Science, Engineering, and Mathematics Education: Status and Issues

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Summary

An important aspect of U.S. efforts to maintain and improve economic competitiveness is the existence of a capable scientific and technological workforce. A major concern of the 111th Congress may be regarding the future ability of the U.S. science and engineering base to generate the technological advances needed to maintain economic growth. Discussions have centered on the quality of science and mathematics education and training and on the scientific knowledge of those students entering other disciplines. Even students pursuing nonscientific and nonmathematical specialities are likely to require basic knowledge of scientific and technological applications for effective participation in the workforce. Charges are being made that many students complete high school scientifically and technologically illiterate.

Precollege science and mathematics instruction has an important relationship to the future supply of U.S. scientific and technological personnel and to the general scientific literacy of the nation. However, several published reports indicate important shortcomings in science, technology, engineering, and mathematics education (STEM) and achievement of U.S. students at the precollege level. Some findings in the reports revealed that many science and mathematics teachers do not have a major in the discipline being taught; and that U.S. students, themselves, on international measures, perform less well than their international counterparts.

A September 2006 report on the future of higher education states that while our colleges and universities have much to applaud for in their achievements, there are some areas where reforms are needed. As higher education has evolved, it simultaneously has had to respond to the impact of globalization, rapidly evolving technologies, the changing needs of a knowledge economy, and a population that is increasingly older and more diverse.

In the 21st century, a larger proportion of the U.S. population will be composed of certain minorities—blacks, Hispanics, and Native Americans. As a group, these minorities have traditionally been underrepresented in the science and engineering disciplines compared to their proportion of the total population. A report of the National Science Foundation (NSF) reveals that blacks, Hispanics, and Native Americans as a whole comprise more that 25% of the population and earn, as a whole, 16.2% of the bachelor degrees, 10.7% of the masters degrees, and 5.4% of the doctorate degrees in science and engineering.

Legislation introduced during the 111th Congress in support of science and mathematics education includes H.R. 1709, STEM Education Coordination Act of 2009. This bill would establish a committee under the National Science and Technology Council with the responsibility of coordinating STEM activities and programs for all federal agencies. The committee would provide a description for the role of each agency in supporting programs and activities designed to achieve annual and long-term objectives. H.R. 461, 10,000 Trained by 2010 Act, would authorize funding for competitive grants to generate innovative approaches in the health care information fields. The bill would establish or improve undergraduate and master's degree health care information programs, attract students to such programs, and provide students with discipline-related experiences at the federal level or in the private sector.

This report will be updated as events warrant.

Contents

Contacts

Background

An important aspect of U.S. efforts to improve economic competitiveness is the existence of a capable scientific and technological workforce. Concern has been expressed about the future ability of the U.S. science and engineering base to generate the technological advances needed to maintain economic growth.[1] Some discussions have centered on the quality of science and mathematics undergraduate education and training. The design and structure of the scientific curriculum are thought to discourage a number of highly qualified students from entering and remaining in the disciplines.[2] Other discussions have focused on the scientific knowledge of those students entering other disciplines. Even students pursuing nonscientific and nonmathematical specialties will require basic knowledge of scientific and technological applications and mathematical reasoning in order to adapt to constant changes in the labor market.[3]

Precollege science and mathematics instruction also has an important relationship to the future supply of U.S. scientific and technical personnel. A basic science and mathematics education is considered necessary not only for those who will enter science as majors, but for all citizens to understand scientific and technical issues that affect their lives. However, several indicators of the performance of U.S. students in science and mathematics education at the precollege level reveal a mixed picture of successes and shortcomings.[4] Still other indicators show that the science and mathematics curriculum at the precollege level is unfocused and that many science and mathematics teachers lack a major or minor in the subject area being taught.[5]

Reform efforts at improving precollege science and mathematics education have included the development of recommended national standards. Such standards describe what children should know, when they should know it, and how to assess what they know. These standards emphasize inquiry based education as being the most effective in retaining the interest of all students. While many states and school districts have created new science and mathematics standards that to some degree are drawn from standards of the National Council of Teachers of Mathematics and the

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[1] See for example The National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, Committee on Science, Engineering, and Public Policy, Washington, DC, National Academy Press, 2007, 664 pp., RAND Corporation, National Defense Research Institute, Titus Galama and James Hosek, *U.S. Competitiveness in Science and Technology*, June 2008, 155 pp, Noyes, Andrew, "DHS Official Warns U.S. Workforce Faces Skills 'Crisis'," Congress Daily PM, June 16, 2008, http://www.nationaljournal.com/congressdaily/print_friendly.php?ID=cdp_20080616_9335, and Augustine, Norman R., "Living Off Past Investments," *Education Week*, vol. 26, January 7, 2007, p. 28.

[2] National Science Board, *Science and Engineering Indicators 2008*, Volume 1, NSB08-01, Arlington, VA, January 15, 2008, pp. 2-22 - 2-24.

[3] See for example Cavanagh, Sean, "Frustrations Give Rise to New Push for Science Literacy," *Education Week*, vol. 27, March 5, 2008, p. 12, The National Academies, *Research on Future Skill Demands: A Workshop Summary*, Division of Behavioral and Social Science and Education, Washington, DC, National Academy Press, 2008, 126 pp., and National Center on Education and the Economy, *Tough Choices or Tough Times, The Report of the New Commission on the Skills of the American Workforce*, Executive Summary, January 2007, 26 pp.

[4] Department of Education, National Center for Education Statistics, *Highlights From the Third International Mathematics and Science Study (TIMSS) 2003*, NCES2005-005, Washington, DC, December 2004, pp. 1-25.

[5] See for example the Department of Education, National Center for Education Statistics, *Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987-88 to 1999-2000*, NCES 2002-603 Revised, Washington, DC, August 2004, 92 pp, and Ingersoll, Richard M., "Out of Field Teaching and the Limits of Teacher Policy," A Research Report Sponsored by the Center for the Study of Teaching and Policy and The Consortium for Policy Research in Education, September 2003, 29 pp.

National Research Council, adoption and implementation of the standards at the local school level where there is often limited resources and unprepared teachers has proven to be problematic.[6]

The change from a labor-based manufacturing to a knowledge-based manufacturing and service economy demands certain skills of our citizenry.[7] The National Science Foundation (NSF) projects that in the increasingly changing context for science and technology, a workforce trained in the sciences and engineering is necessary for continued economic growth. A May 2007 report of the Department of Education states that:

> There is increasing concern about U.S. economic competitiveness, particularly the future ability of the nation's education institutions to produce citizens literate in STEM concepts and to produce future scientists, engineers, mathematicians, and technologists. Such experts are needed to maintain U.S. preeminence in science, technology, engineering and mathematics. While other countries around the world strive to improve their own education systems and to expand their economies, the U.S. will have to work even harder in the coming years to maintain its competitive edge.[8]

In this report, selected science and education issues are presented, along with a summary of findings from various studies. The issues discussed include precollege science and mathematics concerns; improving undergraduate and graduate education; demographics and the science and engineering talent pool; foreign science and engineering students; and congressional activity. For expanded discussion of science and mathematics education issues see CRS Report RL34539, *The U.S. Science and Technology Workforce*, by (name redacted) and (name redacted), and CRS Report RL33434, *Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action*, by (name redacted). This report will be updated as events warrant.

