Standards-Based Education

by Joseph G.Rosenstein
Professor of Mathematics, Rutgers University
Director, New Jersey Mathematics Coalition

"You have to know where you're going before you figure out how you're going to get there"! This simple advice was the basic thrust of Colorado Governor Roy Romer's keynote address to the February 9-11 education conference sponsored by the National Science Foundation on the theme "Beyond National Standards and Goals: Excellence in Mathematics and Science Education K-16."

Although the context of Governor Romer's remarks was mathematics and science education, his advice applies, of course, to education in general. In discussing our educational system as a whole, or the curriculum of an individual school, we have at present no good way of evaluating how we're doing, since as a society we have no clear idea of what we value.

"Standards-based education" requires us to develop a vision of what we value, articulate that vision in clear statements of what we want to accomplish (called "standards"), and then figure out how we get there. With a goal and a plan in place, we will be able to assess how we're doing and take corrective action as necessary.

Why are standards needed, and why now? This question was addressed in a companion keynote address by economist Ray Marshall, formerly Secretary of Labor, and presently Professor at the Lyndon B. Johnson School of Public Affairs of the University of Texas. The economic success of the United States in the first half of this century was based to a large extent on mass-production, as exemplified by the automobile industry. Assembly-line workers did not need to know how to think in order to do their jobs -- that was left to the managers; at best, they needed to be literate in order to read their instructions. Our educational model has been a two-tier system, with the "Three R's" for the many and thinking for an elite.

That model, Marshall argues, doesn't work anymore because of the emergence of technology, which renders obsolete many mindless occupations, and the globalization of the economy, which forces us to compete in unfamiliar areas. In response to this challenge to be competitive, we may either increase productivity or decrease wages; Marshall notes that by failing to develop a strategic plan to increase productivity we have "backed into" the lower-wages solution, the results of which are increasingly evident.

The key to increased productivity is quality education, since the investment which yields the greatest return is investment in human resources, a theme echoed by President Clinton. And quality education requires a commitment to high standards.

Standards-based education has now become a major direction in education as the result of the success of the *Curriculum and Evaluation Standards for School Mathematics* developed by the National Council of Teachers of Mathematics (NCTM) between 1985 and 1989. While the implementation of the NCTM *Standards* has only just begun, the document has clearly served as a rallying point (another meaning of "standard") for those seeking to improve mathematics education.

The response to the NCTM *Standards* has been very positive. It was endorsed by the National Governors Association, now chaired by Gov. Romer and previously by Gov. Bill Clinton, and was supported by former Secretary of Education Lamar Alexander, former Governor of Tennessee. A major project is now underway to develop science standards by the end of 1994 (under the leadership of the National Academy of Sciences), and other content areas are not far behind.

Quality education, based on high standards, must be provided to all students. The NCTM *Standards* asserts that all students can learn and do mathematics. In other countries, children are successful with mathematics; our children can enjoy the same success. In a recent study, the students at the best of 20 Minneapolis schools were on a par with those at the worst of 40 schools in Taiwan and Japan. Parents in other countries believe uniformly that the key to learning mathematics is persistence and hard work; only in this country do many believe that the key to success in mathematics is innate talent. The commitment of the mathematics community is to all students, as exemplified by the "Math 4 All" logo of the New Jersey Mathematics Coalition. Developing high standards for all students, world-class standards which will enable us to compete with world-class economies, is a major challenge for those committed to education.

In New Jersey, the Department of Education has established panels which are working to articulate a vision and develop content standards in eight different areas. In addition, the New Jersey Mathematics Coalition together with the Department of Education have obtained a three-year grant from the U.S. Department of Education to permit us to translate the "where do we want to go?" of the standards into the "how do we get there?" that will follow. The project involves developing a mathematics curriculum framework and working with schools on implementing the framework.

Readers are invited to share with the Coalition their responses to "Where do we want to go?" More concretely, we seek your responses to the following question: "What do we want our high school graduates to know and be able to do in mathematics and science, so that they may succeed in careers and in college, as citizens and as consumers?" Let us hear from you! Our address is NJMC, P.O. Box 10867, New Brunswick, NJ 08906; responses dealing with other content areas will be forwarded to the appropriate panels.

(This article appeared in the Star Ledger in March 1993.)

