U.S. Competitiveness: The Education Imperative

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U.S. competitiveness and the country's standing among our global counterparts have been persistent issues in public policy debates for the past 20 years. Most recently they have come to prominence with the publication of reports from the National Academies, the Electronics Industries Alliance, and the Council on Competitiveness, each of which argues that the United States is in danger of losing out in the economic competition of the 21st century.

There is no single cause for the concerns being raised, and there is no single policy prescription available to address them. However, there is widespread agreement that one necessary condition for ensuring future economic success and a sustained high standard of living for our citizens is an education system that provides each of them with a solid grounding in math and science and prepares students to succeed in science and engineering careers.

Unless the United States maintains its edge in innovation, which is founded on a well-trained creative workforce, the best jobs may soon be found overseas. If current trends continue, along with a lack of action, today's children may grow up with a lower standard of living than their parents. Providing high-quality jobs for hard-working Americans must be our first priority. Indeed, it should be the central goal of any policy in Congress to advance U.S. competitiveness.

The United States is in direct competition with countries that recognize the importance of developing their human resources. The numbers and quality of scientists and engineers being educated elsewhere, notably in China and India, continue to increase, and the capabilities of broadband communications networks make access to scientific and engineering talent possible wherever it exists. The result is that U.S. scientists and engineers must compete against their counterparts in other countries, where living standards and wages are often well below those of the United States. Policies for maintaining U.S. competitiveness must consider how to ensure that U.S. scientists and engineers are educated to have the skills and abilities that will be in demand by industry and will allow them to command salaries that will sustain our current living standards.

Because the foundation for future success is a well-educated workforce, the necessary first step in any competitiveness agenda is to improve science and mathematics education. Unfortunately, all indications are that the United States has some distance to go in preparing students for academic success in college-level courses in science, mathematics, and engineering. Current data show that U.S. students seem to be less prepared than their foreign contemporaries.

The National Assessment of Educational Progress (NAEP), often referred to as the nation's report card, has tracked the academic performance of U.S. students for the past 35 years. Achievement levels are set at the basic (partial mastery of the knowledge and skills needed to perform proficiently at each grade level), proficient, and advanced levels. Although student performance in mathematics improved between 1990 and 2000, most students do not perform at the proficient level. In the NAEP assessment for grades 4 and 8 in 2003 and for grade 12 in 2000, only about one-third of 4th- and 8th-grade students and 16% of 12th-grade students reached the proficient level.

In science, progress has also been slow. Between 1996 and 2000, average NAEP science scores for grades 4 and 8 did not change, and grade 12 scores declined. For grades 4 and 8 in 2000, only about one-third of 4th- and 8th-grade students achieved the proficient level, and only 18% achieved that level by grade 12.

The United States also fares poorly in international comparisons of student performance in science and mathematics, such as the Program for International Student Assessment (PISA), which is coordinated by the Organization for Economic Cooperation and Development (OECD). PISA focuses on the reading, mathematics, and science capabilities of 15-year-olds and seeks to assess how well students apply their knowledge and skills to problems they may encounter outside of a classroom. In the recently released 2003 PISA results, U.S. students, compared with contemporaries in 49 industrial countries, ranked 19th in science and 24th in mathematics. U.S. students' average science scores did not change from the first PISA assessment in 2000, whereas student scores increased in several OECD countries. Consequently, the relative position of U.S. students declined as compared with the OECD average.

A separate set of international comparisons-the Third International Mathematics and Science Study (TIMSS)-tracked the performance of students in three age groups from 45 countries. Although U.S. 4th-grade students performed quite well (above the international average in both mathematics and science), by the 8th grade, U.S. students scored only slightly above the international average in science and below the average in mathematics. By the 12th grade, U.S. students dropped to the bottom, outperforming only Cyprus and South Africa. The TIMSS results suggest that U.S. students actually do worse in science and mathematics comparisons the longer they stay in school.

Boosting teacher expertise

Although these findings are not encouraging and there are no simple answers for how to improve K-12 science and mathematics education, doing nothing is not an option. The place to start is to reduce the number of out-of-field teachers. Research has indicated that teachers play a critical role in students' academic performance. It is unlikely that students will be proficient in science and mathematics if they are taught by teachers who have poor knowledge of their subjects.

The urgency of solving this problem is evident. For example, 69% of middle-school students are taught by math teachers with neither a college major in math nor a certificate to teach math. 93% of those same students are also taught physical science by teachers with no major or certificate. Although the situation at the high-school level improves, even there 31% of students are taught by math teachers with neither a college major in math nor a certificate to teach math. Likewise, 67% of high-school physics students are taught by similarly unqualified teachers.