Precollege Science and Mathematics Concerns

Precollege (K-12) science and mathematics instruction has an important relationship to the future supply of U.S. scientific and technological personnel. The technological demands of the workforce are increasing exponentially. A basic science and mathematics education is necessary not only for those who will enter science as majors, but for all citizens to understand scientific and technical issues that affect their lives. In addition, scientific and technical skills are a requirement for an increasingly wide range of occupations such as health care, banking, insurance, and energy production. Whether individuals are in the service sector, manufacturing, government, or management, many believe that some level of scientific literacy is required.

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[6] The National Academies, Division of Behavioral and Social Sciences and Education, Hollweg, Karen S. and David Hill, *What is the Influence of the National Science Education Standards?: Reviewing the Evidence, A Workshop Summary*, Washington, DC, 2003, 208 pp.

[7] Deitz, Richard and James Orr, "A Leaner, More Skilled U. S. Manufacturing Workforce," *Current Issues in Economics and Finance*, vol. 12, February/March 2006, 7 pp., and Olson, Lynn, "Economic Trends Fuel Push to Retool Schooling," *Education Week*, vol. 25, March 22, 2006, pp. 1, 20, 22, 24, The Task Force on the Future of American Innovation, "*The Knowledge Economy: Is the United States Losing Its Competitive Edge?*," February 16, 2005, 16 pp.

[8] Department of Education, *Report of the Academic Competitiveness Council*, Washington, DC, May 2007, p. 5.

The term "reform" is repeated throughout discussions of science education at the precollege level, covering such issues as: school curriculum and the quality of science instruction, student interest in science, the shortage of qualified teachers, teacher training and retraining, student achievement on science and mathematics measures, and the participation of minorities and women in science.[9] The U.S. educational system has a long history of attempted education reforms. One particular report that received considerable attention was released in 1983 by the Department of Education (ED). The report, *A Nation At Risk*, attacked the school system, declaring that U.S. schools were sinking under a "rising tide of mediocrity," partly as a result of a shortage of qualified teachers in science, mathematics, and other essential disciplines.[10] More than 25 years after the report, there is some debate as to whether or not our educational system is still "at risk."[11]

Reforms in science and mathematics education have focused on both what to teach and how to teach it. A 1998 publication of the American Association for the Advancement of Science (AAAS), *Blueprints for Reform - Science, Mathematics, and Technology Education*, presented goals for science, mathematics, and technology literacy.[12] The goals offered multidisciplinary instructions in the real world, structured so students would use the discovery process to study issues that are multidimensional, to arrive at alternative approaches, and to be able to anticipate both positive and negative consequences of their choices.

In 2000, the National Council of Teachers of Mathematics (NCTM) released a revised *Principles and Standards for School Mathematics*, which described how students should be taught to solve non-routine problems in meaningful context.[13] The NCTM standards promoted the policy of students learning through induction rather than memorization, directing the instructional process on inquiry[14] as opposed to the traditional tell-and-test approach, and promoting assessment methods that are open-ended instead of machine-scoreable. More recently, a 2005 report of the Fordham Institute states that "While state standards are very much in flux, the nation, in its

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[9] See for example Story, Jamie, Brooke Dollens Terry, and Beau Tyler, "Math and Science Reform Agenda," *Policy Perspective*, Texas Public Policy Foundation, Center for Education Policy, October 2007, 7 pp., Banilower, Eric R., Sally E. Boyd, Joan D. Pasley, and Iris R. Weiss, Lessons From a Decade of Mathematics and Science Reform, Prepared for the National Science Foundation by Horizon Research, Inc., December 2006, 78 pp., and Echevarria, Marissa, "Hands on Science Reform, Science Achievement, and the Elusive Goal of 'Science for All' in a Diverse Elementary School District," *Journal of Women and Minorities in Science and Engineering*, vol. 9, no. 3 and 4, 2003, pp. 375-402.

[10] Department of Education, *A Nation At Risk: The Imperative for Education Reform, A Report to the Nation and the Secretary of Education*, Washington, 1983, 65 pp.

[11] See for example Kirsch, Irwin, Henry Braun, Kentaro Yamamoto, and Andrew Sum, *America's Perfect Storm: Three Forces Changing Our Nation's Future*, A report of the Educational Testing Service, Policy Information Center, January 2007, pp. 8-10, Thornburgh, Nathan, "Dropout Nation," *Time*, April 17, 2006, pp. 32-40, Anderson, James, and Dara N. Byrne, "The Unfinished Agenda of Brown v. Board of Education," *Black Issues in Higher Education*, 2004, 222 pp., and "Fifty Years After Brown," *U.S. News & World Report*, March 22, 2004, pp. 64-95.

[12] American Association for the Advancement of Science, *Blueprints for Reform - Science, Mathematics, and Technology Education*, Project 2016, Washington, 1998, 299 pp.

[13] National Council of Teachers of Mathematics, Commission on Teaching Standards, *Principles and Standards for School Mathematics*, Reston, VA, July 28, 2000, 402 pp.

[14] "Inquiry is a multifaceted activity that involves looking for patterns; making observations; posing questions; looking for and thinking about relationships; examining other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results." "Inquiry-Based Instruction," http://www.nyssi.org/nyssi/nyssib.htm.

entirety, is neither making progress nor losing ground when it comes to its expectations for what students should learn in science."[15]

The ongoing discussions of reform in science education stressed the importance of inquiry-based instruction as the most beneficial in assisting students to think critically, to work independently or cooperatively, and to solve problems as they encounter them in different and novel situations.[16] In 2002, the National Research Council released its publication, *Investigating the Influence of Standards, A Framework for Research in Mathematics, Science, and Technology Education.*[17] The report examined two primary questions: (1) How has the system responded to the introduction of nationally developed mathematics, science, and technology standards?, and (2) What are the consequences for student learning? The report offered guideposts for determining the influence of nationally developed science, mathematics, and technology standards and evaluates the significance of the influence on student learning, on teachers and pedagogy, and on the education system as a whole.

A 2007 publication of The National Academies, *Taking Science to School*, states that there are four recommended goals of science education.[18] They are to:

1. know, use, and interpret scientific explanations of the natural world;
2. generate and evaluate scientific evidence and explanations;
3. understand the nature and development of scientific knowledge; and
4. participate productively in scientific practices and discourse.[19]

It has been found that many science instructors, at the precollege and the college level, do not focus on all of the recommended goals. Bruce Alberts, Editor-in-Chief, *Science*, states that: "[A]ll four types of science understanding are critical not only to a good science education but also to the basic education of everyone in the modern world."[20]

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[15] Gross, Paul R., with Ursula Goodenough, Susan Haack, Lawrence S. Lerner, Martha Schwartz, and Richard Schwartz, Thomas B. Fordham Institute, *The State of Science Standards*, December 2005, p. 19, and Barton, Paul E., Educational Testing Service, Policy Information Report, *Unfinished Business: More Measured Approaches in Standards-Based Reform*, January 2005, 53 pp.

[16] See for example Duffett, Ann, Steve Farkas, Andrew J. Rotherham, and Elena Silva, *Waiting to be Won Over: Teachers Speak on the Profession, Unions, and Reform*, Education Sector Reports, May 2008, 25 pp., Cavanagh, Sean, "Science Labs: Beyond Isolationism," *Education Week*, January 10, 2007, Hanauer, David I., Deborah Jacobs-Sera, Marisa L. Pedulla, Steven G. Cresawn, Roger W. Hendrix, and Graham F. Hatfull, "Teaching Scientific Inquiry," *Science*, v. 314, December 22, 2006, pp. 1880-1881, and Teicher, Stacy A., "The Mystery of Teaching Science ... Solved!," *The Christian Science Monitor*, December 1, 2005, p. 13.

