tute a major element of uncertainty about the duration of present population and employment deconcentration. Suburban sprawl of the 1950's and 1960's is sometimes explained as the product of cheap energy and profligate automobile use; the logical corollary seems to be that rising energy prices and potential gasoline shortages might serve to recentralize population. Although population began to grow faster outside than inside metropolitan areas before the 1973–1974 oil embargo that set in motion gasoline price increases, there is no evidence that the rate of population dispersion was slowed in the late 1970's (*4*). Little is known, however, about what the long-term constraints on population dispersion may be.

What is more certain at present is that enough people and jobs located in rural settings in the 1970's to effect considerable mixing of life-styles ordinarily thought to be discrete. As manufacturing jobs were moving to the countryside, some evidence of an increase in small-scale (possibly part-time) farming was reported (*13*). There is no evidence of a return to agriculture as a primary way of making a living, but there seems to be greater mixing of farm and nonfarm employment and more combining of retirement with employment in rural settings. Options for combining life-styles in these ways are both cause and consequence of new patterns of population dispersion.

References and Notes

1. See C. Beale, *The Revival of Population Growth in Nonmetropolitan America* (Government Printing Office, Washington, D.C., 1975); P. Morrison, *Rural Renaissance in America? The Revival of Population Growth in Remote Areas* (Population Reference Bureau, Washington, D.C., 1976); C. J. Tucker, *Demography* **13**, 435 (1976); B. J. L. Berry and D. Dahmann, *Population Redistribution in the United States in the 1970s* (National Academy of Sciences, Washington, D.C., 1977); J. M. Wardwell, *Rural Sociol.* **42**, 156 (1977).
2. In this article "metropolitan" refers to Standard Metropolitan Statistical areas (SMSA's) or to New England County Metropolitan Areas (NECMA's). In New England, the basic units for constructing SMSA's are towns and cities rather than counties, but we have used the NECMA scheme, which employs whole counties.
3. C. Taeuber, *Science* **176**, 773 (1972).
4. L. Long and D. DeAre, *Migration to Nonmetropolitan Areas: Appraising the Trend and Reasons for Moving* (Government Printing Office, Washington, D.C., 1980), pp. 3–8.
5. An issue in examining the relation between size and growth in the metropolitan context is whether to use the SMSA's and NECMA's shown in Table 1, groups of SMSA's known as Standard Consolidated Statistical Areas (SCSA's), or some other clustering of individual metropolitan areas into larger agglomerations. For example, should a resident of Norwalk, Connecticut, be considered as living in an area of 127,000 (the population of the Norwalk SMSA), an area of 16 million (the population of the New York–Newark–Jersey City, N.Y.–N.J.–Conn. SCSA), or an area of 42 million, the population of Jean Gottmann's megalopolis, the urbanized northeastern seaboard extending from Boston to Washington, D.C. Below we show population change in terms of the SCSA scheme; the basic conclusion that highest growth rates shifted to the smallest size category in the 1970's is unchanged.

Population	Increase (%)	
	1960–70	1970–80
Under 100,000	14.8	20.4
100,000 to 249,999	15.7	17.9
250,000 to 499,999	15.4	17.8
500,000 to 999,999	16.1	12.0
1,000,000 to 2,999,999	25.2	13.9
3,000,000 or more	13.8	1.6

6. A. T. Day and L. H. Day, *Science* **181**, 1016 (1973).
7. D. Vining and A. Strauss, *Environ. Plann. A* **9**, 752 (1977).
8. The Northeast consists of New England and the Middle Atlantic states of New York, Pennsylvania, and New Jersey. The North Central region consists of the Great Lakes states and Missouri, Kansas, Iowa, Nebraska, and the Dakotas. The South is made up of all states south of the Mason-Dixon line (including Delaware, Maryland, West Virginia, and Kentucky) and extends as far west as Texas and Oklahoma. The rest of the states are in the West.
9. G. V. Fuguitt and J. J. Zuiches, *Demography* **12**, 491 (1975).
10. L. Long and D. DeAre, *The Economic Base of Recent Population Growth in Nonmetropolitan Settings* (Center for Demographic Studies, Bureau of the Census, Washington, D.C., 1982).
11. J. Kasarda, *Soc. Sci. Q.* **61**, 381 (1980); J. F. Long, *Population Deconcentration in the United States* (Government Printing Office, Washington, D.C., 1981), pp. 86–87.
12. Bureau of the Census, *Current Population Reports*, P-23, No. 99 (Government Printing Office, Washington, D.C., 1979), p. 11.
13. B. Chapman, *New York Times*, 16 December 1981, p. A13.

Education, Science, and National Economic Competitiveness

John R. Opel

The United States still ranks first in the world in its total economic, educational, and technological strength. But there is a national problem which is seen in international competition: that we risk losing out against tougher, more pragmatic, more adventurous international contenders in the years ahead. We have seen signs of slippage: our imports of Japanese and German automobiles, steel, and television sets (not to mention semiconductor memory chips); our loss of market share in exports of manufactured goods; and above all our rate of increase in manufacturing productivity, which has been lagging behind that of virtually every other industrialized country in the world.

These signs of decline, of course, have many causes and require many solutions, including more savings and more investment in plant and equipment. But I want to focus on the trend that to me seems most alarming of all: that the United States is slipping in the race to strengthen not its capacity in buildings and machines, vital as they are, but the capabilities of its people: talented, educated, and trained human beings—the ultimate resource in any nation.