Even teachers with basic science or mathematics proficiency may still be poorly prepared to teach these subjects. In a 1997 speech, Bruce Alberts, then president of the National Academy of Sciences (NAS), pointed out that one of the most informative parts of the TIMSS survey was a series of videotapes showing randomly selected teachers from the United States and Japan teaching 8th-grade math classes. The results of expert reviews of the taped classes found that none of the 100 U.S. teachers surveyed had taught a high-quality lesson and that 80% of the U.S. lessons, compared with 13% of the Japanese, received the lowest rating. Clearly, content knowledge must be combined with pedagogical skill to achieve the best educational outcomes.

In 2005, I and several of my colleagues on the House Science and Technology Committee asked NAS to carry out an assessment of the United States' ability to compete and prosper in the 21st century. In particular, we asked NAS to chart a course forward, including the key actions necessary for creating a vital, robust U.S. economy with well-paying jobs for our citizens. NAS formed a panel of business and academic leaders ably chaired by Norm Augustine, the former chairman of Lockheed Martin. The panel conducted a study that was neither partisan nor narrow and subsequently released a report in the fall of 2005 called Rising Above the Gathering Storm.

The NAS report outlines a number of actions to improve the U.S. innovation environment. Its highest-priority recommendation addresses teachers. In particular, the report states that "laying the foundation for a scientifically literate workforce begins with developing outstanding K-12 teachers in science and mathematics." The report calls for recruiting 10,000 of the best and brightest students into the teaching profession each year and supporting them with scholarships to obtain bachelor's degrees in science, engineering, or mathematics, with concurrent certification as K-12 science or mathematics teachers.

I believe the report was right on target in identifying teachers as the first priority for ensuring a brighter economic future. To implement the recommendations, I introduced legislation in the last Congress, which was approved by the House Science and Technology Committee, and have introduced largely similar legislation in the current Congress (H.R. 362).

The legislation provides generous scholarship support to science, mathematics, and engineering majors willing to pursue teaching careers, but even more important, it provides grants to universities to assist them in changing the way they educate science and mathematics teachers. It is not sufficient just to encourage these students to take enough off-the-shelf education courses to enable them to qualify for a teaching certificate. Colleges and universities must foster collaborations between science and education faculties, with the specific goal of developing courses designed to provide students with practical experience in how to teach science and mathematics effectively based on current knowledge of how individuals learn these subjects. In addition to early experience in the classroom, students should receive mentoring by experienced and expert teachers before and after graduation, which can be especially helpful in stemming the current trend in which teachers leave the profession after short tenures. Teachers who emerge from the program would combine deep knowledge of their subject with expertise in the most effective practices for teaching science or mathematics.

This approach is modeled on the successful UTEACH program, pioneered by the University of Texas (UT), which features the recruitment of science majors, highly relevant courses focused on teaching science and mathematics, early and intensive field teaching experiences, mentoring by experienced and expert teachers, and paid internships for students in the program.

The UTEACH program, which began as a pilot effort in 1997 with 28 students, has grown to more than 400 students per year. It has been successful in attracting top-performing science and mathematics majors to teaching careers. UTEACH students have average SAT scores and grade point averages that exceed the averages for all students in UT's College of Natural Sciences. Moreover, a high proportion of graduates from the program remain in the classroom. 75% of UTEACH graduates are still teaching five years past graduation, which is well above the national average of 50%.

In addition to improving the education of new teachers, my legislation provides professional development opportunities for current teachers to improve their content knowledge and pedagogical skills. The activities authorized include part-time master's degree programs tailored for in-service teachers and summer teacher institutes and training programs that prepare teachers to teach Advanced Placement and International Baccalaureate courses in science and mathematics.

NSF's key role

The legislation I authored would house most of these education programs at the National Science Foundation (NSF). I strongly believe that NSF's role is key to success because of the agency's long history of accomplishment in this area, its close relationship with the best scientists and engineers in the nation, and its prestige among academics and educators in math and science education, which is unmatched by any other federal agency.

The effectiveness of NSF programs in attracting the participation of science, math, and engineering faculty in K-12 science and mathematics education initiatives is demonstrated by the NSF Mathematics and Science Partnership (MSP) program, which aims to improve science and mathematics education through research and demonstration projects to enhance teacher performance, improve pedagogical practices, and develop more effective curricular materials. The program focuses on activities that will promote institutional and organizational change both at universities and in local school districts. It is highly competitive, with a funding rate of 8% in the 2006 proposal cycle. Through the summer of 2006, the program has funded 72 partnerships involving more than 150 institutions of higher education, more than 500 school districts, more than 135,000 teachers, and more than 4.1 million students. Approximately 50 businesses have also participated as corporate partners.

A major component of the MSP program is teacher professional development. Grant awards under the program require substantial leadership from disciplinary faculty in collaboration with education faculty. Of the 1,200 university faculty members who have been involved with MSPs, 69% are disciplinary faculty, with the remainder principally from education schools.