[17] National Research Council, Committee on Understanding the Influence of Standards in K-12 Science, Mathematics, and Technology Education, *Investigating the Influence of Standards, A Framework for Research in Mathematics, Science, and Technology Education*, Washington, 2002, 130 pp.

[18] The National Academies, Committee on Science Learning, Kindergarten through Eighth Grade, Duschi, Richard, A., Heidi A. Schweingruber, and Andrew W. Shouse, *Taking Science to School: Learning and Teaching Science in Grades K-8*, Washington, DC, 2007, 387 pp.

[19] Ibid., p.2.

[20] Alberts, Bruce, "Redefining Science Education," *Science*, vol. 323, January 23, 2009, p. 437.

Teacher Training and Qualifications

Many elementary teachers reportedly admit that they feel uncomfortable teaching science because they lack confidence in their knowledge about science and their understanding of scientific concepts.[21] A 2008 publication of the Education Trust reports that in the middle grades, approximately 42.0% of core academic subjects (science, mathematics, social studies, and English) are led by an out-of-field teacher.[22] In secondary schools, 17.2% of core academic classes are assigned to out-of-field teachers.[23]

Supplemental teacher training can be effective for those teachers who did not have science or mathematics education majors or who took few lecture-based science and mathematics courses in college.[24] Award-winning teachers testifying before the House Science Committee stated that in order for professional development to be effective, teachers need to be provided with proper materials and resources (internal and external to the school), training in the inquiry-based learning process, and class release time.[25] The National Academies report, *Rising Above the Gathering Storm - Energizing and Employing America for a Brighter Economic Future*, calls for the "enhanced education" of teachers at the precollege level by focusing on teacher education and professional development.[26] The report states that:

> We need to reach all K-12 science and mathematics teachers and provide them with high-quality continuing professional development opportunities—specifically those that emphasize rigorous content education. High-quality, content-driven professional

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[21] The National Commission on Teaching and Americas Future reports that teachers with the least amount of experience are generally working in urban areas—school districts that have the greatest need for qualified teachers. See also National Research Council, Division of Behavioral and Social Sciences and Education, Singer, Susan R., Margaret L. Hilton, and Heidi A. Schweingruber, *America's Lab Report, Investigations in High School Science*, Washington, DC, 2006, p. 146, Friel, Brian, "A New Sputnik Moment?," *The National Journal*, vol. 37, July 30, 2005, pp. 2452-2453, Center for the Study of Teaching and Policy, University of Washington, *Out-of-Field Teaching, Educational Inequality, and the Organization of Schools; An Exploratory Analysis*, January 2002, 32 pp. and King, Ledyard, "Richer Areas More Successful in Attracting Qualified Teachers," *USA Today*, April 24, 2006,http://www.usatoday.com/news/education/2006-04-24-education_x.htm?POE=NEWISVA.

[22] An "out-of-field teacher" is defined as one who does not possess an academic major or certification in the subject being taught. The highest rates of out-of-field teaching occur in high-poverty and high-minority schools. See also National Science Board, *Science and Engineering Indicators 2008*, Volume 1, pp. 130 – 1-31.

[23] The Education Trust, *Core Problems, Out-of-Field Teaching Persists in Key Academic Courses and High-Poverty Schools*, November 2008, p. 2. A report of the Educational Testing Service found that for both science and mathematics, students whose teachers majored or minored in the subject being taught outperformed their classmates by approximately 39% of a grade level. Educational Testing Service, Wenglinsky, Harold, *How Teaching Matters: Bringing the Classroom Back Into Discussions of Teacher Quality*, October 2000, p. 26.

[24] See Committee for Economic Development, Research and Policy Committee, *Learning for the Future - Changing the Culture of Math and Science Education to Ensure a Competitive Workforce*, May 7, 2003, pp.36-40, and National Science Board, Committee on Education and Human Resources, *The Science and Engineering Workforce - Realizing America's Potential*, NSB 03-69, August 14, 2003, pp. 31-35.

[25] House Committee on Science, *The 2004 Presidential Awardees for Excellence in Mathematics and Science Teaching: A Lesson Plan for Success*, Testimonies from the 2004 Presidential Awardees for Excellence in Mathematics and Science Teaching, 109th Cong., 1st Sess., April 14, 2005, http://www.house.gov/science/press/109/109-51.htm. See also Stanley, Marshall J., "A Veteran's View of Science Education Today," *The Review of Policy Research*, vol. 20, December 22, 2003, p. 629.

[26] The National Academies, *Rising Above the Gathering Storm - Energizing and Employing America for a Brighter Economic Future*, pp.112-135.

development has a significant effect on student performance, particularly when augmented with classroom practice, year-long mentoring, and high-quality curricular materials.[27]

Student Achievement

Various assessments and reports have documented the progress of U.S. students and their participation in science and mathematics. In September 2007, the National Assessment Governing Board[28] released the results of the National Assessment of Educational Progress (NAEP) 2007 mathematics assessment for grades 4 and 8.[29] The NAEP 2007 mathematics assessment was based on a framework that was developed through a comprehensive national consultative process. The results are reported according to three basic achievement levels—basic, proficient, and advanced.[30] The proportion of students performing at the basic and proficient levels increased for 4th and 8th grade students from 2005 to 2007. Higher percentages of black and Hispanic students, at both grade levels, scored at or above basic and proficient in 2007 than in any previous assessment. The score gap between white students and black and Hispanic students continues, but it has narrowed, primarily in grade 4.

In May 2005, the NAEP's 2005 science assessments were released.[31] The NAEP 2005 science assessment is to provide a baseline for science achievement and to assist in determining the progress being made toward strengthening science and mathematics in the U.S. school system. Similar to the mathematics assessments, results are reported at three achievement levels. Data revealed that the average scores of 4th graders rose approximately four points in comparison with 1996 and 2000. For 8th grade students, there was no significant change in overall scores in 2005 from the previous assessments.[32] For 12th graders, there was no change in performance from the administration in 2000. However, in 2005, 12th graders received lower average scores than in 1996. At this grade level, the percentage of students performing at or above the basic level, at or above the proficient level, and at the advanced level all declined since 1996. In addition, the number of students who scored below basic increased since 1996.

Several reports on the state of precollege education, especially international comparisons, have revealed that U.S. students do not perform at the level of their international counterparts. The Trends in International Mathematics and Science Study (TIMSS) for grades 4 and 8, conducted in

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[27] Ibid., p. 119.

[28] The National Assessment Governing Board is a bipartisan 26-member Board authorized by Congress to make policy for the NAEP and to measure the academic achievement of students in selected grades at the precollege level. The Board is authorized to establish performance levels in the areas of science, mathematics, reading, U.S. history, geography, and other subjects.

[29] Department of Education, Office of Education Research and Improvement, *The Nation's Report Card: Mathematics 2007*, NCES2007-494, Washington, DC, September 2007, 64 pp.

The 2007 assessment included nationally representative samples of 197,000 4th graders and 153,000 8th graders. The racial/ethnic groups are black, white, Hispanic, Native Americans/Alaska Natives, and Asian/Pacific Islanders.

[30] The basic level represents partial mastery of prerequisite knowledge and skills, the proficient level represents solid academic performance, and the advanced level denotes superior performance. These achievement levels, however, are developmental and remain in transition.

[31] Department of Education, Office of Education Research and Improvement, *The Nation's Report Card: Science 2005,* NCES 2006-466, Washington, DC, May 24, 2006, 42 pp. The assessment was administered to a representative sample of 304,800 students in grades 4, 8, and 12. The 2009 NAEP science assessment was administered to students in grades 4, 8, and 12 between January and March 2009. It is anticipated that findings will be released in the spring of 2010.

