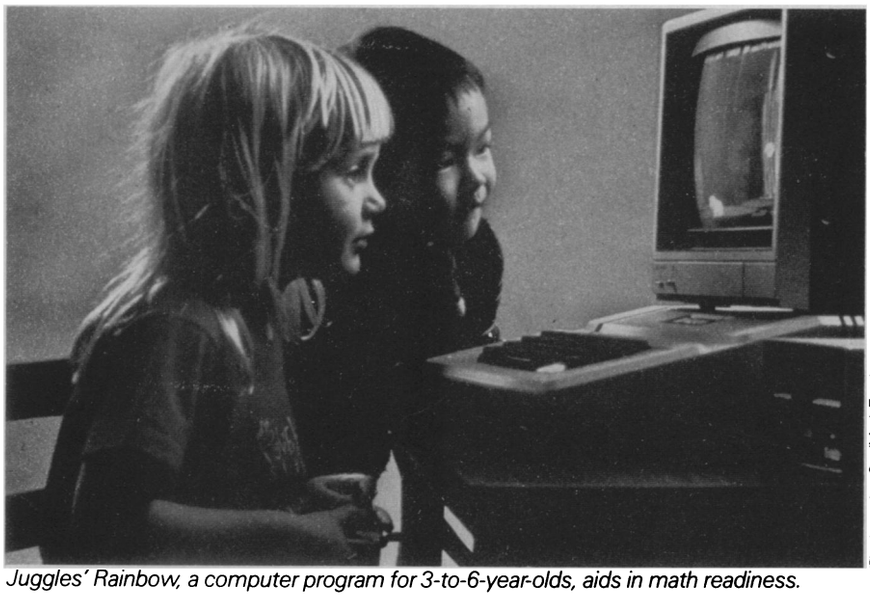
Math Education — Does It Have the Right Stuff?

Evidence is mounting that schools are not teaching the skills necessary for coping with an increasingly technological society



The Learning Co./Mark Tuschman

Juggles' Rainbow, a computer program for 3-to-6-year-olds, aids in math readiness.

By JANET RALOFF

In recent months, a number of prominent groups have reported observations suggesting that the health of mathematics education in this country may be in serious jeopardy. Most worrisome, the observed symptoms suggest the problem is both deep-seated and pervasive — a product of the economy, school curricula, new technologies, changing employment opportunities for teachers and a liberalization of high-school graduation requirements.

The third National Mathematics Assessment offers the latest barometric reading of the situation. Conducted every four years, this federally funded survey monitors mathematics ability in 9-, 13- and 17-year-olds. Since the last survey, a decline in the mathematics prowess of elementary- and secondary-school students has leveled off, in some cases even reversed marginally. But dampening the optimism of analysts poring over the newest survey results is the finding that what gains have been registered occurred almost entirely in mastery of low-level skills; these include computing, recognizing geometric figures, and answering simple, one-step story problems. This particular finding dovetails alarmingly well with recent observations by the National Academy of Sciences and other prominent groups on the state of mathematics education in this country.

"It is disappointing to find no improvement in applications items — on those items that call for a deeper understanding of principles — nor in the problem solving that is more realistic precisely because it is nonroutine," laments Shirley Hill, past president of the National Council of Teachers of Mathematics. The University of Missouri professor of mathematics and education foresees that "there is certainly going to be less and less demand for paper-and-pencil computations and storing isolated facts in one's head. Yet the assessment results suggest that these are what the schools are emphasizing.

"Narrow focus on low-level computation — rote memory," says Hill, "is in my mind a formula for obsolescence. Skills are only tools and their value rests with the times. We are moving into a future that demands higher levels of reasoning ability, technical skills and the ability to determine applications."

Results of the new assessment were issued April 14 in Washington by the Denver-based National Assessment of Educational Progress (NAEP). Mathematics is but one of the fields it surveys for the U.S. Department of Education. Students were tested last year, and the roughly 2,000 in each age group were selected so that their scores could be generalized as characteristic of their age group in the national population.

The latest assessment records several positive trends. For one, junior-high students scored, overall, two percentage points higher than their counterparts in 1978, and four points higher than in 1973. Notes NAEP director Beverly Anderson, "Our senior-high students had been declining from '73 to '78, but the decline has leveled off." Both these findings may be attributable to the recent back-to-basics drive in school curricula, she says.

