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Embracing Globalization: Meeting the Challenges to U.S. Scientists and Engineers

Assuring a Globally Engaged Science & Engineering Workforce

REPORT HIGHLIGHTS

"Nothing in life is to be feared. It is only to be understood."

Marie Curie

Introduction

From the Industrial Revolution to the Internet Age, innovations produced by U.S. scientists and engineers have fueled much of the nation's economic growth. These advances in technology have also changed the way science itself is conducted, allowing scientists and engineers from around the world to collaborate and compete in the process of research and development.

One of the results of the globalization of science is that knowledge discovery is increasingly taking place outside the United States. Since the 1980s, more than 40 percent of U.S. patents have been awarded to foreign inventors and companies.[1] Other countries have developed strong research communities of their own and are able to compete with the United States for investment. China, for example, now receives more direct foreign investment than any other country. Companies based in the United States are also taking advantage of skilled workforces around the world, increasing their expenditures on research and development abroad from $12 billion to $21 billion between 1994 and 2002. In terms of actual dollars spent, the United States still leads in R&D spending, but as a percentage of gross domestic product, U.S. spending lags behind that of Sweden, Finland, South Korea and Japan. The share of articles on science and engineering topics by U.S. researchers also continues to decline, dropping from 38.1 percent in 1988 to 30.3 percent by 2003.[2]

The United States has been one of the major catalysts of globalization, but that has not always meant that it has prepared its citizens for the changing demands of the workplace. For the United States to continue to succeed in what will surely be an increasingly globalized world, it must have scientists and engineers who can thrive in international environments, whether this entails working abroad, collaborating with scientists from other countries or simply being more aware of important scientific, political and economic developments around the world.

To address the need for a globally engaged science and engineering workforce, leading figures from industry, academia and policy-making gathered in September 2006 at National Science Foundation headquarters in Arlington, Virginia, for a three-day workshop sponsored by Sigma Xi, The Scientific Research Society. Workshop participants discussed the implications of globalization for the nation's scientists and engineers and offered specific recommendations for assuring that the workforce of the future will be able to adapt to the requirements of a global economy. In July 2007, the findings were presented to the National Science Foundation in the report *Embracing Globalization: Meeting the Challenges to U.S. Scientists and Engineers*.

This summary of the full report provides an introduction to the challenges posed by globalization to U.S. scientists and engineers and highlights the most essential conclusions. It also presents several models of international education and engagement introduced by participants at the Sigma Xi workshop. These models could be quickly adapted to other fields and institutions, helping to create a science and engineering workforce that can better contribute to the social and economic well-being of the nation and the world.

The Challenge

To adapt to the changes brought about by globalization, U.S. scientists and engineers must be prepared to work with and learn from their colleagues abroad. But at the moment, U.S. students and professionals show less willingness to travel and work abroad than their counterparts in other developed countries. Whereas about 10 percent of highly skilled workers from the European Union work outside of their home country, only about one percent of similar employees born in the United States do the same. Among students, just one percent of undergraduates study abroad, and most who do take part in programs that last less than a full semester.[3] These trends may be due in part to the abundance of opportunities within the United States, but they also seem indicative of a disinclination among U.S. residents—only about 20 percent of whom hold passports—to travel abroad.

Another component of assuring a successful science and engineering workforce is simply having sufficient numbers of scientists and engineers. Employment opportunities in science and engineering are projected to grow more rapidly than in the overall workforce, but enrollment in science and engineering majors has remained at about one-third of degrees awarded over the last two decades.[4]

Preparing students for careers in science and engineering begins long before the undergraduate level. Elementary and middle school students in the United States continue to trail students in many other countries on international tests of science and math. A report on primary education published by the nonprofit Asia Society found that teachers in East Asian nations that consistently rank ahead of the United States on elementary and middle school math and science tests are much more likely to have degrees in the fields they teach than U.S. educators. In Singapore, for example, 92 percent of eighth-grade science teachers have degrees in science, compared to just 43 percent of eighth-grade teachers in the United States.[5]

