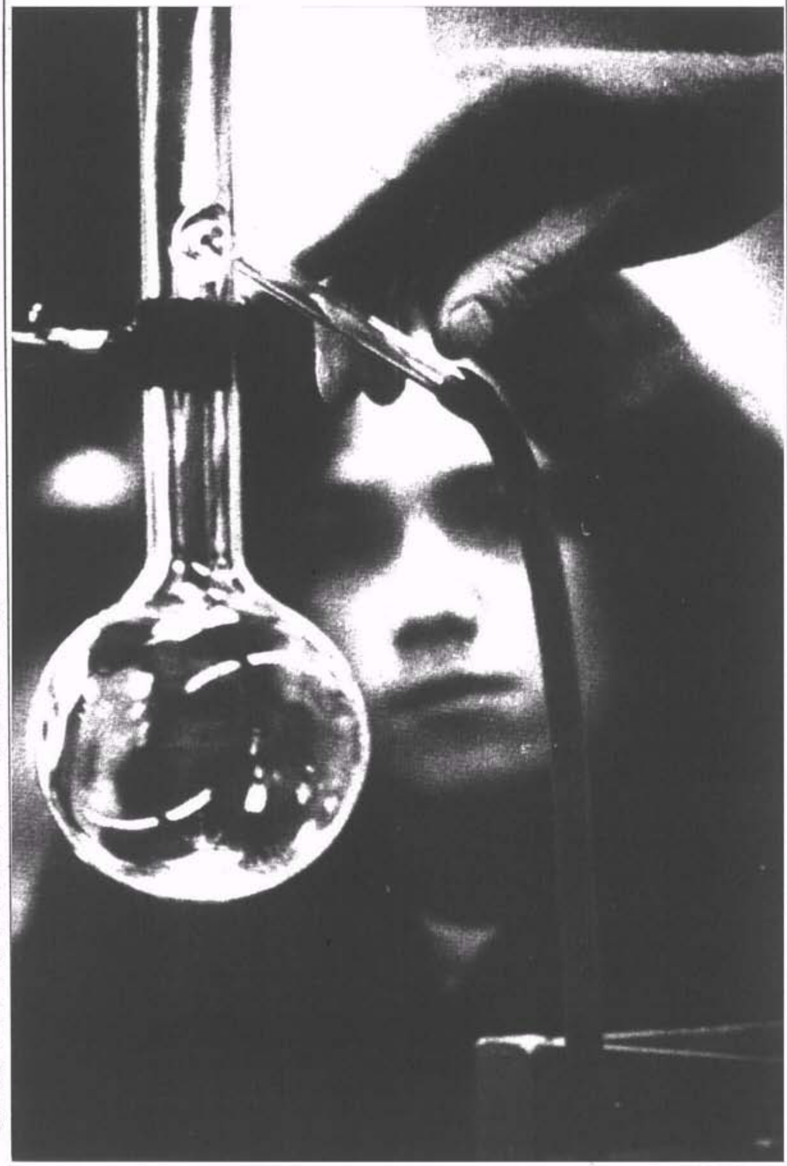
A report to the President supports the contention that the U.S. lags behind the Soviet Union, Japan, and Germany in science and mathematics education.

HOW THE U.S. COMPARES WITH OTHER COUNTRIES

NATIONAL SCIENCE FOUNDATION



There is today a growing discrepancy between the science, mathematics, and technology education acquired by high school graduates who plan to follow scientific and engineering careers and those who do not. Scientific and technical literacy is increasingly a necessity in our society, but the number of our young people who graduate from high school and college with only the most rudimentary notions of science, mathematics, and technology portends trouble in the decades ahead. Thomas Jefferson's axiom that an enlightened citizenry is the only safe repository of control over the ultimate processes of society surely includes the necessity for scientific and technological enlightenment. While students who plan scientific and engineering careers are receiving an adequate educational foundation, more students than ever before are dropping out of science and mathematics courses after the tenth grade, and this trend shows no signs of abating. This situation has several troubling implications:

• The role of science and technology is increasing throughout our society. In business, in government, in the military, in occupations and professions where it never before intruded, science is becoming a key to success. Today, people in a wide range of nonscientific and nonengi-

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neering occupations and professions must have a greater understanding of technology than at any time in our history. Yet our educational system does not now provide such understanding.

