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ABSTRACT

This document examines various topics and issues related to the quality of science and mathematics education in the United States. They include: (1) competition from Japan and the Soviet Union; (2) federal programs and legislation designed to improve the quality of science and mathematics education; (3) scientific literacy; (4) the basics in mathematics education, outlining those recommended in the National Council of Teachers of Mathematics report, "An Agenda for Action" and discussing the importance of problem-solving skills and real-world mathematical applications; (5) science and pseudoscience, examining the scientific method and the Creationist threat; (6) National Assessment of Educational Progress science and mathematics achievement data; (7) exemplary mathematics programs and the criteria for excellence in these programs (including the development of thinking skills); (8) exemplary science programs; (9) science and mathematics teacher shortage; and (10) the restructuring of American values and attitudes toward learning for science and mathematics. (JN)

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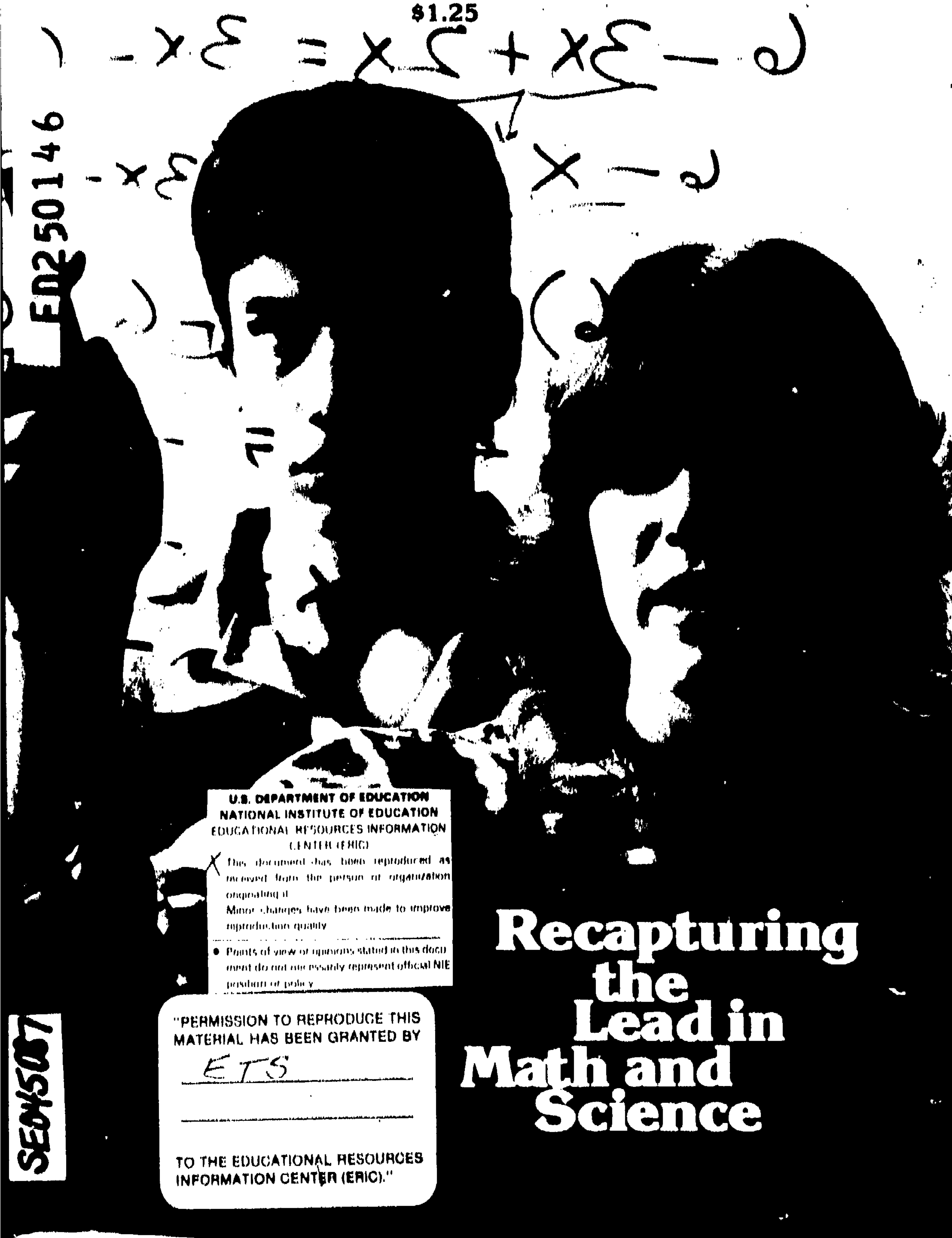

Recapturing the Lead in Math and Science

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Each issue of FOCUS discusses a critical problem in education and the work Educational Testing Service and others are doing to cope with it. Most widely known for standardized tests, ETS is also one of the nation's largest nonprofit educational research organizations.

RECAPTURING THE LEAD IN MATH AND SCIENCE

by Albert Benderson

Design by Joseph L. Belica
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Recapturing the Lead in Math and Science

The nation's confidence in its technological prowess has fluctuated wildly during the last three decades. When the Soviets launched Sputnik I in 1957, spasms of self-doubt shook the national ego, and emergency federal funds were allocated to bolster education in science and mathematics.

Twelve years later, Americans were walking on the moon, fulfilling President Kennedy's pledge to beat the Russians there. Perhaps it is no accident that, with national self-confidence in our technology restored, the sense of urgency surrounding science and math education began to abate. Throughout the '70s, National Science Foundation support for education dropped precipitously and student performance in science and math, as measured by the National Assessment of Educational Progress, declined steadily, even while we were enjoying some of our most spectacular technological triumphs.

Shortly thereafter, however, the growing awareness that other nations, particularly Japan, were edging us out in the world marketplace began to sap our self-confidence. Particularly galling was the fact that the Japanese were outdoing us in the manufacture of high tech products that we had viewed as American monopolies.

Experts began to suggest that an inadequate system of math and science education was at the root of our inability to compete effectively. In 1983, the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology released a report, *Educating Americans for the 21st Century*, that was designed to alert the American public to the consequences of inferior math and science education. The report emphasized the superiority of Japanese science and math education and pointed out that Japan is committed to educating all its students in science and math, as opposed to the United States, where only the college-bound take demanding science courses.

"Japan, like America," the report says, "pursues the goal of universal education. The top students in both nations score equally well in mathematics and science achievement tests. But the remaining 90 percent of Japanese pupils do far better than their American counterparts. The variation in mathematics and science achievement scores among Japanese students in the same grade is said to be relatively narrow. For American students, the variation at the same grade level is much wider.

"The results strongly suggest that Japan is doing much better than the United States in realizing the goal of having *all* students learn science and mathematics. This is ironic, since the Japanese school system, reconstructed in 1945, was closely modeled on our own."

University of Chicago professor Herbert J. Walberg, in his Spring 1983 *Daedalus* article, "Scientific Literacy and Economic Productivity in International Perspective," suggests that Japan's emphasis on quality science and mathematics education for the masses has enabled it to outproduce nations that require only the best students to do extensive work in these fields.

"Although scientific and engineering breakthroughs occasionally raise productivity dramatically," he writes, "progress comes mainly from adaptation of scientific and technological ideas, some of them quite old; small, incremental improvements in services, manufacturing processes, and materials; redesign or substitution of activities, components, and products; reductions in costs; steady advances in performance, quality, style, and consumer appeals; and intelligent attention to details by the work force. To discover, plan, implement, and measure the results of such changes in traditional or high technology requires manufacturing, service, and sales forces that are knowledgeable and motivated; it requires not necessarily superior scientists, engineers, and managers, but educated workers who are skilled with materials, technology, and quantitative data; who can absorb and propagate applied science, and who can communicate and cooperate with one another for the individual as well as the corporate and national good."

Walberg predicts that if present trends continue, Japan's per-capita income will be twice that of the United States within a decade or two.