Preparing U.S. students for life in a global economy, where science and math skills are likely to grow in importance, is essential, but filling the needs of the science and engineering workforce in the United States also depends on the continued presence of large numbers of international employees. Students from abroad who complete their degrees in the United States and stay in the country to work have long comprised a significant part of the high-skilled workforce, but these graduates are increasingly returning to their home countries or pursuing employment in other developed countries upon graduation. In 2003, 44 percent of doctoral degrees in mathematics, 35 percent in the physical sciences and more than half in engineering were awarded to international students. It is crucial that the United States retain many of these students to assure that the employment needs of U.S. companies can be met.[6]

Foreign workers are important to the United States for more than just filling jobs. Being open to foreign investment and talent has provided a number of other economic benefits. In California, for example, as more immigrants from a particular country arrive in the state, exports to that country increase correspondingly. High-skilled immigrants also create jobs and revenue within California. Chinese and Indian engineers ran almost 30 percent of Silicon Valley's technology companies by the end of the 1990s, accounting for almost $20 billion in revenue and more than 70,000 jobs.[7]

Since the 1980s, more than 40 percent of U.S. patents have been awarded to foreign inventors and companies

R&D Spending as a Percentage of GDP

COUNTRY	%
Sweden	3.98
Finland	3.49
Japan	3.15
South Korea	2.64
United States	2.60
Germany	2.55
France	2.19
United Kingdom	1.89

Data from 2003

Source: OECD Science, Technology and Industry: Scoreboard 2005

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Improving education at all levels, attracting high-skilled international workers and promoting international engagement are a few of the challenges that raise questions about the ability of the United States to maintain its preeminence in the international science and engineering community. As the Sigma Xi workshop made clear, however, these challenges can be met successfully, particularly if the United States is willing to learn from the achievements of scientists and engineers around the world, just as the rest of the world has long learned from the example set by the United States.

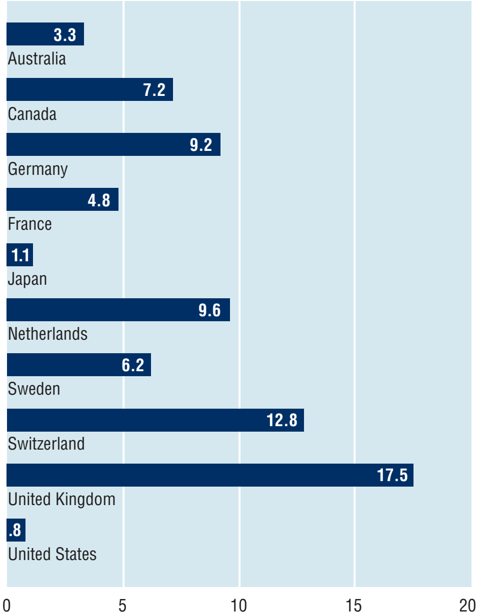
Getting to Global Competence

Workshop participants offered a number of different approaches to meeting the challenges posed by globalization, but there was widespread agreement about what is most needed. Of utmost importance is to develop a culture within the U.S. science and engineering community that embraces international engagement and that sees global competence as a fundamental part of the training of a successful scientist or engineer.

Global competence can be defined in a number of ways, but it certainly includes the ability to work with scientists and engineers from different countries and cultures—to be able to understand how and why colleagues from abroad might approach problems differently. It is also essential to be sensitive to differences in business environments, local economies, laws and cultural values. Ideally, scientists and engineers would also be able to speak another language. A final step, and one that is useful both within the United States and abroad, is the ability to lead diverse groups of scientists and engineers in the pursuit of a common goal or solution.