• Students who take no more mathematics and science after their tenth year in school have effectively eliminated, by the age of sixteen, the possibility of science or engineering as a career. The pool from which our future scientific and engineering personnel can be drawn is therefore in danger of becoming smaller, even as the need for such personnel is increasing.

• Education has long been the route by which upward mobility has been achieved by disadvantaged groups in our society. This verity has not changed. Increased emphasis must be given to aiding those who have been excluded, for too long, from careers in science and engineering. We stress this imperative both for reasons of equity and to increase the size of the pool of talent from which the nation's scientists, engineers, and technicians can be drawn.

• The declining emphasis on science and mathematics in our school systems is in marked contrast to other industrialized countries. Japan, Germany, and the Soviet Union all provide rigorous training in science and mathematics for nearly all their students at the precollege levels. We fear a loss of our competitive edge.

Figure 1. Relationship Between World Trade and Engineer Training

	Percentage of World Trade 1963	1977	Engineering Graduates as Percentage of Relevant Age Group (1977-78)
United Kingdom	15	9	1.7
W. Germany	20	21	2.3
Japan	8	15	4.2
United States	21	16	1.6

Comparisons between the U.S. and our international competitors suggest that our eminence in basic research is secure. However, our ability to apply technology to our military and industrial pursuits may well be hampered by the relatively low level of scientific and mathematical competence of our nonscientists and, in some respects, by the apparent cooling of science interest among our students generally.

The contribution of science and technology to our security and prosperity rests on two bases. The first of these is the competence and inventiveness of the practitioners, the scientists, and engineers who design and build the system. But the second base is equally important to our overall success as a nation.

This second base consists of the overwhelming portion of our population which has no direct involvement in science and technology, or with the science and engineering community. They are indirectly involved through their influence on the governmental and industrial sources of funding for scientific and technological endeavors. They are involved in the regulatory and policy decisions that set directions for scientific inquiry and technological development. They reap the benefits of science and technology. Many need some knowledge of science and technology to do their jobs well. However, the current trend toward virtual scientific and technological illiteracy, unless reversed, means that important national decisions involving science and technology will be made increasingly on the basis of ignorance and misunderstanding.

In Japan, Germany, and the U.S.S.R., national policy promotes the comprehensive science and mathematics education of far greater numbers of people than are expected to engage in scientific and engineering pursuits. In the Soviet Union and Japan especially, managerial positions in both government and industry are heavily populated by people with engineering degrees.

Over the past 15 years or so, while British training of engineers fell behind so drastically that a comprehensive inquiry was commissioned by the government, while Germany and Japan continued to stress science and mathematics for all their secondary students, and while U.S. secondary students not intending to major in science or engineering were choosing to take fewer science and mathematics courses, those countries' share of world trade in manufactured items (excluding food and fuel) changed as can be seen in Figure 1.

Between the same years (1963 to 77) productivity increased in the manufacturing industries of the United Kingdom, West Germany, Japan, and the U.S. (using 1963 as the base year) by 51 percent, 114 percent, 197 percent, and 39 percent, respectively.

In considering cross-national comparisons of training in science and engineering one must be cautious because educational systems are not parallel and often are quite dissimilar. For example, the group labeled "engineers" in one country may include an unknown number of those termed "technicians" in the U.S. Nevertheless, some of the differences in outcome are dramatic.

In Japan, for instance, the number of degrees granted to engineers in recent years has surpassed the number granted in those same years in the U.S., though its base population is roughly one half of ours. In Japan, 20 percent of all baccalaureate and about 40 percent of all master's degrees are granted to engineers, and these figures have been nearly stable for the past ten years. This compares with a figure of about 5 percent at each degree level in the U.S. Japanese education officials point out that students view the engineering degree as a "ticket" to business and social success in much the same way as the liberal arts degree (and now the M.B.A. degree) was viewed in the U.S. two generations ago.

The large number of Japanese students who enter scientific fields (65 percent of baccalaureate degrees versus 30 percent in the U.S.) is made possible by a secondary educational system which has a heavy emphasis on science and mathematics. There is a national guideline for lower secondary education (grades seven-nine) which calls for about 25 percent of the classroom time to be mathematics and science courses, and virtually all students are thus exposed. In upper secondary school, nearly all of the college-bound students (roughly one-third of the total) take three natural science courses (physics, chemistry, biology, or earth science) and four mathematics courses (algebra, geometry, calculus, and statistics) during their three-year high school career.