The MSP grants are large enough to allow the awardees to implement substantial, sustained, and thorough professional teacher development activities. For example, the Math Science Partnership of Greater Philadelphia involves 13 institutions of higher education and 46 school districts. This partnership targets teachers of grades 6 through 12, spanning the full breadth of mathematics and science courses and encompassing a wide geographical region, with a focus on the densely populated Philadelphia suburbs.

The preliminary assessment data for the MSP program show that the performance of students whose teachers are engaged in an MSP program improves significantly. Initial findings from nine MSP programs, involving more than 20,000 students, shows that 14.2% more high-school students were rated at or above the proficient level in mathematics after one year with a teacher in an MSP program. This reverses the national trend in which a declining number of students achieve this rating each year. Not all of the preliminary data show such dramatic improvement: The corresponding figure for middle-school students is 4.3%, and the first data evaluating improvement in science suggest that gains are more modest than they are in mathematics.

It is too soon to expect final evaluations of the MSP partnerships. The goal of all teacher professional development is to improve student performance, but there is a substantial time lag between announcing an MSP grant program and the final analysis of data measuring student improvement. Even among partnerships funded in the first year, many are still working with their first cohorts of teachers. However, the initial data trends are promising.

The main lessons from the MSP program thus far are that it has succeeded in attracting substantial participation by science, mathematics, and engineering faculty, along with education faculty; it has generated widespread interest in participation; and it shows preliminary success in reaching the main goal of improved student performance. NSF's track record shows it is the right place to house the proposed program to improve the education of new K-12 science and mathematics teachers.

Solving the attrition problem

The programs I have described for increasing the number of highly qualified science and mathematics teachers address the long-term problem of ensuring that the nation produces future generations of scientists, engineers, and technicians, as well as a citizenry equipped to function in a technologically advanced society. But there is also the problem of ensuring adequate numbers of graduates in science and technology (S&T) fields in the near term.

The legislation I plan to move through the Committee on Science and Technology in this Congress includes provisions aimed at improving undergraduate science, technology, engineering, and mathematics (STEM) education with the goal of attracting students to these fields and keeping them engaged. A serious problem with undergraduate STEM education is high student attrition. In most instances, attrition is not because of an inability to perform academically, but because of a loss of interest and enthusiasm.

This leak in the STEM education pipeline can be addressed in many ways. Certainly, increased attention by faculty to undergraduate teaching and the development of more effective teaching methods will help. In addition, there is a role for industry and federal labs to partner with universities for activities such as providing undergraduate research experiences, student mentoring, and summer internships.

The murky supply and demand picture

Although a well-educated S&T workforce of adequate size is generally regarded as an essential component of technological innovation and international economic competitiveness, there is disagreement and uncertainty about whether the current supply and demand for such workers is in balance and about the prospects for the future ability of the nation to meet its needs for such workers. The supply part of the equation centers on whether our education system is motivating and preparing a sufficient number of students to pursue training in these fields and whether the country will be able to continue to attract talented foreign students to fill openings in the S&T workforce, a third of which is currently made up of individuals from abroad. The demand side of the equation is clouded by increasing evidence that technical jobs are migrating from the United States.

In general, the migration of high-tech jobs mirrors what has happened in the manufacturing sector during the past 20 years. In the case of manufacturing, the decline in U.S.-based jobs has been attributed to lower production costs in low-wage countries, improved infrastructure in foreign countries, and the increased productivity of foreign workers. Now this same trend is encompassing high-tech jobs, which generally require a technical education, often for the very same reasons.

The overseas migration of manufacturing led to a deep restructuring of the hourly workforce: a switch to service jobs with generally lower wages and benefits and an increase in temporary workers. The trend for technical workers could result in similar dislocations of currently employed scientists and engineers and affect future employment opportunities. In addition, it is likely that current well-publicized trends will influence the career choices of students-a result that could accelerate the migration of jobs.

Some policy groups have advocated training more scientists and engineers to ensure that the nation can meet future demand and as a solution to the offshoring phenomenon. Advocates frequently cite increased graduation rates of scientists and engineers in China and India as one justification of this policy. Industry also frequently states that there is a shortage of trained scientists and engineers in the United States, forcing them to move jobs overseas that would otherwise remain here. In addition, these groups claim that we need to train more scientists and engineers to maintain U.S. technology leadership, which will result in greater domestic employment across the board. However, many professional societies and organizations (representing scientists and engineers) dispute these assessments.