"What accounts for the great disparities in performance?" asks the National Science Board Commission. "Two key answers are *time-on-task* and *motivation*. Japanese students attend school 220 days a year. American students go to school 180 days a year (and are absent more often than the Japanese). During the school day, Japanese children spend two-thirds or more of their time on academic subjects. Over 12 years of schooling, they average 26 percent of their time on mathematics and science. Their American counterparts spend far less time on these subjects from the first grade on. For example, in the primary grades, U.S. students spend less than 20 minutes a day on science. In terms of class hours, a typical Japanese secondary school graduate will spend three times the number of hours in science than even those U.S. students who elect four years of science in high school.

"The premise in Japan is that all children can and must do well in mathematics, science, and other academic areas. This expectation of excellence stands in sharp contrast to what is demanded from students and teachers in many American schools."

The Soviet Challenge

Other critics have drawn similar comparisons between American and Soviet education. Izaak Wirszup, professor of mathematics at The University of Chicago, writes in his February 1981 *Educational Leadership* article, "The Soviet Challenge," "For the 98 percent of the school-age population that now completes secondary school or its equivalent [compared to 75 percent in the United States], the Soviets have introduced science and mathematics curriculums whose content and scope place them far ahead of any other nation, including the United States."

Wirszup contends that Soviet students cover in 10 years the equivalent of 13 years of American mathematics schooling, and are taught more thoroughly and effectively than are American students. The curriculum includes five years of algebra, 10 of geometry, and culminates with two years of calculus. "From grade four on," he points out, "all Soviet children are taught by specially trained mathematics teachers, whose mathematical background is at least equivalent to that of a master's degree program at any U.S. university."

He adds that, in 1978 and 1979, 5,000,000 graduates of Soviet secondary schools studied calculus for two years compared to 105,000 American secondary school students who were reported to have taken only one year of calculus in 1976.

Other experts question the validity of these claims. University of Wisconsin professor of curriculum and instruction Thomas A. Romberg argues, in his response to Wirszup's article in the same issue of *Educational Leadership*, that learning in Soviet schools does not necessarily keep pace with governmental objectives and that Soviet educators in mathematics are concerned about the quality of their programs and are frustrated by a lack of adequate teaching materials and equipment.

"Also, in classrooms I visited," he writes, "it was apparent that neither the teachers nor the students were interested or excited about their mathematics lessons. They covered them perfunctorily. Students seemed to be performing with little understanding."

HELP FROM WASHINGTON?

Whatever the justification for our alarm over international competition, the fact remains that proposals have already been advanced for an infusion of federal funds that will help us to catch up. The National Science Board Commission, in its report, presented a broad range of ambitious proposals, to be financed largely by the federal government, for improving science and math education in the U.S. The commission recommends that the federal government establish and finance "exemplary schools or programs in mathematics, science, and technology in each community throughout the nation to serve as examples and catalysts for upgrading all schools."

The commission envisions a thousand schools at the secondary level and a thousand more at the elementary at a cost to the government of $829 million during the first year.

The commission also recommends that the National Science Foundation (NSF) take the lead in promoting curriculum evaluation and development in science and mathematics. The NSF has announced its acceptance of the commission's goals and is soliciting funding proposals for precollege science and technology education projects. It has offered to support research in teaching, learning, and the development of instructional materials. It will also support programs that provide incentives for teachers and develop their capabilities as well as activities that enhance out-of-school science, mathematics, and technology education.

In March 1983, the House of Representatives approved more than $1 billion in new programs to upgrade math, science, and foreign language education during the next five years. The bill authorized $425 million in 1984 programs, $250 million of which would be distributed by formula to school districts for use in in-service teacher training, course planning, and other activities. Of the $75 million earmarked for postsecondary education, $20 million would be set aside for national teacher scholarships. The rest would go to summer teacher-training institutes, education research, college improvements, and the Minority Institutions Science Improvement Program.

In May 1983, the Senate Labor and Human Resources Committee approved a bill that would authorize an identical $425 million in math and science education expenditures this year. Since then, however, the bill has been tied up in a battle over a desegregation-aid rider, and has not yet been brought to the floor.

Should the conflict be resolved, Senate passage is virtually assured. The bill differs in significant respects from the House version, however, and these differences will have to be hammered out in a joint committee before the measure becomes law. Ron Preston, science advisor to Senator Orrin Hatch (R-Utah), a bill cosponsor, describes the House version as a shotgun approach with some money set aside for almost every purpose as opposed to the Senate version which, he says, focuses on retraining and upgrading math and science teachers in elementary and secondary schools.

THE REAL ISSUE

Stephen R. Graubard, editor of *Daedalus* in his Spring 1983 article, "Nothing to Fear, Much to Do," says that injections of massive federal aid typify the American politician's response to perceived emergencies of any kind, but he suggests that money may not buy genuine education reform. "A characteristic twentieth century intellectual mindset—which Americans have no wish to abandon—is used again, principally to instill fear. We still have time, but not a great deal. We must do something at once. If we fail to act, something terrible will happen. Some version of this argument, it is imagined, is the intellectual fuel that can be depended upon to set the federal engines going again. No other will do.

"So long as these things are believed," he adds, "there is little prospect of the country becoming seriously preoccupied with its more fundamental educational problems: *that scientific knowledge and understanding, by any reasonable standard, is so uncommon among Americans of all ages and races today that it is no exaggeration to speak of mass illiteracy in the sciences.*"

Graubard questions, however, whether this widespread ignorance of science should be considered more damaging to the individual or society than an equivalent ignorance of other subjects, such as English or finance. "Is there indeed conclusive evidence to show that an advanced industrial (or postindustrial) society requires great numbers of men and women educated in the sciences? Is this America's great intellectual lack? Are comparable insufficiencies in the education of children and adults in humanistic or social scientific subjects less damaging? Has it been demonstrated, for example, that work efficiency is tied to scientific capability, that scientific illiteracy seriously impedes the careers of significant numbers of men and women, and that the economy of the nation is hampered by these conditions?"

He suggests that when international competition becomes the prime motive for education reform, it reflects the same materialistic values that have undermined American education from the start. Americans tend to value education only in relation to success, and in our society this relationship is often tenuous:

"While some say that there is a good deal of cynicism in the country, and much 'back turning,' a more convincing argument might be that 'success' remains the country's only stable currency, achieved in some fields as much through 'conning,' through personality, pulchritude, and connections, as through intelligence, training, and education; and that in a society where so many find places at the top, where so few show evidences of clearly superior talent, where the avenues to success are so various, where second, third, and fourth chances are so common, and where money is so frequently the principal measure of achievement, education, in the more traditional sense of the term, is thought to have only limited utility."

Science education, therefore, is treated as if it is necessary only for those who plan careers in related fields, and instruction is designed accordingly. Most students learn the rudiments of science but are generally permitted to evade it through "softer" options. Scientific illiteracy, Graubard argues, along with illiteracy in other fields, exists because America's schools and colleges permit it to exist.

MATH—WHAT'S REALLY BASIC?

This pervasive materialism was reflected in the "back-to-basics" movement of the '70s, which emphasized drill on computational skills that would result in rapid improvement in test scores, rather than upgrading thinking skills with broader application.

Stephen S. Willoughby, president of the National Council of Teachers of Mathematics, says, "On the basis of evidence being accumulated, it seems that Japan is putting more emphasis on teaching thinking in mathematics than has been the case in the past, while America, with the back-to-basics movement, has been deemphasizing thinking in favor of inappropriate skills. The back-to-basics movement has been a very strong and disastrous influence in mathematics education. It uses the psychology of the 1920s to teach the thought content of the 1930s to children who will have to live in the 1990s and past 2000. This has to have a bad effect, and the leaders in the field of mathematics do not approve."

To counter this regressive trend, the National Council of Teachers of Mathematics, in 1980, published *An Agenda for Action* calling for a revision of the mathematics curriculum emphasizing skills truly relevant to the intellectual demands of the twenty-first century. The council recommended that:

- problem solving be the focus of school mathematics in the 1980s;
- basic skills in mathematics be defined to encompass more than computational ability;
- mathematics programs take full advantage of the power of calculators and computers at all grade levels;
- more mathematics study be required for all students and a flexible curriculum with a greater range of options be designed to accommodate the diverse needs of the student population;
- public support for mathematics instruction be raised to a level commensurate with the importance of mathematical understanding to individuals and society.