[32] Black students showed the only score increase among all racial/ethnic groups at grade 8.

2007, investigated mathematics and science curricula, instructional practices, and achievement in 59 countries (at either the 4th or 8th grade level or both).[33] Results at grade 4 showed that in mathematics, U.S. students scored higher than those in 23 of the 36 participating countries, lower than in eight countries (all eight were in Asia or Europe) and not significantly different than the average scores of students in the remaining four countries. Hong Kong SAR[34] was the top performing jurisdiction in mathematics at the 4th grade level, followed by Singapore, Chinese Taipei, Japan, Kazakhstan, Russian Federation, England, Latvia, Netherlands, and Lithuania. U.S. 8th grade students were outperformed by students in eight jurisdictions. Chinese Taipei received the top average mathematics score, followed by Korea, Singapore, Hong Kong, Japan, Hungary, England, and Russian Federation. At the 8th grade level, the average score for U.S. students exceeded those of their peers in 27 of the 48 participating countries.[35]

The results for TIMSS in science revealed that at the 4th grade level, U.S. students outperformed 25 of the other 35 participating countries. U.S. students, with a higher average score than the international average, performed less well than Singapore, Chinese Taipei, Hong Kong SAR, Japan, Russian Federation, Latvia, and England. At the 8th grade level, U.S. students again received a higher average score than the international average and outperformed their peers in 35 of the other 47 participating countries in the subset of measures. U.S. students ranked 11th, scoring below that of Singapore, Chinese Taipei, Japan, Republic of Korea, England, Hungary, Czech Republic, Slovenia, Hong Kong, and Russian Federation.[36]

Some in the education community have charged that international comparisons are statistically invalid because of widely disparate culture, diversity in school systems, and significant differences in curriculum. However, there is the counter argument that due to refinement in collection of data and methodological procedures employed in the analyses, the comparisons are valid for the student populations examined. ED estimates that the United States spends approximately $455.0 billion annually for elementary and secondary education.[37] What is puzzling to some is with that level of funding, how can the U.S. system of education with graduate schools considered to be the best in the world, a system that produces some of the best scientists and engineers, also produce some students in elementary and secondary schools who perform less well on international measures? How can the performance of U.S. students on the TIMSS be explained when some groups of students showed no measurable difference from the previous assessment, and some scored lower than the TIMSS scale average?

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[33] International Association for the Evaluation of Educational Achievement, International Study Center, Trends in International Mathematics and Science Study (TIMSS), *TIMSS 2007 International Science Report*, Michael O. Martin, Ina V.S. Mullis, and Pierre Foy, December 2008, 497 pp., and *TIMSS 2007 International Mathematics Report,* 473 pp. See also Einhorn, Bruce, "Innovation-Singapore is No. 1, Well Ahead of the U.S.," *Business Week*, March 25, 2009

[34] Hong Kong is a Special Administrative Region (SAR) of the People's Republic of China.

[35] http://nces.ed.gov/timss/table07_1.asp.

[36] http://nces.ed.gov/timss/table07_3.asp. For expanded discussion of international trends see for example Department of Education, National Center for Education Statistics, *Highlights From TIMSS 2007: Mathematics and Science Achievement of U.S. Fourth-and Eighth-Grade Students in an International Context,* NCES 20069-001, Washington, DC, December 2008, http://nces.ed.gov/pubs2009/2009001.pdf.

[37] Department of Education, National Center for Education Statistics, *Revenues and Expenditures for Public Elementary and Secondary Education: School Year 2002-2003,* NCES 2005-353R, Washington, DC, October 2005, p. 1.

Improving Undergraduate and Graduate Education

Undergraduate Education

While the uncertain job market for some scientists and engineers may have an effect on the enrollments in science and engineering, the U.S. system of higher education is called upon to continue to produce the qualified scientific and technical personnel necessary to maintain an intellectual and economic leadership.[38] Colleges and universities are facing the mounting task of better educating their undergraduate and graduate students by restructuring their curricula to increase the versatility and employability of the graduates. All disciplines have been targets, however, considerable importance is placed on graduates in the natural sciences, engineering, health sciences, computer sciences, and other quantitatively-based fields.

One challenge facing research institutions is that of finding a balance between the basic academic activities of teaching and research. Within the scientific and engineering disciplines, attempting to find the flexibility to blend the priorities of teaching and research has been a perennial problem. The standing of an institution is in direct relationship to the research productivity of its faculty, and the competition for grants and scholars has led many research institutions to place increased emphasis on research at the expense of teaching. In many research institutions, research productivity has been given more weight than teaching effectiveness when deciding tenure or promotion. Efforts are underway at some institutions to change the reward system and evaluation of their faculty members.[39]

An additional challenge for research universities is the need to address the complaints concerning undergraduate teaching. Many of these complaints are focused on the use of graduate students as teaching assistants in the undergraduate programs, especially in the science and engineering disciplines. A considerable number of undergraduate courses in science and engineering are taught by foreign graduate students who do not have a good command of the English language. *Reinventing Undergraduate Education* found that "... [T]he classroom results of employing teaching assistants who speak English poorly, as a second language, and who are new to the American system of education constitute one of the conspicuous problems of undergraduate education."[40]

In 2003, the National Research Council released the report, *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics.*[41] The report noted that colleges and universities are being held far more accountable for the education of their

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[38] See for example Jackson, Shirley Ann, President, Rensselaer Polytechnic Institute, "Intellectual Security and the Quiet Crisis," November 29, 2005, 7 pp., Freeman, Richard B., National Bureau of Economic Research, "Does Globalization of the Scientific/Engineering Workforce Threaten U. S. Economic Leadership?," Working Paper 11457, June 2005, 45 pp, http://www.nber.org/papers/w11457, and National Science Board, *An Emerging and Critical Problem of the Science and Engineering Labor Force,* NSB04-07, Arlington, VA, January 2004, pp. 1-4.

[39] O'Meara, KerryAnn, R. Eugene Rice, and Russell Edgerton, *Faculty Priorities Reconsidered: Rewarding Multiple Forms of Scholarship*, August 2005, 368 pp.

[40] Ibid., p. 7.

[41] National Research Council, Committee on Recognizing, Evaluating, Rewarding, and Developing Excellence in Teaching of Undergraduate Science, Mathematics, Engineering, and Technology, *Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics,* Editors, Fox, Marye Anne and Norman Hackerman, Washington, DC, 2003, 215 pp.

students than in the past. Institutions with peer review mechanisms to evaluate faculty research in science, mathematics, and engineering, should have the same of attention directed at evaluating the faculty teaching in those disciplines. The public and private sectors that make significant investments in university research suggested that faculty members excelling in the classroom should be recognized and rewarded similar to those faculty engaged in research.