"Another piece of good news," Anderson announced, "is that students who traditionally have been viewed as disadvantaged are improving." She said that "while they're still performing below national levels, black and Hispanic students at each grade are tending to make greater gains than their white counterparts." Admitting there has been no scientific attempt to correlate whether or how "entitlement programs" in largely minority schools may have contributed to these findings, Hill says, "Obviously it's a logical leap to assume they have been a strong help. I fully believe that, anyway." Also interesting is that low achievers (those scoring in the lowest 25 percent) improved more than the high achievers (ranking in the top 25 percent of all tested).

Overall, 9-year-olds improved mastery of whole-number subtraction and improved by seven percentage points in their knowledge of multiplication facts since the last testing. Knowledge of division facts improved 10 percentage points since the last assessment among 13-year-olds.

"Our children are indeed learning what they're taught," notes Hill. For example, 13-year-olds gained eight percentage points in decimal computation — a topic now stressed because of its importance with the growing use of hand-held calculators. And increased emphasis on metric measures seems to have paid off in a better understanding among all age groups.

"I'm not surprised, but it really should amaze us" that today's students are so much better at computation than estimation, Hill contends. "Estimation is a valuable basic skill that should be easier than computation." Also disturbing, Hill finds, national-assessment data indicate "a tendency of students to guess if they encounter a problem for which they have no learned formula or algorithm. They are led astray by extraneous information and fail

often to be able to decide what information they need to solve a problem." Even those who demonstrate a knowledge of concepts and who possess a firm grasp of symbol manipulation "often seem unable to see a relationship between the two," Hill observes. "Thus they do not apply the rules they know with any understanding." One might compare it to a student who fully understands the rules of grammar, but is unable to string his or her sentences together into meaningful paragraphs.

Hill reads two major messages from the national-assessment data: that "our mathematics curriculum is becoming obsolete," and that schools should attack "fundamental problems, not just the ones that are easiest to teach." In explaining the latter, Hill notes that several math teachers who have studied under her complain their administrators have handed them ultimatums: Get the average class scores up on standardized tests, or else. As a result, Hill says, these teachers feel compelled to drill students far more than might be warranted on those types of skills that will appear on tests—frequently to the exclusion of more difficult-to-teach and difficult-to-measure problem-solving techniques. For many parents and school administrators, Hill contends, "success has become synonymous with test scores," especially from "those standardized tests in which you can do quite well with the lower-level cognitive skills." Unfortunately, she says, those skills that are easiest to teach and to test are probably not the ones most important for successfully dealing with situations in the real world.

Science and Mathematics in the Schools, a report published last year by the National Academy of Sciences, notes that effects measurable today result from a 20-year erosion of mathematics and science education. The report points out, for example, that the mean score in mathematics of students taking the Scholastic Aptitude Test—perhaps the best known of college-entrance exams—declined from 502 in 1963 to 466 in 1980. "Even the proportion of students scoring above 700 ... on the SAT mathematics test [where a perfect score is 800] declined 15 percent between 1967 and 1975," the report says. "Over the same interval, students scoring below 300 on that test increased 38 percent."

Courtesy of The Franklin Institute Science Museum

With ellipse generator, child learns math-related shapes can be made mechanically.

The NAS report contends that lowered requirements for high-school graduation and for college entrance, and increased stress on grade-point averages, have contributed to declining enrollments in mathematics and other courses perceived as being difficult. In fact, it termed "dismayingly low" total high-school enrollment in advanced math.

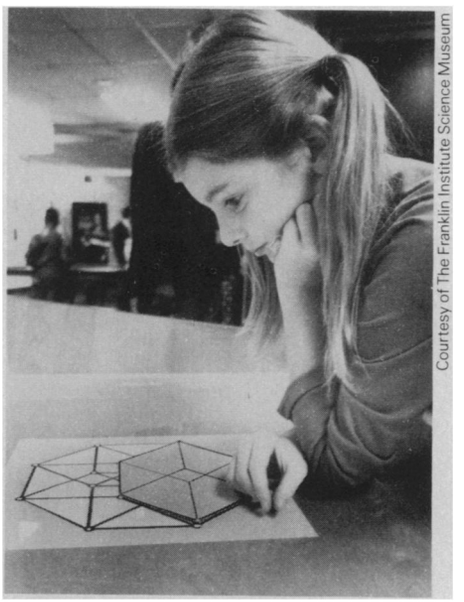
As a result of the "liberalization"—that is, reduction—of requirements for high-school graduation instituted about 15 years ago, only a third of the nation's school districts now require more than a year of math and science. And in fact, only a third of today's high-school graduates have completed three years of math; fewer than eight percent have taken calculus. This trend toward declining math enrollments is presenting a problem for college educators, who find students increasingly unprepared for the numerical rigors of today's standard undergraduate curricula.