"It is dangerous," the agenda says, "to assume that skills from one era will suffice for another. Skills are tools. Their importance rests in the needs of the times. Skills once considered essential become obsolete, and this is likely to increase in pace and scope as advances in technology revolutionize our individual, social, and economic lives. Necessary new skills arise from the dimensions of the mathematics pertinent to an age of population explosion, space exploration, economic and fiscal complexity, and microelectronic wonders. Time and space for including these new skills in the curriculum must be purchased by eliminating the obsolete."

"Common sense," it adds, "should dictate a reasonable balance among mental facility with simple computations, paper-and-pencil algorithms for simple problems done easily and rapidly, and the use of a calculator for more complex problems or those where problem analysis is the goal and cumbersome calculating is a limiting distraction."

Problem Solving

Willoughby explains the necessity for switching to a problem-solving orientation. "While knowing facts and algorithms is understandably useful in conjunction with thinking and problem solving, computation was *never* basic to mathematics; and the wide availability of calculators and computers makes it less basic today than ever. The important, human parts of mathematics are the original abstraction of relevant features from a situation, the decision of what mathematics to apply to this material, and the interpretation of the results. The actual computation can be done by cheap calculators or computers."

ETS test developer Ann F. McAloon points out that mathematics is more complex than just being able to add, subtract, multiply, and divide. One of the skills in mathematics is to select as well as to apply the proper computational mode to solve problems. "The objective of mathematics is to go beyond computation. Otherwise, it is like setting out to build a house and only laying the foundation. All mathematics should teach you to think logically. The virtue of problem solving is that it requires you to think."

ETS test developer James S. Braswell sees the problem-solving approach as a way to interest more students in mathematics by cutting down on tedious computations, such as long division, that can be done more swiftly and accurately by a calculator. "I think teachers need to find ways to get students to do more nontrivial homework. A lot of homework is busy work. Even if the students do it, they haven't accomplished much."

Braswell says that not enough is being done in the schools to develop true problem-solving skills that will enable students to handle conceptual problems with more than one step. He cautions, however, that it is difficult to get a consensus on what kinds of problems should be solved by students or on what kinds of problems are most meaningful.

"The emphasis in mathematics today is on developing problem-solving skills, and the fly in the ointment is to come up with meaningful problems that foster these skills," he says. "There are all sorts of problems, but few are meaningful in the sense that they have some practical real-world value. Perhaps the best we can do is to search for realistic problems in as many areas as possible. When such problems cannot be found, it will still be necessary to use artificial or abstract exercises to develop the desired skills.

"The hope is that problem-solving skills can be generalized to other areas, such as physics or chemistry," he says, "but very little research has been done on what generalizes and what doesn't. In writing computer programs, for example, we like to think that designing algorithms to solve problems will carry over to other areas, but we don't know how much transfer really takes place."

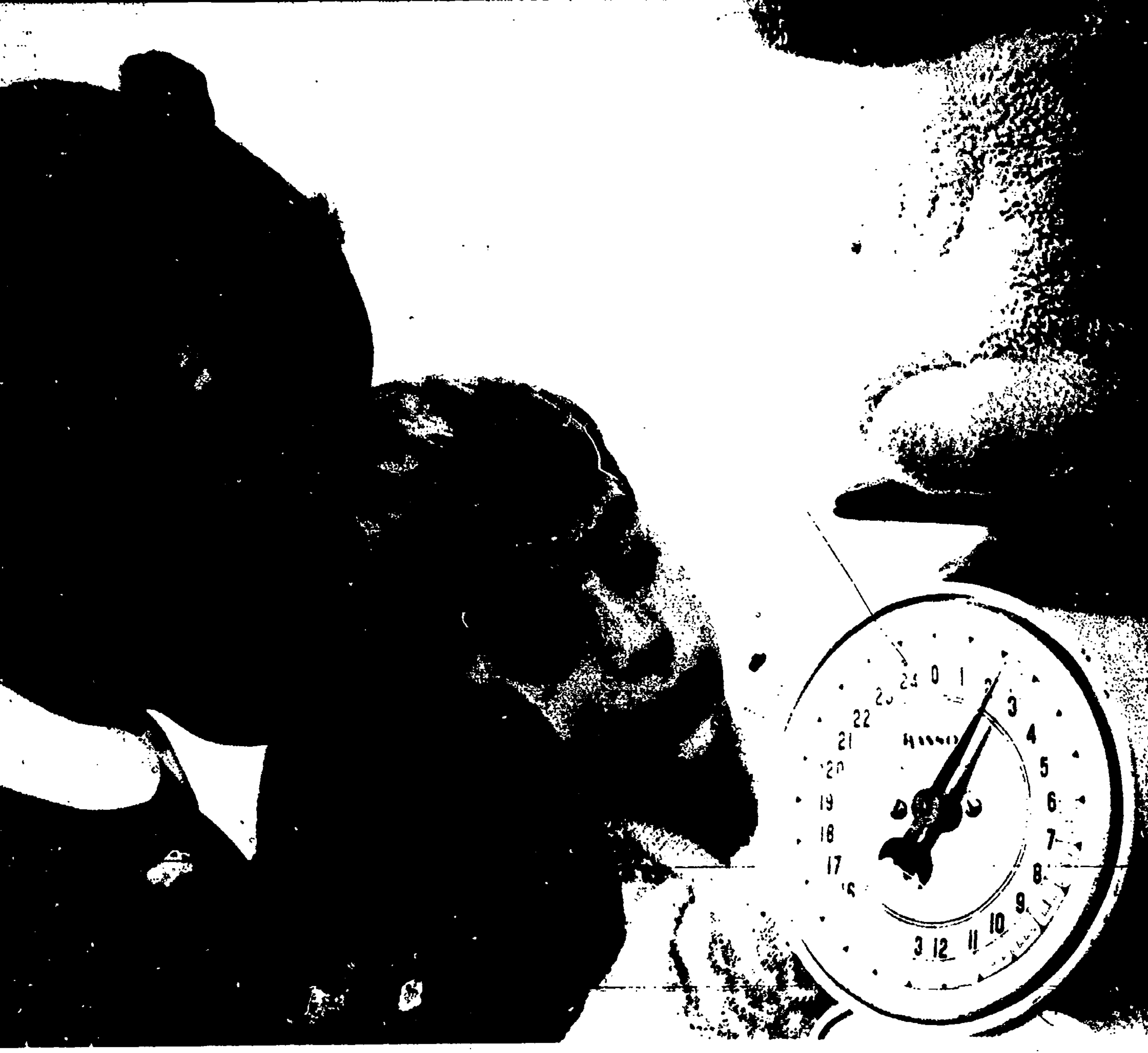
Real-World Applications

Willoughby agrees that the problems to be solved should be realistic and denounces most textbook problems as "grossly unrealistic." They give students the impression, he suggests, that one studies math to become a teacher but not for application in real-life situations.

He also points out that, when word problems appear in mathematics textbooks, they usually don't require much thinking. Frequently, 20 problems, all requiring the same mathematical operation, will all be listed on the same page. Cues and key words will be provided as clues. Children quickly catch on, he says, to the fact that, once they figure out how to solve the first problem, they can solve them all.

Willoughby, therefore, favors texts that place many different kinds of problems on the same page without familiar key words, such as "more than," "less than," or "how many were left." "The kind of word problems I'd like to see are those that the student has to think about in order to decide what kind of mathematics are needed to find the solution."

He by no means advocates that traditional arithmetic be dispensed with entirely in favor of problem-solving exercises. "There are certain parts of traditional arithmetic that are as important or even more important than before," he says. "Adding and the times table should be automatic by the time students are 10 or 11, so they can use these facts to



do other things like estimation or mental arithmetic.

"Long division, however, is an algorithm you don't use much in life. Almost anyone who does it uses a calculator. I don't object to teaching kids long division as long as you don't spend time teaching them to be good—they will never be as good as a $5 calculator. It is better for them to spend their time thinking.

"In the higher grades it is important to know what a square root is. Once you have done that, any idiot can find one with a calculator."

Estimation skills, he and other experts suggest, should be emphasized more in the curriculum so that students will be able to discern whether the answers they obtain on their calculators are reasonable or whether they have made an error in entering data.

Willoughby would also teach decimals in first or second grade, because an understanding of decimals is fundamental when using a calculator. He adds that the relationship between decimals and fractions should be mastered by fifth or sixth grade.