The report recommended strategies for evaluating undergraduate teaching and learning in science, mathematics, engineering, and technology. The methods used for evaluation could serve as a basis for the professional advancement of faculty. Faculty are encouraged to set definitive goals for their students and then determine if the goals are being met. In addition to the faculty, recommendations for evaluating teaching and learning were made for presidents, boards, and academic officers; deans, department chairs and peer evaluators; and for research sponsors and granting and accrediting agencies. The recommendations were based on the following tenets:

- Effective postsecondary teaching in science, mathematics, and technology should be available to *all* students, regardless of their major.
- The design of curricula and the evaluation of teaching and learning should be collective responsibilities of faculty in individual departments or, wherever appropriate, through interdepartmental arrangements.
- Scholarly activities that focus on improving teaching and learning should be recognized as bona fide endeavors that are equivalent to other scholarly pursuits. Scholarship devoted to improving teaching effectiveness and learning should be accorded the same administrative and collegial support that is available for efforts to improve other research and service endeavors.[42]

On March 15, 2006, the House Science Committee held a hearing to explore the efforts of colleges and universities in improving their scientific and engineering programs.[43] The Committee was interested also in what role the federal government could play in encouraging more students to enter the science, mathematics, and engineering disciplines. Witnesses testified about the factors that shape the quality of undergraduate reforms in the scientific and engineering disciplines. Elaine Seymour, University of Colorado, contends that there is a decline in the perceived value of teaching. Teaching as a career is believed by many undergraduates as being of low status, pay, and prospects. Also, faculty in many institutions are more focused on research than teaching. Academic success is measured by grant writing and publications. In many science and engineering departments, a portion of faculty salary is from research grants. As a result, there is less interactive teaching by many faculty and more “straight lecturing.” Many classes become the responsibility of teaching assistants. In numerous surveys, students have indicated that “poor teaching” and “unsatisfactory learning experiences” were the primary reasons for switching majors and leaving the sciences. Seymour states that the institutional reward system and the pressure to obtain grants have consequences for both undergraduate and K-12 education in the science, mathematics, and engineering.

John Burris, President, Beloit College, testifying before the March 15 hearing, offered several recommendations as to how the federal government can identify, assess, and disseminate that

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[42] Ibid., p.2.

[43] House Committee on Science, Subcommittee on Research, *Undergraduate Science, Math and Engineering Education: What’s Working?,* 109th Cong., 2nd Sess., March 15, 2006, http://www.house.gov/science/hearings/research06/march%2015/index.htm.

which works in undergraduate science, mathematics, and engineering programs. He suggested that with the proposed doubling of the NSF budget over the next ten years,[44]there should be a doubling of the funding targeted specifically for strengthening and sustaining undergraduate programs in colleges and universities. Burris stated that "Significant parts of what works are: I) attention to how students learn; ii) an institutional culture that has a common vision about the value of building research-rich learning environments; and iii) faculty who are eager to remain engaged within their disciplinary community, and who have the resources of time and instrumentation to do so."[45] He suggested that the increased funding be directed at networks, collaborations, and partnerships. He further called for the establishment of a taskforce to oversee the proposed doubling of undergraduate funds. The task force would be charged with outlining NSF undergraduate priorities that are contained in the numerous reports calling for the federal government to strengthen and reenergize investments in science and engineering education.[46]

A September 2006 report on the future of higher education states that while our colleges and universities have much to applaud for in their achievements, there are areas where improvements are needed.[47] As higher education has evolved, it simultaneously has had to respond to the impact of globalization, rapidly evolving technologies, the changing needs of a knowledge economy, and an increasingly diverse and aging population.[48] The report notes that:

> The United States must ensure the capacity of its universities to achieve global leadership in key strategic areas such as science, engineering, medicine, and other knowledge-intensive professions. We recommend increased federal investment in areas critical to our nation's global competitiveness and a renewed commitment to attract the best and brightest minds across the nation and around the world to lead the next wave of American innovation.[49]

Graduate Education

Graduate education in science and mathematics has been the subject of several reports and committees. In the fall of 1993, the Committee on Science, Engineering, and Public Policy (COSEPUP), a joint committee of the NAS, the National Academy of Engineering, and the Institute of Medicine (IOM), proposed a comprehensive study on the status of the graduate education and research training being offered in U.S. colleges and universities. The committee's

[44] The American Competitiveness Initiative (President Bush, February 2006), and several pieces of legislation have, among other things, proposed the doubling of NSF research and related activities budget over five to 10 years.

[45] Ibid., Written testimony of John Burris, President, Beloit College, p. 5.

[46] See for example Business Roundtable, Brush, Silla, "Fixing Undergraduate Education," *U. S. News & World Report*, March 6, 2006, p. 28, *Tapping America's Potential - The Education for Innovation Initiative*, Washington, DC, July 2005, 18 pp., the Business-Higher Education Forum, *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education*, January 2005, 40 pp., Association of American Universities, *National Defense Education and Innovation Initiative, Meeting America's Economic and Security Challenges in the 21st Century*, Washington, DC, January 2006, 24 pp., and National Science Board, *America's Pressing Challenge-Building A Stronger Foundation*, NSB06-02, Arlington, VA, January 2006, 6 pp.

[47] *A Test of Leadership—Charting the Future of U.S. Higher Education*, A Report of the Commission Appointed by Secretary of Education, Margaret Spellings, September 2006, 51 pp.

[48] Ibid., p. ix. The "typical" undergraduate student is no longer 18- to 22-years old. Data reveal that of the approximately 14 million undergraduates, more than four in 10 are enrolled in community colleges, 33% are over the age of 24, and 40% are attending classes on a part-time basis. Ibid., p. viii.

[49] Ibid., p. 26.

actions led to the release of the 1995 report, *Reshaping the Graduate Education of Scientists and Engineers*. The report stated:

> The three areas of primary employment for PhD scientists and engineers—universities and colleges, industry, and government—are experiencing simultaneous change. The total effect is likely to be vastly more consequential for the employment of scientists and engineers than any previous period of transition has been.... A broader concern is that we have not, as a nation, paid adequate attention to the function of the graduate schools in meeting the country's varied needs for scientists and engineers. There is no clear human-resources policy for advanced scientists and engineers, so their education is largely a byproduct of policies that support research. The simplifying assumption has apparently been that the primary mission of graduate programs is to produce the next generation of academic researchers. In view of the broad range of ways in which scientists and engineers contribute to national needs, it is time to review how they are educated to do so."[50]

COSEPUP had solicited responses concerning the existing structure of graduate education from such groups as: postdoctoral researchers, professors, university officials, industry scientists and executives, representatives of scientific societies, and graduate students themselves. The general sentiment was that while the basic structure of graduate education was sound, some change was warranted in order to respond to "changing national policies and industrial needs."[51]

COSEPUP presented a national strategy that was intended to emphasize both versatility and information. One recommendation in the report was that graduate programs should provide a wider variety of career options for their students. This could be accomplished in a program that has a student grounded in the fundamentals of one field that is enhanced by a breadth of knowledge in a related field. Added to such a program would be off-campus experiences exposing the student to the skills requested by an increasing number of employers: the ability to communicate complex ideas, and the experiences of working in groups of interdependent workers. Another recommendation offered to foster versatility in graduate programs was to have those entities providing financial assistance to graduate students adjust their support mechanisms to include new education and training grants.

In February 1998, the National Science Board (NSB) released a policy paper—*The Federal Role in Science and Engineering Graduate and Postdoctoral Education*.[52] Some of the many issues examined by the NSB were: (1) the relative merits of fellowships and traineeships; (2) the role of graduate students as teachers; (3) the mentoring of graduate students; (4) access to faculty and time to degree; (5) and the continuing underrepresentation of minorities and women in many areas of graduate science and engineering programs. The NSB identified several areas of concern in the federal/university partnership where adjustments "may enhance the capacity of the enterprise to serve the national interest in a changing global environment."[53] The NSB noted that because of changes over the past 50 years, such as increased demand for higher education, the need to respond to advances in communications and information technology, rising tuitions and

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[50] The National Academies, *Reshaping the Graduate Education of Scientists and Engineers,* Committee on Science, Engineering, and Public Policy, Washington, DC, 1995, p. 3.

