For decades, New England's innovation-based economy has depended upon a supply of people with science, technology, engineering and math (STEM) skills. But there is growing concern that New England's poorly flowing STEM pipeline will cause the region's high-tech leadership to dry up. ***THE NEW ENGLAND JOURNAL OF HIGHER EDUCATION*** *asked five experts to reflect on education issues related to the region's science and technology economy. …*

Red Flags in High-Tech

PATRICIA M. FLYNN

The United States has long been a world leader in education, innovation, high-tech employment, and research and development (R&D). Its future status, however, is not secure. This is the conclusion of more than two dozen reports in recent years from a variety of groups of business leaders, educators and government officials. There also is consensus that science and engineering (S&E) skills—now grouped under "science, technology, engineering and math" or "STEM" skills—and a strong R&D foundation are essential if the United States is to remain competitive in the increasingly knowledge-based global economy. This high-tech infrastructure is at risk in the United States, at a time when several other countries, especially those in Asia, are investing aggressively and strategically in these areas.

The findings are especially disconcerting for New England. For decades, the region has drawn its competitive advantage and economic prosperity from its dynamic high-technology infrastructure. The region's extraordinary network of colleges and universities lies at the heart of this infrastructure, providing a plethora of academic degree programs in STEM and other fields, and contributing to a highly skilled workforce, a strong foundation of R&D and a vibrant pool of entrepreneurs. In addition to a significant inflow of private venture capital, federal funds in areas from defense to health care have been instrumental in generating an ongoing mix of innovations, patents and new technologies in the region. Thus, much is at stake for New England, in particular, if the United States loses its leadership role.

S&E Education

S&E education in the United States is still strong, according to the latest data from the National Science Foundation (NSF). S&E degrees represent about one-third of all bachelor's degrees and two-thirds of all doctoral degrees awarded in the United States. While the *share* of worldwide undergraduate S&E degrees awarded in the United States is on the decline, the number has been rising for the past two decades. At the doctoral level, S&E degrees awarded in the United States peaked in 1998; but *enrollments* in such programs have been rising since 1999, NSF reports.

Foreign nationals play a major role in S&E programs in the United States, especially at the graduate level. In 2003, foreign students accounted for 60 percent of the doctorates awarded in the United States in engineering, and 50 percent of those awarded in mathematics and science, according to the American Electronics Association (AEA). China and India are major contributors to these pools of students.

U.S. colleges and universities, however, can no longer depend on a steady inflow of foreign students. Several Asian countries are building S&E educational infrastructures at home. China, for example, now graduates about four times as many engineers as the United States; South Korea, with approximately one-sixth the population of the United States, is producing about the same number of engineers as the United States, according to AEA. In addition, competition for foreign S&E students has intensified from countries such as Canada, Australia, Germany and the United Kingdom. And since September 11, 2001, it has been more difficult for foreign nationals to obtain visas to study in the United States.

The impacts of these trends are already being felt. First-time foreign graduate student enrollment in S&E programs in the United States fell by 13 percent between 2001 and 2003, according to the 2006 Economic Report of the President. A survey by the Council of Graduate Schools cites a 36 percent decline in the number of foreign student graduate applications in engineering in fall 2004 from a year earlier.

Compensating for these gaps in S&E college enrollments with U.S. residents would be a major challenge. U.S. students continue to lag their peers in many developed countries in tests of math and science performance. In 2003, for example, the United States ranked 24th of 29 industrialized countries in math performance among 15-year-old students, according to the Organization for Economic Co-operation and Development (OECD).

The S&E Workforce

The potential loss of foreign S&E graduates in the United States comes at a time of high and rising demand for these skills. From 1980 to 2000, S&E occupations in the United States expanded by more than 4 percent a year, while the total number of S&E degrees awarded grew on average by just 1.5 percent annually, according to NSF. U.S. employment in S&E occupations in the decade ahead is projected to continue to expand well above the average for employment overall. Retiring baby boomers will generate additional vacancies; NSF reports

that approximately 30 percent of all S&E degree-holders in the U.S. workforce are now age 50 or older.

Immigrants account for a growing share of the S&E workforce in the United States. More than one in four college-educated workers in S&E occupations is foreign-born, according to NSF. The higher the education level, the larger the share of immigrants. In 2002, for example, immigrants comprised 17 percent of U.S. S&E workers with bachelor's degree's only, but 43 percent of those with doctorates, according to the 2006 Economic Report of the President. At U.S. universities, meanwhile, about 20 percent of S&E faculty are foreign-born, including more than one in three engineering faculty.

Historically, most foreign S&E doctoral degree recipients intended to stay in the United States after graduation. By 2003, this share had risen to 68 percent, the NSF reports. However, the booming economies in countries including China and India increasingly provide attractive work options for these well-educated, highly mobile workers. Even if the United States is able to attract these individuals as S&E students, growing numbers of them may chose to return home upon graduation.

R&D

America's leadership role in R&D also is being challenged. With R&D expenditures amounting to 2.68 percent of gross domestic product (GDP), the United States ranked fifth in the world by this measure in 2004, following Sweden, Finland, Japan and Iceland, according to OECD. Since 2000, however, R&D's share of GDP has been rising in the European Union and in Asian countries including China, India and Japan, but declining slightly in the United States. Moreover, federal funding of R&D in the United States peaked in the 1980s. Even the NSF, itself, long a supporter of basic research and S&E activities, proved vulnerable in 2004, as Congress voted to reduce its funding for the first time in 16 years.

More than two-thirds of domestic R&D expenditures in the United States are now private-sector investments, which, while important, tend to be cyclical and focused on shorter-term results rather than basic research.

In terms of the number of researchers employed, a key factor in the R&D system, the average rate of growth in OECD countries in recent years has exceeded that in the United States by about one-third.

By other research and innovation measures, the historic dominance of the United States is also at risk. For example, U.S. patent applications from Asia have outpaced those from within the United States in recent years. The U.S. share of S&E papers published worldwide and the share cited by other scientists are also falling, according to the Task Force on the Future of American Innovation, comprised of industry and academic officials. These trends suggest the United States will increasingly depend upon R&D and innovations from other countries. In addition, while long a leader in innovation, the United States has often lagged other countries in the *adoption* of new technologies, especially those developed elsewhere. Thus, a change in mindset and behavior may be required of U.S. managers, workers and consumers if the United States is to remain technologically competitive. Alliances with companies and governments beyond our borders as equal partners may be needed to ensure access to S&E talent and ideas, and for the United States to remain a serious player in the knowledge-based global economy.

Globalization is here to stay. In the years ahead, we are likely to see further dispersion worldwide of R&D, S&E degrees awarded, the production of goods and services, and of better, more highly skilled jobs. The United States must be willing to make the long-term investments in education and research that provide the foundation for its high-tech leadership, or risk watching its competitive advantage fade away. The future of New England and its high-tech economy is very much at stake.

Nearly nine in 10 U.S. students in kindergarten through second grade are interested in specific careers in science and/or math. But starting in grade 3, interest begins to wane, and more than one-third of students in grades 2 through 12 are not interested in any careers in science, math, technology or engineering, according to the an online survey of 270,000 K-12 students and their teachers and parents facilitated by Project Tomorrow, a California-based nonprofit education group.

The survey also found that the students want to learn science and math through real-world problem-solving, visiting places where science is in action, talking to professionals in those fields and using multimedia and interactive simulations. For more, visit: http://www.tomorrow.org/index.html

Patricia M. Flynn *is Trustee Professor of Economics and Management at Bentley College. Email: pflynn@bentley.edu.*