowledge that exists in many of our schools. Discipline and respect for knowledge should start early in a child's schooling and be reiterated each school year. While discipline and standards are largely set at home, the school plays an important role in setting such standards—no child who is well mannered and interested in getting an education should be penalized because school officials are unable or unwilling to maintain similar high standards for others.

4. *Support continued growth of teachers.* A teacher who was certified at the age of 22 in 1937 might still be teaching in 1985. Things have changed since 1937, but in many school systems there is no requirement for teachers to learn about those changes. Unfortunately, many school systems even discourage teachers from continuing to grow after they begin to teach.

Perhaps the most effective and inexpensive way a teacher can remain up–to–date is to belong to, and actively participate in, appropriate professional organizations. In mathematics, the appropriate national professional organization is the National Council of Teachers of Mathematics (NCTM), and there are various state and local affiliates. Reading the appropriate journals (*Arithmetic Teacher* for teachers of K–8 mathematics and *Mathematics Teacher* for teachers of 7–12 mathematics) and attending conventions are important ways to maintain knowledge in the field. Beyond that, every school should subscribe to the *Journal for Research in Mathematics Education*.

Beyond active participation in professional organizations, teachers should be encouraged to return to graduate school for appropriate courses, to read recent books in their field and the latest reports

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of national commissions, and to visit colleagues' classrooms and discuss professional issues. Teachers should be supported in all attempts to remain up-to-date.

When new textbooks are adopted, appropriate inservice education should be provided so teachers will be able to get the greatest benefit from the new material. Conditions having to do with inservice education of teachers and with membership and participation in professional organizations should be written into teacher contracts.

5. *Encourage teachers to teach skills that encompass more than just recall of facts and computational facility.* Many multiple choice tests measure only low-level skills, which are easy to measure. If a teacher is given the impression that student scores on such standardized tests are a major part of the teacher's evaluation, those scores will be emphasized. Teachers and supervisors should work together to identify important goals and decide on methods of evaluating the attainment of those goals.

6. *Show respect for teachers and encourage others to do so.* One of the principal reasons good teachers leave teaching is because they believe that society does not value what they are doing. Teaching is a difficult and important profession. At the very least, educators ought to behave as though we believe that.

7. *Insist that selection of textbooks be taken seriously.* The most important factor in determining what mathematics is taught and learned is the textbook used. All too often, selection of textbooks is by vote of people who have little interest or competence in the subject matter under consideration, even less knowledge of research findings and recommendations of leaders in the field, and an inadequate acquaintance with candidate textbooks acquired in a one- to two-hour superficial skimming of them. Such selection procedures hardly encourage adoption of innovative, effective materials.

Evaluators of textbooks should be aware of and sympathetic to recommendations such as those of the Conference Board of Mathematical Sciences:

- That calculators and computers be introduced into the mathematics classroom at the earliest possible grade and used to enhance the understanding of arithmetic and geometry as well as the learning of problem solving.
- That substantially *more* emphasis be placed on the development of skills in mental arithmetic, estimation, and approximation and that substantially *less* be placed on paper-and-pencil execution of the arithmetic operations. That direct experience with the collection and analysis of data be provided for in the curriculum to ensure that every student is familiar with these important processes.
- That the traditional component of the secondary school curriculum be streamlined to make room for important new topics. The content, emphases, and approaches of courses in algebra, geometry, precalculus, and trigonometry need to be reexamined in light of new computer technologies.
- That discrete mathematics, statistics and probability, and computer science now be regarded as "fundamental," and that appropriate topics and techniques from these subjects be introduced into the curriculum. Computer programming should be included at least for college-bound students.[2]

Some textbooks, especially at the elementary school level, already do the things suggested in the CBMS report. Where possible, long-term pilot tests of promising textbooks should be tried with ordinary teachers teaching the materials to ordinary children in the system. Of course, the pilot teachers should agree to follow the textbook being piloted and not go back to the old textbook when they think a lesson won't work. Then, pilot teachers, and others who have seriously studied available textbooks and information on how they work, should play a dominant role in making the final decision.

8. *Write to legislators in Washington, in your state capital, and in your local community to encourage support for education.* Without a strong national commitment to education, we will fail to live up to our potential as a nation.

Summary

In many respects the condition of mathematics education in the United States is as good as it has ever been in any country. We still have large numbers of dedicated, competent teachers doing an excellent job of teaching bright, motivated students.

Prospects for the future, however, look dim. Conditions in the schools are bad and getting worse. Salaries and prestige of teachers are low. Young people who could be excellent teachers are choosing not to enter the profession, and many of our best teachers are choosing to leave.

An optimist is one who believes that this is the best of all possible worlds. A pessimist is one who agrees. Educators cannot afford to be either optimists or pessimists. We must realize that this is not the best of all possible worlds and take action to improve the world we have.□

[1]National Council of Teachers of Mathematics. *Guidelines for the Preparation of Teachers of Mathematics* (Reston, Va.: NCTM, 1981).

[2]The Conference Board of the Mathematical Sciences. *The Mathematical Sciences Curriculum K–12: What Is Still Fundamental and What Is Not* (Washington, D.C.: Commission on Pre-College Education in Mathematics, Science, and Technology, National Science Foundation, 1983).