[51] Ibid., p. 40.

[52] The National Science Board, *The Federal Role in Science and Engineering Graduate and Postdoctoral Education,* Contribution to the Government/University Partnership, NSF97-235, Arlington, VA, Approved February 27, 1998, http://www.nsf.gov/nsb/documents/1997/nsb97235/nsb97235.htm.

[53] Ibid., p. 6.

administrative burdens, and stresses on universities and faculty, require changes and improvement in the federal/university partnership.

One of the stresses confronted by university partnerships, as discussed by the report, is the unintended consequences of federal policies. The increased federal investment in research and education has come with increased oversight and accountability of funding. The report states that

> The growing Federal focus on accountability tends to emphasize short-term research "products" and to de-emphasize benefits to graduate education from engaging in research at the frontiers of knowledge. Increased emphasis on accountability also may result in an increase in the perceived value of postdoctoral researchers compared with graduate students on research grants, thus reducing options for cutting-edge research experience during graduate training.[54]

The recommendations posed by the NSB placed increased emphasis on the expansion of the partnership to include a wider range of colleges and universities, the integration of research and education, increased flexibility of job opportunities outside of academia, and diversity in graduate education. It recommended that the federal government promote closer collaboration between research and non-research institutions, and to provide greater exposure to both faculty and students to research experiences and opportunities. To address the concern of the narrowness of graduate education, the report suggested that, in addition to the core training, the student should be provided with additional training options that might include interdisciplinary emphasis, teamwork, business management skills, and information technologies. The NSB proposed to reward institutions that established model programs for the integration of research and education.

A 2005 report of the Woodrow Wilson National Fellowship Foundation, *The Responsive Ph.D., Innovations in U.S. Doctoral Education*, analyzed the findings of several studies on doctoral education and detailed the most effective practices from leading doctoral institutions.[55] One of the challenges discussed in the report is the need to combine traditional research with "adventurous" scholarship within and across disciplines. Effective, inclusive, and more relevant training of the doctoral student requires extending knowledge beyond the walls of the institution and the major discipline. Also, the report contends that graduate schools require a significantly stronger central administration and structure that currently exists. A graduate school should guard against operating in isolation within an institution, and instead, create a graduate community of "intellectual cohesiveness" across disciplines. A theme contained in all the reports reviewed was that for reasons of equity and efficacy, there is a need to broaden and reinvigorate efforts to increase the participation of underrepresented minority groups in the sciences. Some recommendations for action offered by the report include:

- Doctoral students need both departmental and extra-departmental structures to give their concerns a strong and effective voice and to cultivate graduate student leadership as a component of graduate education and professional development.
- Information about doctoral education, program expectations, and career prospects must be more transparent to students from the moment they begin to consider a Ph.D.

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[54] Ibid.

[55] The Woodrow Wilson National Fellowship Foundation, *The Responsive Ph.D., Innovations in U.S. Doctoral Education,* September 2005, 76 pp. Responses and participation from 20 graduate schools contributed to the report.

- Doctoral programs urgently need to expand their approaches to mentoring, such as through team mentoring, particularly for attracting and retaining a diverse cohort of students.[56]

The Council of Graduate Schools released a report in April 2007 describing the relationship between graduate education and American competitiveness and innovation.[57] The report stated that: "[A]s our world flattens, we face new and growing competition."[58] It maintains that our nation is in jeopardy of losing its highly trained scientific and technical workforce that is required for economic dominance. The number of scientific papers published by U.S. citizens has remained constant for more than a decade in comparison to a 30.0% increase registered by other countries. In addition, the report suggests that the United States lags behind other countries in providing support and investments in graduate education and in attracting scientific talent. The report further stated that:

> A highly trained workforce is essential to America's future economic competitiveness and national security. Graduate education, a vital part of the U.S. education system, must be strengthened as a part of a national strategy on innovation and competitiveness. The work of graduate students contributes directly to our sustained economic growth and prosperity. Graduate students conduct groundbreaking research in universities, national laboratories, and private industry.[59]

The Council of Graduate Schools proffers recommendations that universities, policymakers, and business leaders should make to ensure the necessary investments for improving and enhancing U.S. innovation and national security.

Demographics and the Science and Engineering Talent Pool

In the 21st century, global competition and rapid advances in science and technology will require a workforce that is increasingly more scientifically and technically proficient.[60] The Bureau of Labor Statistics reports that science and engineering occupations are projected to grow by 21.4% from 2004 to 2014, compared to a growth of 13% in all occupations during the same time period.[61] It is anticipated that approximately 65% of the growth in science and engineering occupations will be in the computer-related occupations.[62] Faster than average growth is expected in the life sciences, social sciences, and the science and engineering-related occupations of

[56] Ibid., p. 25. Approximately 10 major research institutions have agreed to cooperate in the testing of the recommendations proffered in this report. See also Smallwood, Scott, "Graduate Schools Are Urged to Look Outward to Help Society," *The Chronicle of Higher Education,* vol. 52, October 21, 2005, p. A12.

[57] Council of Graduate Schools, *Graduate Education –The Backbone of American Competitiveness and Innovation*, April 26, 2007, Washington, DC, 30 pp.

[58] Ibid., p.1.

[59] Ibid.

[60] For expanded discussion of the scientific workforce see CRS Report RL34539, *The U.S. Science and Technology Workforce*, by (name redacted) and (name redacted).

[61] Department of Labor, Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections, *BLS Releases 2004-2014 Employment Projections*, December 7, 2005, http://www.bls.gov/news.release/ecopro.nr0.htm.

[62] Computer-related occupations include mathematical science occupations.

science manager.[63] In testimony before the House Science Committee, Daniel L. Goroff, Vice President for Academic Affairs, Dean of Faculty, Harvey Mudd College, stated that:

> With less than 6% of the world's population, the United States cannot expect to dominate science and technology in the future as it did during the second half of the last century when we enjoyed a massively disproportionate share of the world's STEM [science, technology, engineering, and mathematics] resources. We must invest more the resources we do have, encourage those resources to produce economically useful innovations, and organize the STEM enterprise by working with diverse groups to make sure that innovations developed here or overseas produce prosperity and progress for all.[64]

There are few in the scientific community who argue about the effect of national demographics on the future science and engineering workforce.[65] In the 21st century, a larger proportion of the U.S. population will be composed of minorities—blacks, Hispanics, and Native Americans, with the fastest growing minority group being Hispanics.[66] As a group, these minorities traditionally have been underrepresented in the science and engineering disciplines compared to their fraction of the total population.[67] These minorities take fewer high-level science and mathematics courses in high school; earn fewer undergraduate and graduate degrees in science and engineering; and are less likely to be employed in science and engineering positions than white males.[68] Data for

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[63] NSF acknowledges that predicting the demand for science and engineers in specific areas is difficult. The NSF states that: "Many spending decisions on R&D by corporations and governments are difficult or impossible to anticipate. In addition, R&D money increasingly crosses borders in search of the best place to have particular research performed.... Finally, it may be difficult to anticipate new products and industries that may be created via the innovation processes that are most closely associated with scientists and engineers." National Science Board, *Science and Engineering Indicators, 2008,* Volume 1, p. 3-12.

[64] House Science Committee, *Undergraduate Science, Math, and Engineering Education: What's Working,* Written testimony of Daniel L. Goroff, Vice President for Academic Affairs and Dean of Faculty, Harvey Mudd College, p.6.