Of course, the first priority of science and engineering education is competence in a specific field of study. And as researchers delve deeper into increasingly specialized areas, it becomes more difficult to provide the type of multidisciplinary education needed to achieve global competence. Several programs presented at the workshop have shown that traditional training in science and engineering can be successfully integrated with a global perspective, and that there are many benefits to such an approach.

Workforce Mobility: Percentage of Highly Skilled Workers Employed in Other OECD Countries, by Country of Birth



Source: OECD Science, Technology and Industry: Scoreboard 2005

Models of Global Engagement

Solutions to the problem of how to adapt to the demands of globalization are now being developed at institutions around the country. More work needs to be done to identify the most successful models and to find ways to replicate these programs elsewhere, but the foundation needed to create a globally competent workforce is already being put in place.

Many of the participants in the workshop are among those working hard to build that foundation. They discussed three primary types of international collaboration for undergraduates:

individual classes that teach basic global-competence skills, courses that make use of technology to create virtual international collaborations, and programs that integrate science and engineering research into a study-abroad environment as part of the core curriculum.

"Engineering Cultures"

Virginia Tech and the Colorado School of Mines now offer a semester-long course that enhances global competence by helping engineering students to understand and value the approaches taken by people who have perspectives different than their own. The course, "Engineering Cultures," outlines the historical development of the profession in various countries, explaining what an engineer is, what counts as engineering knowledge and how expectations of engineers can vary from country to country. The class also tackles broad historical and cultural questions, such as the role of engineers in various countries and how engineers fit into different ideas about "national progress." Multiple-choice and essay tests administered at the beginning and conclusion of the course have shown that students have made significant progress in developing the knowledge, skills and predisposition needed to work with engineers from different countries and cultures. In addition to being offered in classroom format at Virginia Tech and Colorado School of Mines, "Engineering Cultures" and its separate country modules can be taken online at http://www.cpe.vt.edu/engcultures/registration.html.[8]

The Global Seminar

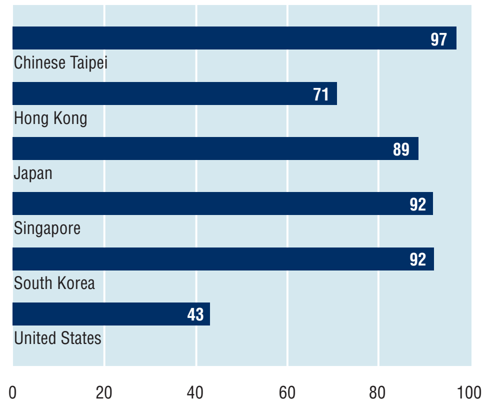
International engagement does not have to mean meeting face to face. The Global Seminar is a collaboration of more than 40 universities in 35 countries that takes advantage of communications technology to facilitate international interactions without the time and expense of traveling abroad. Each semester-long class involves a cluster of five to seven universities. After being introduced to a topic by faculty in a traditional classroom setting, students engage their peers at other universities using discussion boards, video conferences and online chat sessions. At the conclusion of each course, students prepare formal essays on specific case studies. The topics addressed by the Global Seminar fit with the international theme of the class and include climate change, population, biodiversity and natural resource management, all issues that have global implications and require international action.[9]

WPI's Global Perspective Program

Despite its small size (2,800 undergraduate students and about 1,000 graduate students), Worcester Polytechnic Institute sends more science and engineering students abroad than any other U.S. university. One reason for the school's success in promoting global engagement is its innovative Global Perspective Program.