There has been significant effort in recent years to revise and update high school science teaching in Japan, and it is now heavily influenced by the U.S. Physical Science Study Committee (PSSC) and the Biological Science Curriculum Study (BSCS) materials. Chemistry has been upgraded by a committee on chemical education set up by the Chemical Society of Japan.

Mathematics instruction has a more rapid pace in Japan than in the U.S., and a much higher proportion of students take the more advanced courses. Geometry is taught in the seventh, eighth, and ninth grades.

Trigonometry is also studied in the ninth grade. Calculus, probability, and statistics are offered in high school.

In Germany, the general preparation is similar. There is a standard curriculum for all students through the tenth grade, and the only variation is in specialized science-oriented schools where each subject is studied more intensively.

For those headed toward college, science begins early. In the fifth grade students take chemistry and physics (as lab courses) as well as biology. Each is studied two to three hours a week. It is also at this level that geometry is introduced. The study of algebra begins in the seventh grade and, as students progress from year to year, the amount of their contact with each science and math course increases.

The overall picture in Germany is one of a very high level of science and mathematics literacy among college graduates as well as a strong science/mathematics understanding among the general population. This provides them with the basic tools to continue their education (German law guarantees that all people are entitled to a free education to as high a level as they desire) at a later point in their careers, as many choose to do.

The situation in the Soviet Union is less clear. The country has achieved virtually universal education through about the first ten years of schooling. Most of those students (about 60 percent) go on to complete General Secondary School—grades nine to ten (or eleven)—and are exposed to a mathematics and science curriculum which, according to one observer, surpasses that of any other country including the U.S. Algebra and geometry are taught in the sixth and seventh grades, advanced algebra and trigonometry are taught in grades eight to ten, and calculus, which a total of about 500,000 Americans take during their last year in high school or their first in college, is a part of the high school curriculum for over 5,000,000 Soviet students. In addition, all youngsters are required to complete five years of physics, four of chemistry (including a year of organic chemistry), and up to four of biology depending on whether they attend specialized vocational or general secondary schools. While students in specialized secondary schools (about 12 percent of eighth grade graduates) are exposed to less science except in specialty fields related to engineering technology, the avowed goal of Soviet educational policy is to ensure that the future labor force will facilitate the transformation of the economy to a scientific-technical base and to supply more technologically oriented people to fill the military ranks.

The picture of engineering, mathematics, and science education in the Soviet Union is not complete; there are some major problems. Secondary school curriculum changes mandated a decade ago have been implemented slowly and have not spread throughout the educational system. The secondary science courses have little laboratory work associated with them and are generally learned by rote. Rural schools tend to be poor. At the university level, science and engineering education is very narrow-gauge; students specialize sharply at a very early point. The sizable non-Russian-speaking minorities in the country are at a disadvantage because the best university instruction in science and engineering is in Russian.

Though the problem areas in the education and employment of Soviet scientists and engineers appear to be many, their potential capacity to compete internationally should not be underrated. There are many signs that the inefficiencies are being recognized, and the Soviets' general acceptance of the legitimacy of science and engineering pursuits provides a context in which quality may well improve very rapidly.

For all of these countries, it is difficult to separate the effects of government policy, market factors, and social pressures. What is clear is that in each case there is a strong national commitment to quality science and mathematics instruction as an essential part of the pre-college educational process. The result is a work force which, at all levels, has a relatively high degree of science and mathematics skill, and this has been a factor in the very rapid expansion of technical industries.

In the U.S., by contrast, there has been, over the past 15 years or so, a shrinking of our national commitment to excellence and international primacy in science, mathematics, and technology. This lessening of commitment has not been the result of a conscious decision on anyone's part, but it has nevertheless pervaded our society. The schools of this nation are but reflections of the degree of national commitment in any area, and they therefore are not so much a cause of this condition as a result. To correct this debility, therefore, will require that attention be given not only to the schools themselves, but also to increasing public understanding and appreciation of the importance of excellence in these areas. ■