"We have limited time to work with when children are in school," he says. "We must use it to teach them to do the things that calculators cannot do better. The leaders of the future will be those who can do the thinking that computers can't do better.

"This doesn't mean that students shouldn't do long division at all. They should be able to think about it. Nevertheless, a student who knows how to multiply larger numbers or do long division, but does not know when to do it, is, frankly, of no value to society.

"Thinking is the ultimate skill in

mathematics. Without the ability and desire to think, a student who has all the other skills is unlikely to be successful in problem solving."

SCIENCE VS. PSEUDOSCIENCE

The need to train people in thinking skills is equally apparent in the sciences. Graubard speaks of "mass illiteracy" in the sciences as being the fundamental educational problem in the field. Widespread ignorance of scientific thinking has direct consequences for the lives of many Americans that are far more fundamental and damaging than any momentary trade loss to the Japanese.

Some assert that scientific illiteracy is reflected in the proliferation of pseudoscience throughout our culture. Entire industries have emerged promoting belief in phenomena—including astrology, UFOs, parapsychology, astral projection, and holistic healing—that have no proven basis in scientific fact.

James Cornell says, in his March 1984 *Psychology Today* article, "Science vs. the Paranormal," that while a casual interest in such things may seem a "benign diversion," experts warn that pseudoscientific beliefs have far-reaching consequences.

"One consequence is economic," he writes. "Millions of dollars are spent on casting horoscopes, purchasing fad foods and pursuing dubious diets and vitamin regimens. Parapsychology also exists at the expense of serious science: Gresham's law applies to paranormal beliefs, so that bad science, such as creationism or astral projection, drives out good science—or at least muddies it in the public mind.

"Even more dangerous, some paranormal beliefs, especially those involving personal health, can lead to real physical and psychological dangers. As William Jarvis of the California Council Against Health Fraud points out, the psychological damage of quacks and faith healers can be 'the promotion of dependency behavior and the weakening of one's self-image. . . . In fact, the cumulative psychological effects of these beliefs can be lethal,' Jarvis says."

The Scientific Method

Paul Kurtz, a philosophy professor at the State University of New York at Buffalo, heads the Committee for the Scientific Investigation of Claims of the Paranormal (CSICOP), an organization created to counter what he views as a rising tide of irrational beliefs more appropriate to the middle ages than to the twentieth century. Kurtz views an understanding of the scientific method as fundamental to scientific literacy.

"Science," he says, "is a process of investigation. You formulate a hypothesis and test it by experiment. The knowledge obtained is always tentative, but if you can't form a hypothesis to explain the evidence, you have to suspend judgment. The scientist has to be skeptical."

Kurtz finds that even some science majors fail to grasp the essence of the scientific method and believe in all sorts of untestable hypotheses outside their fields. He points out that chemists can be found who literally believe in biblical creation as opposed to Darwinian evolution.

"It bothers me," says Kurtz, "that a student can be competent in engineering or chemistry and yet not competent in the scientific method. You can be trained in a scientific field and look at it as a body of knowledge but miss the sense of it as an enterprise.

"Science is a method of investigation, but they look at it as a body of tested results. They look at it as a product. Once they regard science as the absolute truth, the skeptical approach is lost."

Douglas F. Stalker is an associate professor of philosophy at the University of Delaware who lectures against the pseudosciences as "Captain Ray of Light." He says that people believe in pseudosciences chiefly because "they can't think real well. They are all thumbs when it comes to reasoning. A lot of these people can't tell a good argument from a bad one."

As examples, he cites those who argue for astrology because famous thinkers, such as Galileo, practiced it or those who accept claims of precognitive dreams as proof of parapsychology.

"People ask me," he says, "why I get so angry. So what if they believe in astrology? I take it as a symptom of intellectual disease in the populace. I feel like a pathologist studying diseased minds."

Stalker says that the inability to reason clearly according to scientific methodology can be found even among highly educated people such as doctors. In the April 1983 *New England Journal of Medicine* article, "Engineers, Cranks, Physicians, and Magicians," he writes about doctors who have introduced into their practices, both at the office and in hospitals, elements of holistic medicine, which he describes as a "collection of bizarre therapies," such as psychic healing.

"The level of argument in holistic medicine is a joke," he says, "but many people who practice it have M.D.s. You'd think that quality control in medicine would produce people who would not think in ways embarrassing to a college freshman, but there are M.D.s in the field who do not know how to validate medical theories. They have learned by rote but are methodologically naive."

"The sciences should teach logic, causal logic, and the experimental method," he argues. "Reasoning should be taught, like grammar or the multiplication tables, to everyone, not just to science students."

The Creationist Threat

In the past few years, the widespread ignorance of scientific thinking has enabled those who believe only in the biblical version of creation to undermine the teaching of biology in the United States. Appropriating the mantle of science by calling themselves supporters of "scientific creationism," they denounce Darwinian evolution as "only a theory" and argue for ideas such as the simultaneous creation of all living creatures as recently as 20,000 years ago. They have succeeded, through political pressure, in convincing some publishers to eliminate or dilute discussions of evolution in biology textbooks. They have also convinced legislators in Arkansas and Louisiana to pass laws mandating the teaching of creationism alongside evolution in the public schools.

Harvey Siegel, in his October 1981 *Phi Delta Kappan* article, "Creationism, Evolution, and Education," distinguishes science from creationism. "Science is, first and foremost, nondogmatic; it is open to evidential support and falsification. Scientific hypotheses can be confirmed or disconfirmed by evidence. A bona fide scientific hypothesis must yield testable implications or predictions, and it must be possible to check whether these implications are correct. It must also be possible for a scientific hypothesis to fail the test, and it must be possible that the implications or predictions may *not* turn out as the hypothesis predicted. When it is possible for the hypothesis to fail the test, it is a *falsifiable* hypothesis. All legitimate scientific hypotheses are falsifiable. Scientific hypotheses also have *predictive power* and *explanatory power*. The testable predictions they produce can explain relevant phenomena. Finally, scientific hypotheses are *tentative* and *self-correcting*. Thus scientific hypotheses are never final—they are always open to future refutation in light of future evidence."

According to the scientific method, then, statements such as "God created the universe" are matters of belief rather than of science, as are assertions of the existence of little green men in flying saucers, astrological influences upon our fate, and spirit worlds inhabited by the souls of the dead.

This distinction between science and belief was upheld by U.S. District Court Judge William R. Overton on January 5, 1982, when he struck down Alabama's law mandating the teaching of creationism in the schools. In his decision Judge Overton, in reference to creationism, wrote, "Such a concept is not a science because it depends upon a supernatural intervention which is not guided by natural law. It is not explanatory by reference to natural law, is not testable, and is not falsifiable."

On November 22, 1982, the Louisiana creation-science law was struck down on a technicality stemming from the state constitution.

Carl Sagan argues, in *Broca's Brain*, that the schools, in failing to provide people with an understanding of what constitutes science, have fundamentally cheated them. "There is a vast untapped popular interest in the deepest scientific questions. For many people, the shoddily thought out doctrines of borderline science are the closest approximation to comprehensible science readily available. The popularity of borderline science is a rebuke to the schools, the press, and commercial television for their sparse, unimaginative, and ineffective efforts at scientific education; and to us scientists, for doing so little to publicize our subject."

"In my opinion," he adds, "the claims of borderline science pall in comparison with hundreds of recent activities and discoveries in real science, including the existence of two semi-independent brains within the human skull; the reality of black holes; continental drift and collisions; chimpanzee language; massive climactic changes on Mars and Venus; the antiquity of the human species; the search for extraterrestrial life; the elegant self-copying molecular architecture

that controls our heredity and evolution; and observational evidence on the origin, nature, and fate of the universe as a whole."

THE NATIONAL REPORT CARD

Despite a manifest need for teaching thinking skills in both science and math, however, there is little indication that much progress is being made. Willoughby, for instance, is not optimistic about the pace of reform in mathematics. "A lot of people say they want change," he says, "but when the chips are down, we don't see much change. Things are not changing as fast as they should if we are going to turn out people who can solve the problems of the future."

Willoughby's pessimism is supported by the results of the third National Assessment of Educational Progress (NAEP) survey of mathematics achievement, released in April 1983. It reflected the influence of the back-to-basics movement in improved computational performance coupled with disappointing scores in areas requiring problem-solving skills.