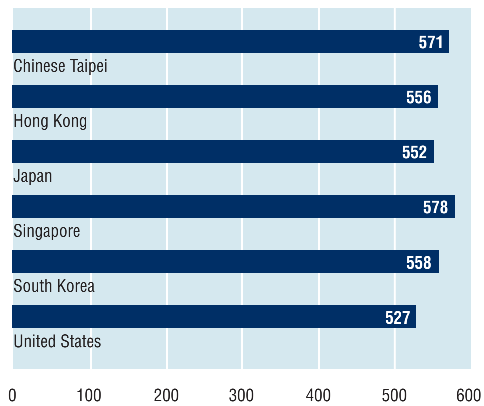
Universities, for the most part, have not yet made the effort to convince students of the importance of international education

Percentage of 8th-grade Science Teachers with a Degree in Science



Source: Asia Society, *Math and Science Education in a Global Age: What the U.S. Can Learn from China*, 2006

Average Scores of 8th-grade Students in the United States and East Asia on International Science Tests



Data from 2003

Source: International Association for the Evaluation of Educational Achievement, Trends in International Mathematics and Science Study

"We need to educate our scientists and engineers— as well as our doctors, lawyers and educators— to be citizens of the world"

Indira V. Samarasekera, keynote address at "Assuring a Globally Engaged Science and Engineering Workforce"

This program allows engineering students to apply practical problem-solving skills in an international setting. Students who take part in the program spend two months laying the groundwork for their trip abroad by taking classes that focus on language skills, cultural awareness, and research and teamwork development. After completing a formal written proposal, students spend two months working at one of 20 project centers around the world, in countries such as Australia, Costa Rica and South Africa. Each project center consists of 24 students and two WPI faculty members (about half of WPI faculty members are involved with the Global Perspective Program at some point in their careers). Students work on projects that use their engineering skills to provide sustainable solutions to locally defined problems. At one project site in rural Thailand, for example, WPI students successfully designed and installed solar panels and trained the village's residents in the use of the panels. Since the first international project center was launched in 1984, more than 3,600 students have taken part in the program, and currently more than half of graduating students have been involved with at least one international project.[10]

University of Washington–Sichuan University Collaboration

A multiyear program developed by the University of Washington and China's Sichuan University promotes international interaction while addressing issues of global importance. Participating students at the University of Washington begin preparing for global engagement from the start of their undergraduate careers. As freshmen, they take classes on Chinese language and culture, and they continue with language studies during their sophomore year. The junior year is typically spent in China working with collaborators at Sichuan University, where students continue their language and cultural studies while taking part in international research. One benefit of the program is that half of the applicants and participants are female students, a higher percentage than of the body of science and engineering students in general, showing that this type of program may help attract a more diverse pool of science and engineering talent.[11]

Purdue's Global Engineering Alliance

The goal of Purdue University's Global Engineering Alliance for Research and Education (GEARE) is to weave professional, technical and global competence into a single program. In partnership with eight companies and four international university partners, GEARE integrates engineering coursework and internships in foreign countries into the four-year curriculum. University partners currently include institutions in Germany, China, India and Mexico, and the program is reciprocal, so students from all these universities can benefit. Students take language and cultural orientation classes and then work as interns, first within the United States and then abroad. The internships consist of one paid internship at a company's work site in the United States and a later internship with the same company abroad, each of which lasts about three months. The final component of the program is a two-semester experience in which students in multinational cohorts spend one semester at one of the partner institutions abroad. One unique element is the two-semester global design project carried out by the global teams. GEARE's comprehensive approach allows students to become globally and culturally fluent at the same time that they are developing more traditional technical and professional skills.[12]

There are few long-term quantitative data on the effects of taking part in study-abroad programs, but there is some evidence that science and engineering students who study abroad are more likely to continue their education beyond the undergraduate level and more likely to remain in science and engineering fields. Despite positive feedback from students involved in these programs, the rate of study-abroad participation continues to grow slowly among science and engineering students. Workshop participants discussed a number of factors, including the cost, language barriers and the difficulty of gaining credit for science and engineering classes taken at foreign universities. One final barrier is that universities, for the most part, have not yet made the effort to convince students of the importance of international education, and programs such as those at WPI, the University of Washington and Purdue remain isolated models rather than a normal part of the training of a scientist or engineer. The success of the programs outlined above is due largely to the commitment made by the participating universities. It will take this type of commitment, but on a national rather than local scale, to make global competence the norm rather than the exception.