Regardless of viewpoint, the most remarkable aspect of the debate about the supply and demand for S&T workers and the effects of offshoring is that the arguments are based on very little factual data. A recent RAND report, commissioned by the President's Office of Science and Technology Policy, pointed out that the information available to policymakers, students, and professional workers is not adequate to make informed decisions either about policies for the S&T workforce or about individual career or training opportunities. The RAND study includes eight specific ways in which federal agencies can improve data collection in this area. Unfortunately, the Bush administration has not comprehensively enacted the RAND recommendations. A Government Accountability Office report also highlights the lack of data on the extent and policy consequences of offshoring.

At a roundtable discussion on June 23, 2005, the Democratic members of the Committee on Science and Technology attempted to frame what is known and not known about supply and demand for the U.S. S&T workforce; to delineate factors that influence supply and demand, including the offshoring of S&T jobs; and to explore policy options necessary to ensure the existence of an S&T workforce in the future that meets the needs of the nation. (The papers presented at the roundtable are available on the committee's Web site.)

On the basis of available data on unemployment levels and inflation-adjusted salary trends of S&T workers, Michael Teitelbaum of the Alfred P. Sloan Foundation and Ron Hira of Rochester Institute of Technology concluded that no evidence exists for a shortage; in fact, the available data suggest that a surplus may exist. For example, Institute of Electrical and Electronics Engineers surveys of their membership show higher levels of unemployment during the past five years than for any similar time period during which such surveys have been conducted (starting in 1973) and also show salary declines in 2003 for the first time in 31 years of surveys. Teitelbaum indicated that there may well be exceptions in demand for some subfields that are not captured by available data, and Dave McCurdy, president of the Electronics Industries Alliance, said that it is necessary to look industry by industry in assessing the actual state of shortage or surplus.

Discussion of the effects of offshoring on the S&T workforce is constrained by the lack of reliable and complete data. However, the data that are available suggest that offshoring is growing and becoming significant. Hira compared data for major U.S. and Indian information technology (IT) services companies that showed significant differences for employee growth in 2004: up 45% for Wipro, up 43% for Infosys, and up 66% for Cognizant (three Indian companies) versus an 11% decline for Electronic Data Systems, no growth for Computer Sciences Corporation, and an 8% increase for Affiliated Computer Services (three U.S. companies).

Hira also described examples of high-level engineering design jobs moving offshore and provided anecdotal evidence that venture capitalists are beginning to pressure start-up companies to include offshoring in their business plans. As an indirect indicator of the increase in offshoring, Teitelbaum presented unpublished data from a study funded by the Sloan Foundation that showed substantial growth in Indian employment in software export companies (from 110,000 to 345,000 between 1999-2000 and 2004-2005) and in IT-enabled services companies (from 42,000 to 348,000 for the same interval).

The panelists agreed that the data available for characterizing the S&T workforce and for quantifying the impact of offshoring are inadequate. George Langford, the immediate past president of the National Science Board Committee on Education and Human Resources, noted the need for better information on science and engineering skill needs and on utilization of scientists and engineers. Both Hira and Teitelbaum suggested the need for government tracking of the volume and nature of jobs moving offshore, and particularly services jobs, for which little reliable data is available.

The policy recommendations from the roundtable fell into two areas. The first was that better data are needed to characterize the state of the S&T workforce and particularly to quantify the nature and extent of the migration of S&T jobs. This recommendation was shared by all the panelists.

The second set of recommendations focused on education and training. The thrust of these recommendations was that U.S. S&T workers will need to acquire skills that will differentiate them from their foreign competitors. This implies the need to identify the kinds of skills valued by industry and the need for much better information about the skill sets that industry can easily acquire abroad. This information should then inform the reformulation of science and engineering degree programs by institutions of higher education. In addition, the identification of skills requirements will allow the creation of effective retraining programs for S&T workers displaced by offshoring.

Finally, the panelists agreed that it is necessary to make careers in S&T more appealing to students. Specific recommendations included funding undergraduate scholarships and generous graduate fellowship programs and providing paid internships in industry.

There is much that the federal government, states, and the private sector can do in partnership to bring about the result we all seek: ensuring that the United States succeeds in the global economic competition. I believe that the Gathering Storm report provides an excellent blueprint for action. The question is simply this: Are we willing to invest in our children's future? I know that I am not alone in answering "yes" to that question. We know what the problem is and we have solutions. What we need now is the will to stop talking and start taking substantive action.

Recommended reading

Committee on Science and Technology, U.S. House of Representatives, http://science.house.gov/investigations/ investigations_detail.aspx?NewsID=1167.

Council on Competitiveness, Innovate America: National Innovation Summit and Report: Thriving in a World of Challenge and Change (Washington, DC, 2004).

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National Center for Education Statistics, Qualifications of the Public School Teacher Workforce: Prevalence of Out-Of-Field Teaching 1987-1988 to 1999-2000 (U.S. Department of Education, Washington, DC, 2003).

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UTEACH program at the University of Texas, http:// uteach.utexas.edu/

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