[65] The current scientific and engineering workforce is aging. The NSF reports that the number reaching retirement age will increase dramatically over the next two decades. National Science Board, *Science and Engineering Indicators 2008,* Volume 1, pp. 3-45 - 3-46. See also National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering,* December 2008 Update, pp. 1-20, *Science and Engineering Indicators 2008,* Volume 1, pp. 3.27-29, *Rising Above the Gathering Storm,* p. 7-4., and Jackson, Shirley Ann, President, Rensselaer Polytechnic Institute, "Science and Society: A Nexus of Opportunity," Speech presented on January 17, 2007.

[66] See for example Fry, Richard, "The Rapid Growth and Changing Complexion of Suburban Public Schools," Pew Research Center Publications, March 2009, Gasbarra, Paul and Jean Johnson, "Out Before the Game Begins," A Public Agenda Report Prepared for America's Competitiveness: Hispanic Participation in Technology Careers Summit, May 5-6, 2008, 16 pp, Ashburn, Elyse, "New Data Predict Major Shifts in Student Population, Requiring Colleges to Change Strategies," *The Chronicle of Higher Education*, March 20, 2008, and Schmidt, Peter, "Higher Education Is in Flux as Demographics Change, Federal Report Shows," *The Chronicle of Higher Education*, vol. 54, June 6, 2008, p. A23.

[67] See for example Bridges, Brian K., "Bottlenecks and Bulges: The Minority Academic Pipeline," Presentation at the 2nd Annual Conference on Understanding Interventions that Encourage Minorities to Pursue Research Careers, American Council on Education, May 2008, The College Board, *4th Annual Advanced Placement Report to the Nation*, February 13, 2008, 57 pp, National Science Board, *Science and Engineering Indicators 2008,* Volume 1, pp. 1-7 - 1-23, and 3-26 - 3-29, and National Center for Education Statistics, *Status and Trends in the Education of Racial and Ethnic Minorities*, September 2007, 157 pp. Asian Americans are excluded because they are not statistically underrepresented in science, mathematics, engineering, and technology. For example, see Hanson, Sandra L. and Yu Meng, "Science Majors and Degrees Among Asian-American Students: Influences of Race and Sex in "Model Minority" Experiences," *Journal of Women and Minorities in Science and Engineering,* vol. 14, 2008, pp. 225-252.

[68] White, Jeffrey L., James W. Altschuld, and Yi-Fang Lee, "Persistence of Interest in Science, Technology, Engineering, and Mathematics: A Minority Retention Study," *Journal of Women and Minorities in Science and Engineering*, vol. 12, no.1, 2006, pp. 47-64, and Landis, Raymond B. California State University, Los Angeles, "Retention by Design - Achieving Excellence in Minority Engineering Education," October 2005, http://www.nacme.org/pdf/RetentionByDesign.pdf.

2006 reveal that while blacks, Hispanics, and Native Americans/Alaskan Natives as a whole comprise more than 29.5% of the population, and earn, as a whole, 16.0% of the bachelor degrees, 11.3% of the masters degrees, and 8.5% of the doctorate degrees in science and engineering.[69]

NSF data show that between 2000 and 2006, all racial/ethnic groups, except for whites, either increased their share of earned bachelor and degrees in science and engineering or remained level. Blacks were awarded 8.3% of the bachelors degrees in both 2000 and in 2006. Hispanics increased their share of earned degrees from 7.0% in 2000 to 7.7% in 2006. While Native Americans/Alaskan Natives increased their proportion, it remained at less than 1.0%. Asian/Pacific Islanders proportion of bachelors' degrees increased from 8.9% in 2000 to 9.3% in 2006. For foreign students,[70] the proportion was approximately 3.8% in both 2000 and 2006. The decrease in earned bachelors degrees by whites was from 67.8% in 2000 to 64.7% in 2006.[71]

At the master's level, blacks were awarded 6.6% of the degrees in science and engineering in 2006, up from the 5.7% in 2000. The proportion of master's degrees received by Hispanics increased from 3.9% in 2000 to 4.7% in 2006. Asian/Pacific Islanders comprised approximately 7.3% of the masters degrees awarded in 2000 and 7.2% in 2006. For foreign students on temporary visas, there was a slight decrease from 25.9% in 2000 to 25.6% in 2006. Native Americans' increased slightly but remained at less than 1.0% between 2000 and 2006. Again, whites reported a decrease in their proportion of earned degrees, dropping from 52.1% in 2000 to 47.9% in 2006.[72]

An analysis of the data for earned degrees at the doctoral level revealed that blacks registered a slight decrease at this level, from 2.7% of the awards in 2000 to 2.5% in 2006. The degrees earned by Hispanics remained almost level, 2.8% in 2000 and 2.9% in 2006. As at the other two degree levels, Native Americans' proportion remained at less than 1%. Asian/Pacific Islanders reported a decrease in earned degrees, from 6.6% in 2000 to 5.9% in 2006. Whites also reported a decrease in earned degrees, from 51.8% in 2000 to 42.4% in 2006. Doctoral degrees awarded to foreign students increased from 29.5% in 2000 to 38.6% in 2006.[73]

While minorities have increased their share of degrees awarded in the sciences, poor preparation in science and mathematics is said to be a major factor limiting the appeal of science and engineering to even larger numbers of these groups.[74] A large number of blacks, Hispanics, and

[69] National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering*, NSF09-305, Arlington, VA, December 2008 Update, Tables, C-6, C-7, E-3, F-5, and F-6. The calculations use the total number of science and engineering degrees awarded, including U.S. citizens, permanent and temporary residents, and those of unknown citizenship. Population data are from the U.S. Census Bureau.

[70] Foreign students on temporary resident status.

[71] National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering,* Table C-6.

[72] Ibid., Table E-3.

[73] National Science Foundation, *Science and Engineering Doctorate Awards: 2006,* NSF09-311, Arlington, VA, March 2009, Tables 5 and 11.

[74] National Action Council for Minorities in Engineering, Inc. (NACME), *Confronting the "New" American Dilemma,* (continued...)

Native Americans lack access to many of the more rigorous college preparatory courses.[75] Enrollment in college preparatory track or courses offers a student a better chance at being accepted at a college through her/his performance on the Scholastic Aptitude Test (SAT) or American College Testing (ACT), and a better chance at success in college.[76] Despite gains in the past 10 years, the average scores made by blacks, Hispanics, and Native Americans, who take both the SAT and the ACT continue to fall behind the average scores of whites and Asian students who take the test.[77]

In addition to recruitment as a problem for greater minority participation in science and engineering, retention of minorities in the educational pipeline, once recruited, also is of concern.[78] (Attrition rates for blacks, Hispanics, and Native Americans are higher than for whites or Asians). Currently, these underrepresented minority groups are reporting increased enrollments in colleges and universities and in their share of science and engineering degrees.[79] However, there is concern that some of the programs in the universities to attract minorities to the sciences have come under attack as a result of the limitations currently imposed on affirmative action in higher education.[80] In an effort to avoid the threat of litigation or complaints,[81] many institutions

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Underrepresented Minorities in Engineering: A Data-Based Look at Diversity, May 2008, 108 pp., and National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering,* December 2008 Update.

75 There has been an increase in the number of first-generation minority students enrolling in institutions of higher education. Some of these students are found to be underprepared, and as a result, struggle academically. Institutions have developed initiatives to improve the retention of these students. Horwedel, Dina M., "Putting First-Generation Students First," Diverse Issues in Higher Education, vol. 25, April 17, 2008, pp.10-12.