The survey, conducted previously in 1973 and 1978, measures performance by 9-, 13-, and 17-year-olds. In their report, *The Third National Mathematics Assessments: Results, Trends, and Issues*, the researchers conclude, "Nine-year-olds' overall performance was relatively stable over the nine years, neither declining nor improving significantly. Thirteen-year-olds' performance declined about two percentage points between the first two assessments and then improved more than four points between the second and third. Seventeen-year-olds' performance declined about four percentage points between the first and second assessments, and then stayed at about the same level between the second and third."

The NAEP Bulletin, however, urged caution in viewing even the news of some improvement optimistically. While announcing that junior high school students' mathematics skills had improved and that previous declines in the achievement of high school students had leveled off, the *Bulletin* added, "This encouraging news must be tempered with a strong note of caution, however. Progress appears to stem from improvements on more routine skills, such as computing, recognizing geometric figures, and answering simple, one-step story problems."

Nine-year-olds, for instance, showed improvement in whole number subtraction and multiplication facts, and 13-year-olds improved in division facts by 10 points. Performance in geometry, however, was not high—only about half the 13-year-olds and three-fourths of the 17-year-olds could find the area of a square when given its length and width. Although students were fairly successful at solving routine one-step verbal problems of the kind most often found in texts, they had difficulty in solving nonroutine problems requiring more than one computational step. Estimation skills were described in the *Bulletin* as "not well developed."

The *Bulletin's* summary reflected both the gains and losses that have emerged from the back-to-basics drive. "The schools are making good progress in improving lower-level skills, particularly among disadvantaged populations," the panel of mathematics experts agreed. "But the increasing prevalence of calculators and computers may demand a shift in the emphasis of the typical mathematics curriculum. It will become more critical to understand mathematical processes and to estimate whether an answer is in the right ballpark than to strive for 100 percent paper-and-pencil computational accuracy."

"The students who do well in computation are not necessarily those who are good at mathematics," concludes ETS's McAloon, who will be in charge of developing the next NAEP math assessment now that ETS has begun to administer the program. "Computation is the easiest thing to do."

In contrast to the mixed results on the NAEP mathematics assessment, performance on the science assessments has been downright discouraging. A 1982 science survey revealed a continued decline in achievement in and attitudes towards science from assessments conducted in 1970, 1973, and 1977. Science achievement for thirteen-year-olds has dropped about two-and-a-half percent from 1970 to 1982, and science achievement for 17-year-olds plummeted nearly six-and-a-half percent during that period.

Survey director Wayne W. Welch of the University of Minnesota, when reporting his findings to the spring conference of the National Science Teachers Association, said, "The fact that secondary school students—both 13- and 17-year-olds—showed declining interest in science and that high school students continued their achievement decline should be a major concern for policy makers. If people know six percent less than they did 12 years ago, it is a matter of concern.

"I've also been concerned about declining enrollments in science. In 1960-61, 60 percent of the high school students were enrolled in science courses. In 1981-82, the figure was only 46 percent. That's a fairly sharp decline. Declining enrollments undercut instruction because qualified teachers are laid off as classes shrink.

"In the '70s, kids had the attitude that they were just biding time in school. Things may be changing now. Enrollments in the sciences have recently increased; they're up four percent since 1976-77. We have to instill in students a sense of the importance of learning science."

EXEMPLARY PROGRAMS IN MATH

The NAEP findings raise serious questions for the future. Why do students lose interest in math and science in the schools? What distinguishes outstanding programs in math and science from average programs? What can be learned from the best programs?

In mathematics, experts suggest that many students are discouraged by the long hours they spend on repetitive and frequently meaningless drills and exercises. Often, students are also discouraged by parents who talk of the problems they had with mathematics when in school. Girls, in particular, are frequently told that it is not important for them to learn mathematics.

Girls score below boys on nearly every standardized measure of mathematics aptitude and achievement. Experts have offered many explanations—some alleging that girls are conditioned by society to fear mathematics, others that genetic or hormonal differences between women and men account for the difference in performance.

ETS's Patricia L. Casserly, among other researchers, has found that social forces play a stronger role in math achievement than formerly thought. In two major studies she focused on schools that are outstanding in their ability to attract and maintain young women in mathematics, physics, and chemistry programs. In these schools, equal proportions of girls and boys persist in mathematics up through Advanced

Placement (AP) calculus and achieve similarly on the AP calculus exam.

Casserly found that homogeneous grouping of students according to ability in outstanding schools is "critically important" to the success of girls in math because it provides them with a challenging learning environment and a support group. She also found that the math teachers set high goals for girls and make it difficult for them to slide by or drop out. The AP teachers—practicing professionals in mathematics, chemistry, and physics—are excellent agents for recruiting girls to these fields for study and later careers. In these programs, girls are encouraged to keep their college and career options open by taking the full secondary school mathematics sequence.

Criteria for Excellence

Mark Driscoll of the New England Research and Education Exchange is in the second half of a two-year study, funded by the National Institute of Education, of exemplary mathematics programs throughout the United States. The objective of the study is to identify and describe the factors contributing to excellence in precollege mathematics programs.

More than 700 schools responded to advertisements in professional journals seeking information on outstanding math programs. When asked to document the excellence of their programs, 150 complied. A panel of experts chose 28 to visit for further study. Driscoll says that the 28, as well as others that will be studied this year, were all exemplary.

Although the study is not yet complete, Driscoll says that a number of hypotheses have already emerged. Homework, he says, plays an important role in outstanding mathematics programs. "It's used consistently, carefully, and there's a lot of it," he says.

In exemplary programs, he suggests, considerable attention is paid to the needs of the students. Staff members talk to each other regularly about student needs in such areas as placement.

"High expectations for students are characteristic of exemplary programs," he says. "In many cases they are expressed openly in class. There is a supportive environment in the classroom. A lot of respect is shown for students when they take risks and when they make mistakes."

In addition, teachers generally spend a great deal of extra time working with students and preparing materials. The harder the teachers work, the better the results.

In schools with exemplary programs, leadership is very important. Department heads work from early in the morning to late in the evening. The department head attempts to take care of any business that would otherwise be distracting to teachers, in order to create an environment where they can devote themselves to the students.