To cope, the NAS report says, public four-year colleges were forced to increase by 72 percent between 1975 and 1980 the number of remedial math courses offered; these courses now account for a quarter of all math courses they offer. At two-year colleges, 42 percent of the math courses are remedial.

Part of the reason for the decline in performance measured among high-school students over the past two decades may stem from decreased motivation, educators now concede. And part of the motivational problem may result from teachers who are themselves less enthusiastic.

There is a serious shortage of qualified mathematics teachers: as of 1981, 43 states reported being handicapped by this shortage. The problem has several sources, beginning with a 77 percent decline nationally in the number of mathematics teachers trained during the 1970s. Exacerbating this shortage has been a flight by existing teachers from the classroom into higher-paying jobs in business and industry.

According to Betty M. Vetter, executive director of the Washington-based Scientific Manpower Commission, "almost five times more science and math teachers left teaching last year for employment in non-teaching jobs than left due to retirement." Speaking at a National Institute of Education conference on Feb. 9 of this year, she added that if the present exodus of math teachers from the nation's high schools continues at the current rate of four percent annually, within 10 years the existing shortage will be aggravated by the net loss of another 35 percent.



Courtesy of The Franklin Institute Science Museum

Girl plays with her drawing of cube (projection of a 3-dimensional shape) to find the 8 cubes in the drawing of hypercube (projection of a 4-dimensional shape).

At least as worrisome is the cadre of educators being brought in to replace those departing. A December 1981 survey by the National Science Teachers Association found that 50.2 percent of the science and math teachers hired that year were unqualified to teach either field. The randomly sampled 2,000 secondary-school principals who had been polled justified the "emergency" hiring of these individuals (to teach in fields outside those for which they had been certified) by saying there was a lack of qualified applicants. Though it has not been formally established, educators suspect "out-of-field" teachers may lack the enthusiasm and skill to make so potentially abstract a subject as math both accessible and relevant to today's youth.

The situation is worst in Pacific states

where 84 percent of the math teachers have only emergency certificates. In North Carolina — slightly less handicapped than is the norm for South Atlantic states — 55 percent of the state's math teachers are certified. But Vetter notes that 21 percent of the remaining uncertified instructors taught a full course load of math, even though many had only been certified in social studies, physical education, grammar or business. Vetter adds that the emergency shortage of teachers affecting 17 of New Jersey's 21 counties has forced the state to authorize their use of unlicensed teachers — some without a bachelor's degree — to teach math.

As if this weren't disturbing enough, Vetter points out that data collected in two 1980 studies of high-school graduates planning to enter college (which included examination of cognitive-test scores) showed that "students planning to major in education had lower scores than other college aspirants on reading, vocabulary and math tests; their grade point averages were lower than those of students planning other majors; and the number of math and science courses taken in high school was less for education majors than for others, as was the proportion of courses taken that were in academic subjects."

This shortfall of trained math teachers does not bode well for prospects of increasing the number of math courses a school offers, nor for increasing the number of math courses required for graduation; both currently are being advocated by the National Council of Teachers of Mathematics.

Americans should feel no sense of complacency on this issue, according to North Carolina's governor, James B. Hunt Jr., chairman of the Education Commission of the States (a body of governors, legislators and education policymakers representing 48 member states and four member territories). He says that math training in the United States already trails substantially that of high-school graduates in many countries that compete economically with the United States. For example, he says, "Our studies indicate that Japanese children wind up the 12th grade with four years more time on subject — the equivalent of four more years of school — than our children have."

NAS data support that claim. In four countries it studied — Japan, Russia, China and West Germany — the average school year is 240 days long. By contrast, the U.S. school year is typically scheduled for 180 days, and actually runs closer to 160 days because of absences. While foreign students spend eight hours a day in classes five and a half to six days a week, here children attend school only four to five hours a day, five days a week. And because foreign students have shorter vacations, more dispersed through the school year, disruptions in their education tend to be minimized. In the United States a three-month break separates academic years.