Joseph G. Rosenstein

Joseph G. Rosenstein is Director of the New Jersey Mathematics Coalition and a Professor of Mathematics at Rutgers University.

"How do you multiply 255 by 28?", my third-grade daughter Neshama asked. I naturally assumed that this was one of her homework problems, but soon discovered that was not the case. Although she knew how to multiply 55 by 8, she had not yet learned how to multiply numbers with more digits.

On the cover of her dictionary it said "250,000 words and definitions" and Neshama was checking that out. She saw that there were 255 pages, counted 28 words that were defined in a column, and understood multiplication well enough to realize that the number of words in the dictionary should be 255 times 28. But she hadn't yet learned how to compute the product.

Kids are curious about numbers and how they work; they ask interesting mathematical questions -- ones which they often cannot answer with the tools they have mastered. But the study of mathematics has always been sequential, based on mastery of previous topics, and so discussion of interesting questions has often been delayed until all the tools have been learned, by which time the interesting questions may have been forgotten.

Suppose that there was a way for Neshama to figure out easily the answer to 255 times 28, and other such questions. We could imagine that after discussing why we would multiply numbers and after doing simple examples like 4 x 5 , her teacher might ask each student to bring in a real-world question which would be answered by multiplying. One student might suggest using multiplication to count the number of apartments in her building, another the number of words in a book, or the cost of a whole box of candy bars, or the number of tiles on the bathroom floor, or the number of minutes in a day, or ... . If they were able to answer such questions easily, the children could compare the numbers of apartments in different buildings, or the costs of different boxes of candy, long before they mastered the computational skills of multiplication. And it is not difficult to imagine that such problems might provide children with motivation to learn the intricacies of multiplication.

Of course, it is now possible to do such problems, and many other types of problems, very easily -- by using a calculator. The calculator has made it possible for us to teach mathematics in a very different way, one where we can discuss questions involving various skills long before those skills are mastered. Put differently, the calculator allows children to acquire mathematical skills by talking mathematics first and later filling in the details of computation, much like they acquire language skills, by speaking first and later filling in the details of grammar.

A parenthetical remark. Readers who carried out the multiplication undoubtedly noticed that 255 times 28 is far short of the 250,000 words claimed by the publisher, even taking into account that each page had two columns; perhaps the publisher counted all the words occurring in the definitions, but clearly gave Neshama (and me) the impression that 250,000 words were being defined. When we discovered this, Neshama and I had a discussion of the importance of thinking critically about what one reads.

The example given above involves arithmetic at the elementary school level, but there are similar examples at all levels. In the tenth and eleventh grades, one of the major themes is mastering the intricacies of various kinds of functions. The traditional approach focuses on learning the rules involving these functions. Many students take naturally to precalculus topics, but many other students are turned off; they are unable to master these manipulations, and give up on mathematics. The "graphing calculator", whose miniature video screen creates the impression of a hand-held computer, provides a new approach since it provides a vivid picture of the graph of any function in a fraction of a second -- a picture the student and the teacher might not be able to create easily. How do you solve an equation? With a graphing calculator, you can start by drawing a picture. Many college students fail calculus because they can't connect the algebra they have learned with geometry; they can't connect the symbols with the graphs. Graphing calculators can help students make that connection.

The use of calculators (and other technology) in the schools has been endorsed by all of the major professional groups of mathematics educators and by all of the recent national reports, including the *Curriculum and Evaluation Standards for School Mathematics* of the National Council of Teachers of Mathematics. *Everybody Counts*, a report prepared by the National Research Council of the National Academy of Sciences, notes that:

"Calculators enable students to explore a wider variety of examples; to witness the dynamic nature of mathematical processes; to engage realistic applications using typical, not oversimplified, data; and to focus on important concepts rather than routine calculation."

The New Jersey Mathematics Coalition, an umbrella organization involving the corporate, education, public policy, and public sectors of the New Jersey community, has recently adopted the following position statement:

"The New Jersey Mathematics Coalition strongly endorses the use of calculators in mathematics instruction and assessment at all levels of schooling. Further, it encourages the Department of Education, and local school districts, to adopt policies and procedures which will result in optimal use of calculators in both instruction and assessment, and to do so in a matter that assures equity and access for all groups of students."