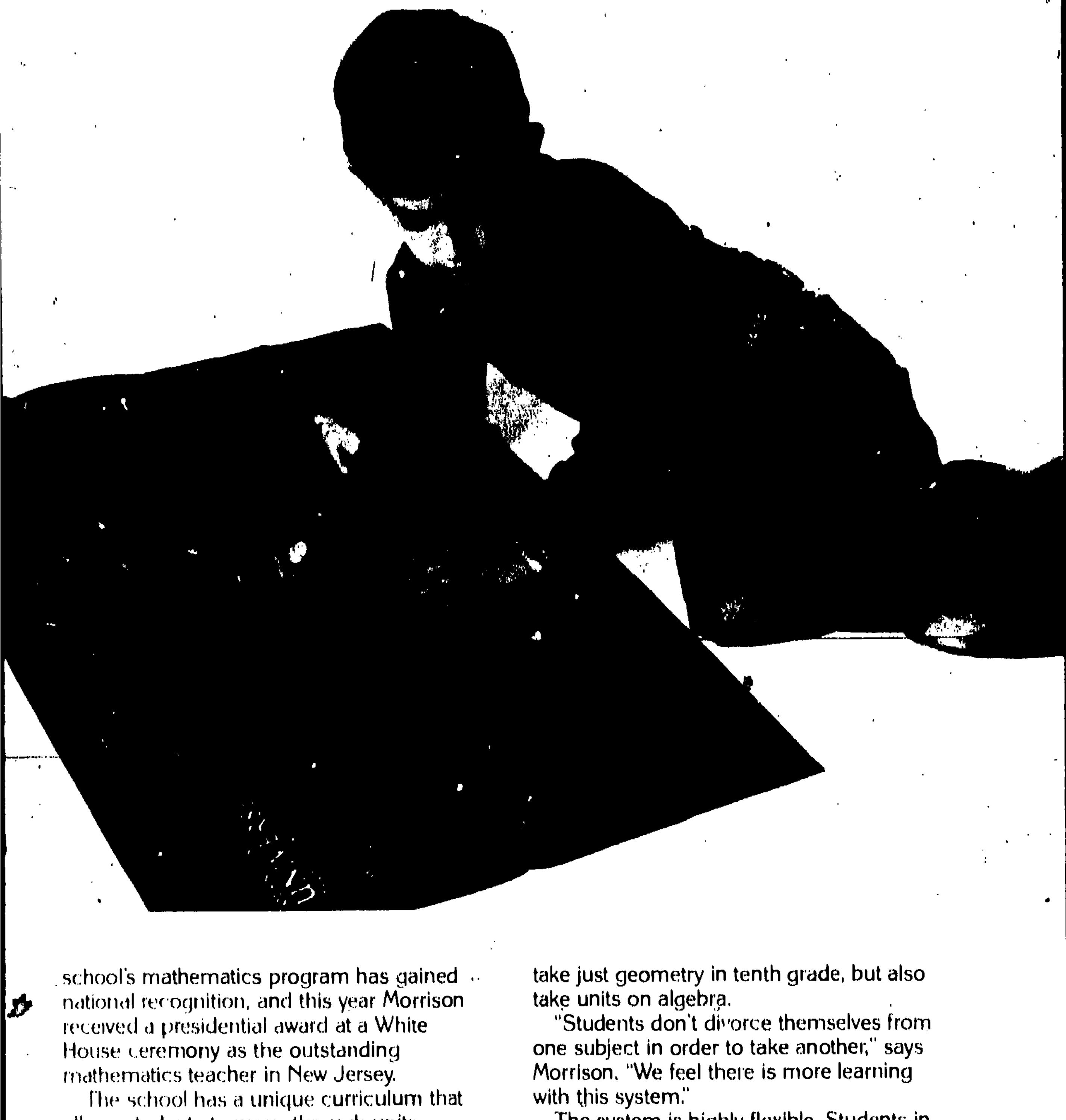
Interestingly, however, Driscoll has so far found no particular methodology common to exemplary programs. Some of the programs are highly innovative, while others use traditional approaches and texts. He points out that problem-solving, of the kind recommended by the National Council of Teachers of Mathematics, is being introduced far more frequently at elementary and junior high schools than at high schools.

Thinking Skills

Whatever the approach, Driscoll says, "In tne most successful classes, students were made to think, mainly because of the teacher in the classroom. Good teachers teach kids math. The best teachers teach kids math and how to learn mathematics. Good problems can help the teacher do that, but in the end it's the teacher who helps foster the growth. The kind and quality of mathematics learned depends on who is teaching the kids."

Conversely, poor teaching can undermine a child's enthusiasm for mathematics for life. "Thinking is the ultimate basic skill in mathematics," says Willoughby. "The willingness to think mathematically is every bit as important as the ability. Without the ability and desire to think, a student who has all the other skills is unlikely to be successful in problem solving. Unfortunately, mathematics instruction has in the past often been so unpleasant that even students who earned straight A's in the subject, and understood it fully, developed such unfavorable attitudes that they resisted using mathematics in their everyday or professional lives."

Mary Dell Morrison, who has taught mathematics for 33 years at Columbia High School in Maplewood, New Jersey, is one of the nation's exemplary teachers. The



school's mathematics program has gained national recognition, and this year Morrison received a presidential award at a White House ceremony as the outstanding mathematics teacher in New Jersey.

The school has a unique curriculum that allows students to move through units, numbered 10 through 99, at their own pace. Slower students might only get to unit 75 by the time they graduate, whereas brighter students might finish unit 99 in their junior year and take calculus when seniors. For those who move through the curriculum quickly, special seminars are also available in subjects such as non-Euclidean geometry. Teaching materials for the units are written by the math department.

The units allow students to mix subjects each year, so that, for instance, they don't take just geometry in tenth grade, but also take units on algebra.

"Students don't divorce themselves from one subject in order to take another," says Morrison. "We feel there is more learning with this system."

The system is highly flexible. Students in slower units can move to more advanced units as their work improves. Units covering the same subject often meet during the same period to facilitate such transfers.

Mathematics is a popular subject at the school. There are 2,100 students at the high school, but 2,400 current enrollments in math courses, because some are taking more than one math course.

"Only one or two years of mathematics are required," says Morrison, "but all the kids take math. It takes hard work on the part of

the teacher to dispel the math phobia some students have."

Morrison says that dedicated and talented teachers are the key to the program's success. She speaks of losing faculty to firms offering higher salaries and work that is more challenging mathematically, and acknowledges that, for many, the temptation to leave teaching is strong.

"It's hard work to motivate low-level kids. We have 24 teachers on our faculty and only eight honors classes. All teachers have at least three slow classes, and if you have a class with discipline problems, it wipes you out. Then there are the extraneous assignments, like hall or cafeteria duty. The teachers who stay are those who love to teach."

EXEMPLARY PROGRAMS IN SCIENCE

The pivotal role of the teacher is also clear in the nation's exemplary science programs. Although one generally finds a greater variety of curricula in top science programs, at the heart of each one are outstanding teachers who communicate their subjects effectively to students.

In 1982, the National Science Teachers of America sponsored a Search for Excellence in Science Education designed to produce case studies that would provide guidance and support for innovative efforts at other schools. During the first year, the project attempted to identify exemplary programs in five areas: elementary science, biology, physical science, science as inquiry, and science/technology/society.

Dr. Robert E. Yager of the University of Iowa, president of the National Science Teachers of America, says that the association was looking for exemplary programs directed towards the needs of all students rather than an elite few who might have a career interest in the field.

"We are stressing science for all people, science for citizenship, science for people to be able to make decisions in a democracy as opposed to science for Harvard-elitism," he says. "This doesn't mean that students with exceptional abilities won't emerge from and benefit from a program. I think that you will get more people fascinated with science if they feel it is important, if they see the need. Kids will really get interested in science rather than just going through a book to get through class."

In part, the association was trying to discover programs that don't turn kids away from science by bombarding them with isolated facts, programs that attempt to retain the interest in science that is often kindled in children by television programs or trips to the museum. The selection criteria also favored programs that related science to societal issues, such as health, consumer behavior, and the environment.

Leading science educators nominated programs in their own states that seemed to meet the criteria. In mid-1982, 165 nominations were forwarded to selection committees that named 50 programs as national exemplars.

In 1983, 30 more schools were added to the list in three categories: physics, science in middle or junior high schools, and science in nonschool settings (museums, zoos, etc.). Complete descriptions of all the exemplary programs are being published in a series of monographs available from the association.

Teachers in exemplary programs are more experienced than the average; the average exemplary teacher is 51 years old as opposed to an average for all science teachers of 41. Seventy-six percent of exemplary teachers hold master's or higher degrees. Nevertheless, they continue to seek education in their fields. Eighty percent have taken a college course within the last four years, as opposed to only 14 percent of all science teachers.

Yager says the preponderance of older teachers reflects their dedication. "These teachers were the ones who had a vision, who did not move out of the schools and go into business but were dedicated to teaching. The teachers who have stuck at it for 20 years, and are good, are the ones who make a difference. It takes time to build a solid program."

The Mesa School District

The exemplary elementary school programs are particularly interesting, because science tends to be slighted in many elementary schools.

The best elementary school programs avoid alienating students by involving them directly in scientific activities. The Mesa, Arizona, school district, for instance, was selected as one of the top 12 districts in elementary school science programming because it emphasizes the use of commercially developed kits and other materials, as opposed to textbooks, to involve students directly in the experience of science.

Susan Sprague, who coordinates science programs in all the district elementary schools, says Mesa was concerned that standardized test scores in science were not good. It was also observed, in comparing results from district elementary schools, that 96 percent of students from one elementary school, in which students worked directly with scientific materials, opted for science in seventh grade, as opposed to only four percent from an elementary school using a textbook approach.

"Junior high teachers," she explains, "said they didn't care what we did as long as we didn't send them kids who hated science. We decided that we had to overcome negative attitudes towards science. In first grade, students are open and excited. In many of our elementary schools, the educational process was turning these kids off, and we have made significant changes in this.

"We have found that students who work directly with science materials get more information than those involved in textbook programs focusing only on information. Since we adopted our new program 10 years ago, scores on the Sequential Test of Educational Progress have gone from the forties to the upper sixties."