Nearly a quarter-century ago the Russians put up Sputnik, the first earth satellite. That event took us by surprise. It frightened us into a sustained national effort, and 12 years later we landed the first man on the moon.

Today we face, I believe, an even more ominous threat. In contrast to Sputnik, we have no spectacular event to jolt us into action. We have only a succession of facts—facts so subtle that we often overlook them or bury them on the inside pages.

For nearly two decades, the average combined verbal and mathematical scores on Scholastic Aptitude Tests (SAT's) given to U.S. high school students have been falling; they have fallen by a total of 90 points.

Half of all U.S. high school students take no mathematics at all after the tenth grade. Only one junior or senior in six takes a science course. Only one in fourteen takes physics.

No wonder so many students graduate from high school unqualified to enter

The author is president and chief executive officer of the International Business Machines Corporation, Armonk, New York 10504. This article is based on his address at the 37th annual meeting of the board of trustees of the Midwest Research Institute, Kansas City, Missouri, 11 May 1982.

engineering school. No wonder 30,000 to 40,000 American students who enter engineering school every year need remedial algebra or remedial trigonometry before they can start on calculus, the beginning math course for an engineering major.

And when we move further up the ladder, what do we find? Some 2000 vacancies in our engineering faculties, with particularly glaring weaknesses in computer science, chemical engineering, and electrical engineering. And, even in a recession, 17,000 unfilled entry-level engineering jobs coast to coast, and no prospect that we can possibly fill that gap any time soon.

The Japanese are outproducing us per capita in engineers by more than 2 to 1. Between 1965 and 1977, for every 10,000 in the labor force, the number of scientists and engineers in research and development nearly doubled in Japan. In the United States it fell.

In the face of these facts, the time has come for action. It could well start with a resounding federal declaration of a long-range commitment to scientific and engineering excellence and with a willingness to spend the money and do the work to make it happen.

Four years ago a distinguished group of university educators recommended that the National Science Foundation increase its competitive graduate fellowships in science and engineering from 500 new starts a year to 2000. What happened? Last year the Administration budget not only did not increase those fellowships, it eliminated new starts altogether. Only congressional action restored the old number, 500. In this year's proposed budget the number of new starts remains flat. That flat trend line discloses a shortsighted penny-wise policy.

We do have to reduce the deficit, we do have to cut out waste, and we do have to make sacrifices. But we cannot foreclose our future—a future which will hinge significantly on the scientific and technological training of our most gifted young people. The IBM company itself is increasing its science and engineering fellowships 20 percent, from 100 to 120 a year.

Another thing we should do is to modernize the equipment in university laboratories. Much of it today is obsolete and worn out. To bring it up to industrial standards would cost between $1 billion and $4 billion. The new tax law encourages donations of corporate equipment to universities. We in industry should act on this provision to help close the gap. Another provision of the tax law permits industrial sponsorship of university research. We should modify the tax law to change that "permit" to "encourage."

We need to unleash a secret weapon: women. Women make up half our population, but they make up less than 10 percent of our scientists and engineers. Why? Because for years we have told them that math and science and engineering belong to the boys. The result is that we have a great reservoir of talent that we are not tapping. And while we are at it, we must do a far better job of tapping the talents of minorities, also sharply underrepresented in our scientific and technological work force.

In addition to these corrections in higher education, we must reach down to the roots of the problem—down into the secondary school system.

Last year a survey of state science supervisors revealed a shortage of high school chemistry teachers in 38 states, a shortage of mathematics teachers in 43 states, and a shortage of physics teachers in 42 states, including 27 states with a "critical" shortage.

In the 1970's the annual average number of new science and math teachers produced by our colleges and universities plunged: the science teachers by 64 percent, the math teachers by 78 percent.

The result is that the schools have been forced to bring in "emergency" science and math teachers, men and women who are unqualified to teach these subjects. Last year they totaled half of all new math and science faculty members hired.

Moreover, while the average SAT scores of U.S. students were declining during the 1970's, the SAT scores of those intending to major in education and to teach in public schools were declining more than 1½ times as fast. No wonder some of our leading scientists—the members of the National Science Board—have set up a commission on precollege education in mathematics, science, and technology. Its findings and its suggestions for action will not come a moment too soon.

However, I believe that we already know much of what we have to do: roll up our sleeves and go to work in our public school systems to insist that they heighten instruction in these fields, pay what it takes to recruit able trained people, and reverse our downhill course.

There are a few specific actions we must take. But let us be clear about the full extent of the problem. It is not confined to science and engineering. It will not be eliminated by a neat programmed solution, by some kind of quick government fix. What we are seeing when we look at all those facts on our eroding performance is a decline in our capacity as a people to solve problems—not just problems in laboratories but all sorts of problems—through a disciplined capacity to think.

So widespread a decline demands a widespread response. We should recall the example of Thomas Jefferson, a man trained and disciplined not only in mathematics and the sciences but also in the arts and history, who was prepared to find pragmatic solutions to practical problems. The productivity of our country in agriculture and in industry throughout our history has relied on that kind of intelligence. Above all, we should recall Jefferson's faith in the individual man and woman—in the power of an aroused citizenry to overwhelm any problem they confront. That, more than anything else, will arrest our present decline. What we need now is another such shock of recognition: an awareness in community after community across the land that we face an urgent national problem and a resolve to overcome it. Without that recognition, we cannot succeed. With it we cannot fail.