At least as important, NAS data indicate specialized study in the four countries begins in sixth grade, with separate courses in math, biology, chemistry, physics and geography. Notes the NAS report issued last year, "These courses last from four to six years and are required of all students. The time spent on these subjects, based on class hours, is approximately three times that spent by even the most science-oriented students in the United States — those who elect four years of science and mathematics in secondary school."

Perhaps more important than the problems posed by out-of-field teachers and time spent on subject, Hill feels, are today's outmoded curricula. "In elementary schools, for example, 87 percent of the instructional time is devoted to purely manipulative kinds of things," Hill explains. Since youngsters are good at manipulating symbols, why not move these students right into algebra, she asks. At the same time, however, students must be taught applications: "As one learns a skill," she says, "one should be taught to apply it."

Similarly, she says, "I would never say youngsters should not learn to divide." From a practical standpoint, however, learning what division means and when it is appropriate to use division is at least as important as knowing how to do it, she says. And doing three-digit divisor problems with paper and pencil is unquestionably no longer "a good use of precious instructional time," she finds.

Andrew Gleason, a Harvard University mathematics professor, tends to agree. At an NAS convocation last year on the state of precollege mathematics and science, he pointed out that "as I speak, there are probably 100,000 fifth-grade children learning to do long-division problems. In that 100,000, you will find few who are not aware that for $10 they can buy a calculator which can do problems better than they ... faster, more accurately, than any human being can expect to...." As a result, Gleason believes, "It is an insult to children's intelligence to tell them they should be spending their time doing this."

New technologies such as the calculator and computer transfer "technical problems of computation to the mechanical domain," he says, and instruction should capitalize on this. The advent of such tools makes "possible something we should have been doing all along, but is imperative now," he says: "to teach *when* to multiply, not *how* to multiply."

Hill also sees a need for greater stress on "handling quantitative data intelligently" via the skills normally encountered in classes on statistics, probability and quantitative analysis. Those not going to college would benefit especially, she feels, from curricula promoting statistics, computer science and pragmatic problem solving.

Finally, Hill would like to see the "If ... then ..." reasoning traditionally taught in secondary school presented earlier. There's no reason that logic, an important foundation for solving problems, shouldn't be introduced at the same time children are first learning to manipulate symbols, she says. And doing so might make tackling other real-life riddles easier.

"I have followed with great interest the Japanese project to develop the Fifth Generation computer, an interim step toward artificially intelligent 'thinking' systems," Hill says. "These computers ... will be based on logical relationships and sequences of logical inferences, rather than on arithmetic operations. What an irony! At the very time we appear to be on the threshold of 'teaching machines to reason,' we are spending the better part of our educational energies teaching our children mechanistic skills."

The real obstacle to revamping curricula today is financing. Robert Bowen, a marketing vice president with McGraw-Hill, a major textbook publisher, portrayed the problem to last year's NAS convocation this way: "[E]xpenditures for textbooks have declined as a percentage of the total spent on education by 50 percent since 1965, while the educational budget has risen at an astronomical rate. Less than one cent of each educational dollar is spent for textbooks and other instructional material despite the fact that 95 percent of academic time is spent with instructional material."

It was to address the kinds of problems seen plaguing math (and also science) education that the Education Commission of the States established its Task Force on Education and Economic Growth last year. It has impaneled 41 national leaders, including governors, legislators, heads of major corporations (among them, those at Xerox Corp., IBM Corp., RCA Corp., Texas Instruments, Control Data Corp., and Dow Chemical Co.), together with representatives of labor, media and the scientific community. Its primary aim, according to ECS chairman Gov. James Hunt Jr., is to develop strategies "for improving the quality of high-school graduates."

Traditionally, business and industry have worked largely with colleges — endowing chairs, providing professors, funding research centers. "I want to see the time when we have endowed chairs in the public schools," Hunt says, and comparable private investments throughout precollege education.

"As we look at our nation's mathematics report card" — epitomized by the latest national mathematics assessment — "we must keep in mind that the performance of our nation's students has major implications for our future," observes NAEP director Beverly Anderson. Increased public demand for higher academic standards may account for gains seen in this last assessment, she believes. "If this is so," she says, "then it is time for us to mobilize public opinion to deal with the report card's 'minuses.'" □