Teacher training is a major part of the program, and Sprague has four people on her staff of five who train teachers. She explains that most elementary teachers don't have solid training in the sciences, particularly since they tend to avoid lab sciences in favor of survey courses while in college. Mesa's teachers were retrained to use the new curriculum, and training continues all the time.

The program has proved so successful that Sprague and her staff have worked with seven other area districts to help them develop similar curricula. Working directly with materials, rather than just relying on textbook facts, she suggests, is particularly suited to the intellectual level of the elementary student. "Elementary students are at the concrete level of learning," she says. "Even in sixth grade, they are still at that level. They do better with work that involves them directly. If you don't make use of the intellectual level children are at, you are wasting your time."

The Jefferson County Schools

The Jefferson County, Colorado, Revised Elementary Science Program, covering all 76 elementary schools, also emphasizes a "hands-on" inquiry approach. It too was cited as exemplary.

Cindy Hrebar, the district science resource specialist, explains that the program operates in grades three through six. It uses commercially developed units, as well as those developed by the district, all of which emphasize hands-on experience.

"The crucial aspect," she says, "is that kids don't read about science, they experience science. The teachers help them develop concepts, and they apply them to their personal lives."

The program, introduced in 1977, covers environmental studies, health, physical science, earth science, and astronomy.

Practical experiences include using the district planetarium to become oriented to the night sky. Students are assigned to report on what they can find there. Students also use a light bulb and batteries to create different kinds of circuits, and set-up and observe the results of various experiments.

The district offers two outdoor education lab sites where sixth graders spend one week at the end of their environmental unit. At the outdoor sites, in the front range of the Rockies, they study ecosystems, the behavior of organisms, and astronomy. Each school puts together its own program. Some may emphasize the watershed, while others look at pollution control.

Other disciplines are also emphasized at the outdoor sites. Students study the pioneer history of the area, write essays for their English classes, do sketches and collages for art classes, and write articles for school newspapers.

"One thing we know about elementary students is that they don't learn science by reading about it," says Hrebar. "Students at this stage are oriented towards concrete thinking. They may talk or have rhetoric about science from their reading, but they won't understand or remember it."

Wausau West High School

Unwillingness to rely on conventional textbook materials also seems to characterize the best high school programs. Wausau West High School in Wausau, Wisconsin, was cited for excellence in both science/technology/society and science as inquiry for a program that attempts to develop scientific literacy in all the students.

According to district science coordinator John Harkness, teachers at the school were interested in developing an awareness of the philosophy at the root of scientific activities and wanted to emphasize the interaction between science and society. They could find no adequate text but were able to obtain funds from the state department of instruction that enabled them to develop a curriculum over a three-year period.

The curriculum takes an interdisciplinary approach emphasizing the teaching of science, rather than just biology, chemistry, and physics as separate entities. It is taught through modules based on interdisciplinary themes. Instruction materials, many dealing with science issues in the real world and including newspaper and magazine articles, were created and are taught by teams of teachers.

The program, consisting of 13 units, is a two-year sequence required of all ninth- and tenth-grade students. Afterwards, electives in conventional subjects, such as chemistry and physics, are available.

The module on food is illustrative. "Food is used as a theme to introduce students to the problem-solving skills of science and its social and cultural implications," says Harkness. "We look at land use since we are in a farm-surrounded area. Biology and chemistry are introduced when we look at food processing and preservation. Consumerism is also introduced. Students grapple with real problems, such as which breakfast cereal contains the most protein per serving for the least cost."

There is also a tenth-grade module on scientific inquiry called "UFOs." It addresses the distinction between science and pseudoscience. The class looks at phenomena such as UFOs or psychokinesis and tries to establish criteria for distinguishing scientifically valid evidence from unscientific speculation.

"We found that young people, in most cases, run science and pseudoscience together," says Harkness. "It is one package to them. We try to give them a way to distinguish scientific practices from the non-scientific. Even the top five percent of students can normally go through a rigorous science curriculum and not have this side of scientific literacy.

"What bothered us about science at other schools was that it was designed to accommodate the needs of teachers trained in science but not students. When nonscientists look at the world, they don't see science-related problems as related to science, they just see problems. But the problems people worry about overlap with all sorts of sciences. Our curriculum enables students to understand this relationship."

Harkness says, however, that since the inception of the new curriculum, enrollments in other science courses have increased.

North Toole County High

Another program designated as exemplary is at North Toole County High School, a rural school with only 80 ninth- through twelfth-grade students located in Sunburst, Montana. About 12 years ago Larry Fauque, the school's lone full-time science teacher, began developing an individualized science

program for the school's juniors and seniors. Participants engage in individual research projects. The program has been so successful that the school has recently instituted minicourses in subjects such as botany, zoology, genetics, and microbiology to satisfy student interest in additional science electives.

"It's not just the gifted kids who participate in the independent study program," Fauque says. "We get high ability kids as well as others who want the experience and who enjoy it."

Each year 10 students, juniors or seniors, take the independent study course. Most of the independent projects are in biology, the field in which Fauque is most expert and, therefore, can give the most supervision.

Fauque handles the independent study programs and minicourses while also teaching biology, chemistry, and physical science. The superintendent teaches the school's physics course.

The school has been able to obtain funds, from various levels of government, that have enabled it to provide fairly sophisticated facilities and equipment to support independent study. The program has its own lab as well as an animal-care facility. The school owns a phase microscope, an interferometer, an environmental chamber, a photospectrometer, microphotography equipment, incubators, and drying ovens. Students correspond and consult with scientists and visit hospitals and universities when they need advice or materials.

Fauque says that his program teaches problem-solving methods and develops stick-to-itiveness. He adds that students also develop their English language skills because each participant has to prepare a professional paper with the help of an English teacher.

The school has produced state science fair grand award winners, as well as participants in international science competitions who have either placed or won special awards. One student won the Westinghouse Science Award, which Fauque terms the Nobel prize of high school science, for a study of different species of cells.

North Toole students have also been regional winners in the space shuttle competition in which students design experiments to be taken aloft in the shuttle, and they have delivered papers at the regional science symposium in Salt Lake City.

In assessing the qualities of a topnotch high school science program, Fauque says, "The high school has to establish a good science program as an important goal and realize that it won't happen overnight. It takes support from the entire community, and we have good community support, including the administrators and school board. And enthusiasm from the teacher has to be there or the program will die. The teacher enthusiasm is it."

The North Carolina School of Science and Mathematics

In contrast to these programs designed to involve a broad spectrum of students in science, the State of North Carolina has instituted an ambitious program to enhance the education of its most gifted science students. The North Carolina School of Science and Mathematics, in Durham, is the nation's first residential public high school for gifted students.

Opened in 1980, the school today has a student body of 400, 46 percent of whom are female and 23 to 24 percent from minority groups. The students represent 85 percent of North Carolina's counties.

According to Phyllis Frothingham, the school's head of communications, "The students are not necessarily all super-achievers. We were also looking for the B student who might have built a computer."

Besides providing a superior education, much of it college-level, in all fields as well as science and math, the school is developing curricular methods and materials that will be useful in science classes across the state.

The school also conducts an outreach program that provides staff support to programs in small rural schools through teleconferencing. Many small schools, Frothingham explains, might have biology teachers teaching physics. Through teleconferencing, the rural teacher can now enlist the aid of the school's physics staff, all of whom have Ph.D.s.

Similarly, in many urban school districts, magnet schools specializing in science and math have been established to encourage voluntary desegregation by attracting students of all races desiring a superior education. Northeast High School in Philadelphia, for instance, provides a specialized curriculum in medicine, engineering, and science for 300 students in the magnet program. In addition to conventional courses in biology, chemistry, and physics, the school offers college-level courses in aerospace technology, astronomy, anatomy and physiology, cat anatomy, engineering electronics, and engineering drawing.

The school also has a space wing which houses a space shuttle simulator built by the students and a control room to monitor simulated launches. NASA has provided considerable help, including a videocassette of the earth as seen from the shuttle for use in the simulator and an hour-long teleconference with specialists in the life sciences. Last year, Philadelphia-born astronaut Guy Bluford visited the school and tested the simulator. This year a two-day mock launch is scheduled.

