

ISSUES AND EVENTS

Science Board Says US Leadership in R&D Strong, but Faces Growing Foreign Competition

While the US remains the world's science and technology powerhouse, spending more than \$264 billion annually on R&D and financing 44% of all global R&D, the country's leadership position could be threatened by continuing problems in K-12 education, the lack of federal support for basic research, and improved science programs in other nations. That is the bottom-line conclusion of the National Science Board's *Science and Engineering Indicators 2002* report, the latest of the biennial "state of science" studies done for the White House and Congress.

The lengthy NSB report, based on data developed by the NSF's Division of Science Resources Statistics, provides an in-depth look at everything from the state of elementary and secondary education to global competitiveness of individual industries. The 2002 report drew primarily on data from 1990 to 2000 and is a blend of both good and bad news.

"As the 21st century begins, the United States occupies a position of strength in the support and conduct of research and development," the report says in its opening chapter. "US R&D expenditures equal the combined total expenditures of Japan, the United Kingdom, Canada, France, Germany and Italy. US scientists and engineers produce nearly one-third of the articles published in the world's most influential technical journals."

The report credits the federal government with fostering "a broad base of research activity, especially in academia, where federal funds represent about 60% of total R&D spending." In addition to training the next generation of scientists, the report notes that universities and colleges "also perform nearly half of the nation's basic research." Federal inflation-adjusted funding of academic research during the past decade increased by 42%, the report says, due largely to increases in life sciences funding.

Federal funding down

The positive news for academic research is offset by the overall federal

Federal funding of life sciences at the expense of basic research in the physical sciences and engineering could eventually erode the premier position of US science.

R&D funding trend during the 1990s, which was down 9%, according to the report. And while life sciences money was increasing, "funding for the physical sciences and engineering slowed, a development which has sparked critical commentary by many in the scientific and science policy communities." Two of those joining in the critical commentary were mathematician Richard Tapia and computer science specialist Anita Jones, the NSB members who presented the report at a Washington, DC, press conference on 30 April. Jones pointed to a dichotomy in the administration's current funding proposal for the National Institutes of Health (\$27 billion) and NSF (\$5 billion) to emphasize the funding imbalance between the life and physical sciences (see PHYSICS TODAY, April 2002, page 30).

Tapia, the Rice University mathematics professor who chaired the NSB subcommittee that oversaw the study, said that "one of the messages coming from the report is that we really are defaulting on support of basic sciences

in this country, while other countries are moving forward." He said he is also concerned that US industry cannot continue to count on using highly trained science and technology workers from other countries to make up for the shortage of qualified domestic-born workers. Because other countries are improving their science and technology training, their best and brightest science students no longer have to come to the US for a first-rate education, he said.

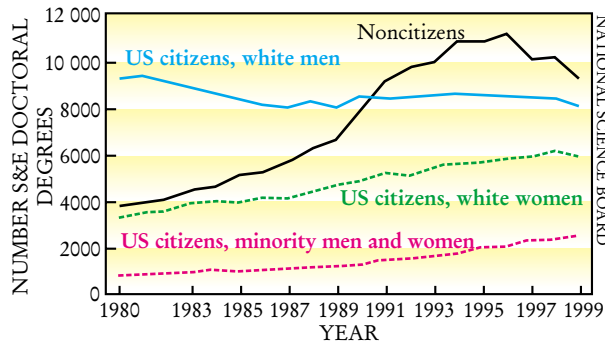
"In the long-term, these are continuing trends that we should view carefully because they provide us with caution flags," Tapia said. "If we don't watch what we are doing, we're not going to be the leaders [in science and technology] that we have been."

Jones, the vice chair of the NSB and a professor of engineering and applied science at the University of Virginia, said that because "the majority of our economy is grounded in technology," the US must produce "trained brains" that can generate the new ideas essential to maintaining a technology-based market system. "Science and technology is the core of the innovative US economy . . . It is the place where new ideas from the newly educated people come from." Jones, like Tapia, tied much of the strength of the US economy

to the support of basic research. "Over the nineties, our government has elected to invest in the life sciences, and that is a wise thing to do because the instruments are there for dramatic breakthroughs," she said. "But that means we are investing less in physics, engineering, and chemistry, and that gives me concern." The report says that federal funding for basic research has risen from 14 to

18% of all federal R&D spending from 1980 to 2000, but that the "share of federal funds for basic and applied research in the physical sciences and engineering dropped from 38 to 32%, whereas the life sciences share . . . rose from 40 to 45%."

Scientific fields are interdependent, Jones said, "and the advances we'll see in the near future in life sciences rely integrally on the instru-



WHILE THE NUMBER of science and engineering doctorates rose rapidly beginning in the mid-1980s, almost all of that growth was attributable to foreign-born students. Virtually all of the slight growth in number of doctorates earned by US citizens reflected degrees earned by white women and minority students of both sexes. The number of US white men receiving doctorates actually declined over the past two decades.

ments built by engineers based on new knowledge that came from physics, chemistry, and basic biology.” What is particularly troubling about the failure to invest properly in the physical sciences, she said, is that “students are trained in the context of research. So we will be training many more biology, medical science, and biomedical engineering students.” In the next decade, she said, “the balance of trained brains” will be skewed toward life sciences, and that, in turn, could exacerbate the shortage of people in the physical sciences and engineering.