Recommendations and Conclusion

Scientists and engineers in the United States have always been on the cutting edge of new technologies and research. But as Thomas Kuhn famously argued in this book *The Structure of Scientific Revolutions*, scientists have also long been resistant to changes in the way science is conducted.[13] Having researchers who are able to take an active role in a global economy is imperative, but it will not be easy to change the culture of science and engineering training to make global competence a fundamental component of the curriculum.

Participants in the Sigma Xi workshop made more than 40 recommendations for education, research and industry to try to move toward that goal. (A list of some of the most important recommendations appears on the next page, and a complete list can be found in the full report, which is available online at www.sigmaxi.org/global.) The most essential recommendations include embedding elements that promote global competence at all educational levels, from elementary school through continuing education; promoting international collaboration at U.S. universities so that it is considered the rule rather than the exception; creating and promoting technologies that facilitate global engagement; and building strong ties between government agencies, universities and industry toward the common goal of creating a workforce that can meet the demands of globalization.

What needs to be done, above all else, is to change the culture of the U.S. science and engineering community so that global competence is recognized as a fundamental component of the training of a successful scientist or engineer. High-skilled workers in technology fields are integral parts of a successful economy, more so today than ever before. Ensuring that the U.S. science and engineering workforce is globally competent will take a considerable investment of time and money, but the return on that investment in economic and social well-being will be well worth it.

1 National Association of State Universities and Land Grant Colleges, *A Call to Leadership: The Presidential Role in Internationalizing the University* (Washington, D.C.: NASULGC, 2004).

2 National Science Foundation, *Science and Engineering Indicators 2006* (Arlington, VA: National Science Foundation, 2006).

3 Open Doors Online: Report on International Educational Exchange, Web site of the Institute of International Education, http://opendoors.iienetwork.org/.

4 National Science Foundation, 2006.

5 Asia Society, *Math and Science Education in a Global Age: What the U.S. Can Learn from China* (New York: Asia Society, 2006).

6 National Science Foundation, 2006.

7 AnnaLee Saxenian, Brain Circulation: How High-Skill Immigration Makes Everyone Better Off, *The Brookings Review* 20, no. 1 (Winter 2002): 28–31.

8 Gary Downey, *et al.*, The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently, *Journal of Engineering Education* 95 (April 2006): 1–16.

9 http://www.globalseminar.org

10 http://www.wpi.edu/Academics/Depts/IGSD

11 http://www.washington.edu/home/international/academics/environment.html

12 http://tools.ecn.purdue.edu/ME/GEARE

13 Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962).

"Let us work together to create the next generation of science and engineering curriculum that will make our science and engineering workforce more effective, more innovative and more creative"

Indira V. Samarasekera, keynote address at "Assuring a Globally Engaged Science and Engineering Workforce"

Select Recommendations for Achieving Global Competence

Recommendations to the National Science Foundation

- Embed global competence skills sets in all of the Foundation's research and education programs.
- Sponsor programs in which members of industry, government and academia can discuss together how to achieve global competence.
- Work to convince the public and policymakers of the importance of achieving global competence.
- Promote the adoption of proven models of global engagement at academic institutions nationwide.

Recommendations for Research and Education

- Create opportunities for math and science teachers to study how their subjects are taught in other countries, particularly those where students perform better on tests of math and science than U.S. students.
- Integrate global competence into the core curriculum.
- Support involvement in multinational and multidisciplinary research by students and faculty.
- Examine how information and communications technology can be used to promote global engagement.
- Develop indicators of global competence among scientists and engineers.
- Support long-term studies that examine the potential benefits for students of taking part in international collaborations.

Recommendations for Industry

- Create partnerships with schools to promote teacher training, curriculum development, mentoring and extracurricular activities that involve global engagement.
- Work with community colleges to develop curriculums that meet the needs of the science and engineering workforce.

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The full report can be found at www.sigmaxi.org/global

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