THE BRAIN DRAIN

Given the crucial role that good teachers play in the most outstanding science and mathematics programs, it is particularly dismaying that the supply of qualified science and math teachers throughout the nation is diminishing. Lured by incomparably higher salaries in private industry, more teachers in these fields are abandoning the schools every year. Moreover, very few college students with science and math backgrounds are entering the teaching profession today.

In her May 1983 *Phi Delta Kappan* article, "Responding to the Economic Sputnik," Phyllis Marcuccio, editor of *Science and Children*, places part of the blame for the teacher decline on decreased federal support for science teacher education. She reports that science education's share of the National Science Foundation budget dropped from 47 to two percent from 1959 to 1980-81. Teachers lost crucial in-service training, she reports, and colleges of teacher education lost more of their already shrinking student population.

Based upon the four percent reduction in science and math teachers in the schools between 1980 and 1981, she projects that by 1992 the number of science and math teachers in the country will be reduced by 35 percent. To further dramatize these figures, she cites a survey indicating that, even in 1982, some 32,000 math and science classes could not be scheduled because of a lack of teachers. "Instead," she writes, "some 640,000 youngsters who wished to enroll in science or mathematics courses were required to take courses in other subjects in which no teacher shortage existed."

In their September 1982 *Phi Delta Kappan* article, "Teacher Supply and Demand in Mathematics and Science," James W. Guthrie and Ami Zusman write that 43 states report shortages of mathematics teachers and 42 report shortages of science teachers. According to them, a 1981 National Education Association (NEA) estimate suggested that 22 percent of all secondary school math positions were either not being filled or were being filled by teachers certified in other fields.

They cite another NEA study indicating that in 1979-80, only slightly more than

8,000 of a million college graduates completed preparation to teach math or science. Out of more than 400,000 students in California's public colleges in 1982, only 97 were preparing to be secondary school math teachers and only 174 were preparing to be secondary school science teachers.

Marcuccio points out that adding one course in either science or math in U.S. schools would require a 20 percent increase in faculty, or 40,000 more science and mathematics teachers.

Former ETS President William W. Turnbull, in testimony before the Joint Economic Committee of Congress, revealed that about one-third of U.S. secondary schools do not offer enough mathematics to qualify their graduates for admission to accredited engineering schools. Fewer than one-third, he said, offer physics courses taught by qualified physics teachers.

Various solutions to this problem have been suggested, and some are being implemented. One suggestion, frequently resisted by unions, is to recognize the laws of supply and demand and offer science and math teachers higher salaries than teachers in other fields.

The Houston Independent School District has met with considerable success offering just such incentives through its "Second Mile Plan." There, teachers in fields with critical shortages, such as science and math, receive bonuses of $1,500. Ronnie Veselka of the Houston school system says that the program has been quite successful, with vacancies reduced from previous years. "We started the school year with the lowest number of vacancies in at least four years," he says.

According to district figures, total district turnover has steadily decreased from 23.9 percent in 1978-79, when the program was instituted, to 13.9 percent in 1982-83. Turnover because of resignation is down from 10.6 percent to 5.4 percent.

Turnbull and Richard Coley, of ETS, have proposed two programs to enable more science and math specialists currently employed in business and industry to teach in the schools. One proposal entails the creation of a national data bank. Institutions could enter vacancies, and qualified scientists and mathematicians from the business world who would like to try their hand at teaching could enter their credentials. Presumably companies, recognizing that it is in their interest to have a steady stream of science graduates from the schools, would loan out their personnel on a temporary basis.

"We are trying to tap the manpower pool that has escaped academic circles and bring it back," says Turnbull. Funds would be sought to make up the salary differential between business and education.

A second proposal calls for rewarding outstanding science and math teachers by matching them with summer jobs relevant to their teaching responsibilities. It is hoped that these corporate jobs would enhance their prestige, add to their experience, provide better linkage between the needs of business and education, and augment their salaries so that they will not be tempted by financial rewards to leave teaching.

In a similar vein, the state superintendent's office in Arizona is working with several companies in the state to create a system of endowed chairs in the high schools that would allow employees to teach specialized courses in areas where there is a shortage of qualified teachers.

"Endowed chairs would help compensate for the shortage of advanced math and science teachers," says David Bolger, assistant to the state superintendent. "A company would place an employee in an endowed chair for one year to teach a subject such as advanced mathematics or physics. The endowment would equal his salary for the time spent in class."

Although Bolger reports that the plan has received strong interest from some companies, it is opposed by state teacher unions. Moreover, the State Education Board has not yet come up with a certification vehicle for endowed teachers.

EDUCATION AND VALUES

Beyond more money, more teachers, and more innovation, there will have to be a fundamental restructuring of American values and attitudes towards learning for science and math to really take hold in our country.

This need is reflected in the comments, in the March 6, 1984, *New York Times*, of Christopher R. Montanaro of Oxford Hills High School in South Paris, Maine, the first-prize winner in the 1984 Westinghouse Talent Search. Montanaro was described as being troubled by a meeting with President Reagan's science advisor, George A. Keyworth II.

"'In every answer there was the subtle implication that we were spending money on science so we can be No. 1, which I don't care about,' he said.

"'For me science transcends patriotic things. Looking for order and beauty in the universe transcends other things. For me education is so much more important than defense.'"

Stephen R. Graubard writes about the revival of science education in *Daedalus* in similar terms equally applicable to mathematics: "The problem, obviously, is to make this happen. For those who imagine that it will be easy, that it depends primarily on the willingness of the federal government to expend monies for such purposes, the future will almost certainly be disillusioning. The achieving of significantly higher levels of scientific competence by substantial numbers in the population is certain to be slow, requiring, in the first instance, a substantially different perspective on science by students, teachers, parents, and employers. This presupposes some understanding of why science is worth noting, why mastering certain fundamentals is not beyond the capacity of ordinary mortals, of active healthy children. It is precisely because we do not live in placid times . . . and that this is as true for those of us who teach as for those who learn, that we must begin by recognizing that science is not a settled thing, a collection of formulas that wait to be committed to memory, that once learned will be possessed forever. Scientific literacy is but an aspect of literacy more generally; scientific learning is a necessary part of learning."

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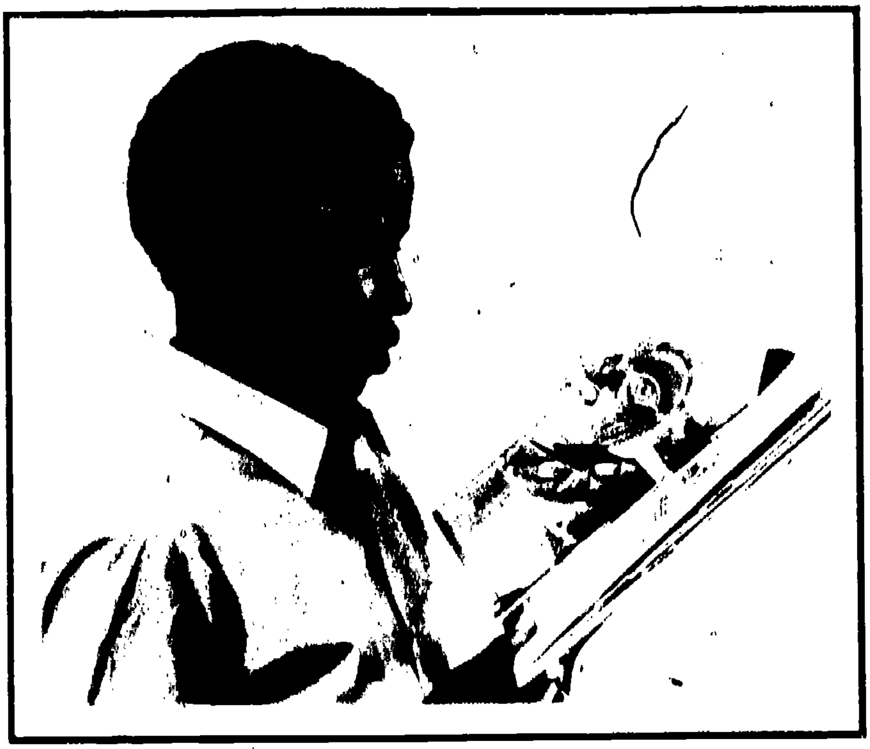

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