Foreign programs improving

Another threat to US science and technology leadership is the improving quality of science training programs in other countries, the report says. “Other countries are building up the natural sciences and engineering [NS&E] capabilities of their younger cohorts at a greater rate than the US has been able to achieve,” the report says. “They have been able to raise—by large increments—the rate at which their college-age youth earn first university NS&E degrees.” The report lists 13 countries, led by the UK, that are ahead of the US in the percentage of 24-year-olds earning undergraduate science degrees. While the UK is near 10%, the US “has fluctuated between 4 and 5% of the nation’s 24-year-olds for the past four decades and barely reached 6% in the late 1990s,” the report says. “US pre-eminence [in science and technology] may erode as competing centers of excellence are established elsewhere,” the report concludes.

Tapia’s fear that the US economy could lose foreign-born scientists and be unable to replace them with highly

educated US-born science and technology workers is discussed at length in the report. “In the US in 1999, 10% of those holding baccalaureate degrees in [science and engineering] were born abroad,” the report notes. “This figure was 20% for master’s degree recipients and 25% for doctorate-holders.” The field with the highest percentage of foreign-born PhDs was civil engineering, with 51.5%.

“The troubling question is, because of our openness, will other countries use what they have learned [by sending students to US schools] and establish strong and eventually competing programs of their own?” Tapia said. “The answer is, ‘Of course.’” Since 1997, there has been a decline in the number of foreign students coming to the US, he said, so we “must learn how to build our own [science and technology] workforce.”

To do that, he said, the US must first solve the crisis in its elementary and secondary school education system. The problems the report identifies in K–12 education, especially in mathematics and science, are longstanding and well known: too few science and math teachers with relevant academic backgrounds; inadequate ongoing training for teachers already on the job; low salaries that keep top science graduates from going into teaching; science and math textbooks of poor quality; and uneven standards and testing across school districts. The report expresses little optimism that the problems with science teachers will be corrected soon: “Over the past three decades, teachers with low academic skills have been entering the profession in much higher numbers than teachers with high academic skills.”

Another trend revealed in the report is that, although more students are taking advanced science courses in high school, universities and colleges have to offer an increasing number of remedial science courses for incoming freshmen. “It is clear to me,” Tapia said, “that advanced courses in high schools are being watered down. Today’s advanced courses are not what yesterday’s advanced courses were.” (See PHYSICS TODAY, May 2002, page 48.)

Some of the other education trends highlighted by the report are the following:

▷ Although mathematics and science achievement, as measured by the National Assessment of Education Progress (NAEP) standards, have improved since the 1970s, few students are attaining levels deemed “proficient” or “advanced” by a national panel that evaluates the scores. Only 17% of 12th-graders scored at the “proficient” level or higher on the NAEP mathematics assessment in 2000.

▷ Female and male students have similar patterns in the science courses they take, although there are some differences. In high school, girls are as likely as boys to take advanced mathematics classes and are more likely to take biology and chemistry; they remain less likely to take physics.

▷ Since the publication of the landmark education study *A Nation At Risk* nearly 20 years ago, most states have increased the number of mathematics and science courses required for high-school graduation. In 2000, 25 states required at least 2.5 years of math and 20 states required 2.5 years of science. In 1987, only 12 states required that much math and only 6 required 2.5 years of science.

JIM DAWSON

Stellarator Fusion Gets a New Look

If the National Compact Stellarator Experiment planned for the Princeton Plasma Physics Laboratory is successful, stellarators could become prime contenders in the snails’ race to achieve fusion energy. The \$70 million NCSX is allotted \$12 million out of the Bush budget’s \$257 million for fusion research in fiscal year 2003. Assuming the money comes through, construction would begin in 2004, and the stellarator would be due to come online in 2007.

Like tokamaks, their currently more advanced cousins, stellarators use magnetic fields to confine plasma in a torus for fusion reactions. But unlike tokamaks, in which the field



Symmetry has rekindled interest in stellarators as a possible path to fusion energy.

varies in only two dimensions, in stellarators the field is fully three-dimensional, with the advantage of sustainability (the plasma doesn’t suddenly collapse, or disrupt) and the disadvantage of poor plasma confinement (the plasma loses particles and energy). New stellarators beat the confinement problem by creating a quasi-symmetric field—trading fiendishly complex magnetic fields for fiendishly complex magnets.

Symmetry solution

In quasi-symmetry, the orbiting plasma particles see the magnetic field as having a constant magnitude in some direction—the long (toroidal) or short (poloidal) way around the torus, or along a helical path, resulting in quasi-axi-, quasi-poloidal, and quasi-helical symmetry, respectively. “[Fusion scientists] have found a way out of the leaky stellarator problem,” says David Anderson, research leader of the two-year-old Helical Stellarator Experiment at the University of Wisconsin–Madison. “HSX is the first of a new generation of stellarators—where we design from the inside out. We target the physics and then design