The concern that is most often expressed -- by educators and parents -- is that the use of calculators will somehow diminish the child's mathematical skills. Over the past twenty years a number of studies have been done about this question, and the results are quite uniform. Students who use calculators develop computational skills just as well as students who do not use calculators. But they are also better at solving problems and have a more positive attitude toward mathematics.

Does that mean that students don't need to be able to do arithmetic on their own? Of course not. They will often need to work without a calculator, and they can solve simple problems much faster without a calculator. They also must be able to check the accuracy of the results they get from the calculator, since we all push the wrong buttons sometime; for this they need to be able to estimate the result of a calculation and compare it to the "answer" on the calculator. In the example above, multiplying 255 by 28, we expect a student at the 5th grade level to say that her answer should be about 250 times 30, which is 7500, and do that in her head.

Mathematics is more than the pencil-and-paper calculations which are often the focus of textbooks and instruction. In an increasingly technological environment, students and graduates will need to analyze a problem, determine what mathematical models and techniques are appropriate, carry out the necessary calculations efficiently and effectively, use estimation to determine whether their answers make sense, use reasoning to determine whether the answer is acceptable, and, if not, modify the problem and start all over again. They will need to apply these skills if they're building a house or buying one, if they're creating a product or selling it. The calculator enables instruction to focus on these skills, rather than dwell exclusively on the computational aspect of mathematics.

As with instruction, so with assessment. If we want to test students' knowledge of mathematical facts and ability to do simple problems, then they should not be using calculators. But if we want to test students' problem solving ability, using real world problems, then they should be using calculators. They will be using calculators outside of the classroom -- at home and at work -- and it doesn't make sense to keep them from using them in school. On the job, they will be evaluated on the answers they get, not on how they get them; no one today, outside of school, is ever asked to multiply two three-digit numbers without a calculator.

In our educational system, like it or not, the curriculum is often determined by the tests students take. As a result, in order to emphasize that students should do more complex real-world problems, and should use a calculator when appropriate, we need tests which include those kinds of problems. We need to test the skills that we value. All of the national reports emphasize that the simple "shopkeeper" mathematics that was adequate 50 years ago is no longer enough. What is valued in today's technological society is the ability to solve a variety of problems using a variety of techniques and tools. And that is what the assessments should reflect.

The College Board has announced that students applying for college will be allowed to use calculators on the SAT (Scholastic Aptitude Test) in 1994. The SAT-II (Achievement Test) permitted the use of calculators last year and will require their use in 1994; the test is expected to be modified so that for a number of problems the use of calculators will actually be necessary.

On the state level, the tests now in place do not permit the use of calculators. The New Jersey Mathematics Coalition, in urging the Department of Education to change this practice, noted that "a requirement that calculators be used on the new High School Proficiency Test (HSPT) would send the message clearly throughout the state that calculators belong in all mathematics instructional activities." This recommendation applies to both the High School Proficiency Test (HSPT) given in the 11th grade and the Early Warning Test (EWT) given in the 8th grade.

The proper use of calculators on these tests will lead to improvement in mathematics curricula throughout the state and should be encouraged wholeheartedly. "Proper use of calculators" includes ensuring that teachers are trained in the instructional use of calculators, that students have and use calculators extensively before taking the EWT and HSPT, that all students use calculators which have substantially the same abilities, and that problems on the test are creatively designed to take full advantage of the technology.

In 1986, the National Council of Teachers of Mathematics issued a position statement which notes that:

"Although extensively used in society, calculators are used far less in schools, where they could free large amounts of the time students currently spend practicing computation. The time gained should be spent helping students to understand mathematics, to develop reasoning and problem solving strategies, and in general, to use and apply mathematics."

The calculator is at present an underutilized instructional tool; with adequate support, more teachers will find better ways of using it to enhance children's understanding of mathematics. The New Jersey Mathematics Coalition supports and encourages this trend.

The New Jersey Mathematics Coalition is an organization dedicated to the improvement of mathematics education in the state of New Jersey. Through the active participation of educators, industry, government, and the public, it seeks to convey the message that mathematics is accessible to all. It informs the community about the recommendations in the recent national reports and encourages and facilitates their implementation, building on the many activities and programs taking place throughout the state. For further information about the New Jersey Mathematics Coalition, the reports mentioned in this article, or about its position on calculators, your are invited to write to the Coalition at P.O.Box 10867, New Brunswick, 08906.

May 18, 1992