76 Students who take the more rigorous high school science and mathematics courses are more likely to continue their education than those who do not. The results of the National Educational Longitudinal Study found that 83% of students who took algebra I and geometry, and approximately 89% of students who took chemistry went to college as compared to 36% who did not take algebra and geometry and 43% who did not take chemistry. In general, approximately 51% of high school seniors planning to attend college did not take four years or more of science, and 31% planning to attend college did not take four years or more of mathematics. Students who do take four years of science and mathematics while in high school have been found to improve their SAT score by 100 points.

77 See for example "There is Good News and Bad News in Black Participation in Advanced Placement Programs," *The Journal of Blacks in Higher Education*, Winter 2005/2006, pp. 98-101, and Lam, Paul C., Dennis Doverspike, Julie Zhao, P. Ruby Mawasha, "The ACT and High School GPA as Predictors of Success in a Minority Engineering Program," *Journal of Women and Minorities in Science and Engineering*, vol. 11, no. 3, 2005, pp. 247-255, and Fountain, Charles, "Making the Grade in Room 33G," *Northeastern University Magazine*, vol. 30, March 2005, pp.14-19.

78 Wyer, Mary, "Intending to Stay: Images of Scientists, Attitudes Toward Women and Gender as Influences on Persistence Among Science and Engineering Majors," *The Journal of Blacks in Higher Education*, vol. 9, 2003, pp.1-16, and Slaughter, John Brooks, "It's Time to Get Angry About Underserved Students," The Chronicle of Higher Education, vol. 55, January 23, 2009, p. A68. Persistence data are sometimes spurious in that many minority students do not necessarily drop out, but "stop out" for a period of time and sometimes enroll at other institutions. In addition, persistence data do not always show the effects of part-time attendance and transfer students.

79 American Council on Education, Office of Minorities in Higher Education, *Minorities in Higher Education Twenty-Second Annual Status Report, 2007 Supplement,* Washington, DC, February 2007, pp. 15-29. The report finds that between 1994 and 2004, minority college enrollment grew by 49%, to approximately 4.8 million students.

80 In June 2003, the U.S. Supreme Court, in landmark cases involving the University of Michigan, Ann Arbor, defined the limits of affirmative action. See for example American Association for the Advancement of Science, National Action Council for Minorities in Engineering, Shirley M. Malcom, Daryl E. Chubin, Jolene K. Jesse, *Standing Our Ground, A Guidebook for STEM Educators in the Post-Michigan Era*, October 2004, 94 pp, Roach, Ronald, "Another Supreme Test?," *Diverse Issues in Higher Education*, vol. 23, June 29, 2006, p. 8, and CRS Report RL31874, *The University of Michigan Affirmative Action Cases: Racial Diversity in Higher Education*, by (name redacted).

81 Complaints filed with the ED have accused institutions of violation of Title VI of the Civil Rights Act (prohibits (continued...)

no longer target programs solely to minority groups or use race-based eligibility criteria in awarding fellowships or participation in academic enrichment programs.[82] These programs that were formerly race-exclusive, have been opened to all students "... to serv[e] the broader and more abstract goal of promoting campus diversity."[83] Most institutions have renamed their "minority" offices and programs as "diversity" or "multicultural" offices and programs.[84]

Women are also found to be underrepresented in selected science and engineering disciplines.[85] Although enrollment in rigorous course work and advanced placement classes in high school has increased for women in more than 10 years, there is still a need to strengthen the course taking and persistence of women all along the educational pipeline.[86] Data reveal that in 2005, women were awarded approximately 50.5% of the undergraduate degrees in science and engineering, a slight decrease from 50.8% in 2002.[87] The number of women who persist in the science and engineering disciplines to the graduate level shows a decline. In 2005, 39.5% of the doctorate degrees in science and engineering were awarded to women, almost level with the 39.2% in 2002.[88] Disaggregated data find that these awards were concentrated in selected disciplines. In 2005, women were awarded 22.5% of the doctorate degrees in engineering, 26.7% in the physical sciences, and 19.8% in computer sciences. The proportion for these awards earned by women in 2002 were 17.5%, 26.6%, and 20.6%, respectively. In the social and behavioral sciences, women earned 55.0% of the doctorates in 2005, an increase from the 54.4% in 2002. There was even more significant participation by women in psychology. Women were awarded 68.0% of the doctorates in psychology in 2005, and 66.7% in 2002.[89]

(...continued)

discrimination in education), and Title VII of the Civil Rights Act (prohibits discrimination in employment by restricting fellowships for minority groups or for women).

82 Some foundations, philanthropic organizations, and federal agencies no longer provide financial support to programs with race-exclusive eligibility criteria. See for example Jaschik, Scott, "Affirmative Action Challenged Anew,"Inside Higher Ed, April 8, 2008, http://www.insidehighered.com/layout/set/print/news/2008/04/08/affirm, and Schmidt, Peter, "NIH Opening Minority Programs to Other Groups," *The Chronicle of Higher Education*, vol. 51, March 11, 2005, p. A26.

83 Schmidt, Peter, "From 'Minority' to 'Diversity'," *The Chronicle of Higher Education*, vol. 52, February 3, 2006, p. A24. Daniel Rich, Provost, University of Delaware states that his institution has changed a scholarship program once reserved for racial or ethnic minorities. It is now opened to students who are first generation members to attend college, who have been classified as financial needy based on federal financial-aid calculations, or who have experienced "challenging social, economic, educational, cultural, or other life circumstances."

84 Glater, Jonathan D., "Colleges Open Minority Aid to All Comers," *The New York Times*, March 14, 2006, and Schmidt, Peter, "Justice Dept. Is Expected to Sue Southern Illinois U. Over Minority Fellowships," *The Chronicle of Higher Education*, vol. 52, November 25, 2005, p. A34.

85 See House Committee on Science and Technology, Subcommittee on Research and Science Education, Hearing, *Fulfilling the Potential of Women in Academic Science and Engineering Act of 2008*, 110th Cong., 2nd Sess., May 8, 2008, and Mullen, Ann L. and Jayne Baker, "Gender, Race, and Ethnic Segregation of Science Fields in U.S. Universities," *Journal of Women and Minorities in Science and Engineering*, vol. 14, no. 2, 2008, pp. 159-176.

86 Virnoche Mary E., "Expanding Girls' Horizons: Strengthening Persistence in the Early Math and Science Education Pipeline," *Journal of Women and Minorities in Science and Engineering*, vol. 14, no. 1, 2008, pp. 29-44; The National Academies, *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*, Washington, 2007, pp. 59-60; Dean, Cornelia, "Women in Science: The Battle Moves to the Trenches," *The New York Times*, December 19, 2006; and Ripley, Amanda, "Who Says a Woman Can't Be Einstein?," *Time*, March 7, 2005, pp. 51-59.

87 National Science Board, *Science and Engineering Indicators 2008*, Volume 2, Appendix Table 2-27.

88 Ibid., Appendix Table 2-31.

89 Ibid.

Shirley Ann Jackson, President, Rensselaer Polytechnic Institute, states that in the "altered environment" resulting from the Supreme Court decisions, the nation is challenged more than ever to confront the changing demographics. Blacks, Hispanics, and women, groups underrepresented in the science, engineering, and technical disciplines, comprise more than 66% of the entire workforce. It is expected that this "new majority" will replace the impending retiring scientific and engineering workforce which is largely white and male.[90] Jackson notes that:

> [W]e are experiencing pressure to replace the graying science and engineering workforce with new talent—educated young scientists and engineers who will make the discoveries and innovations which have paid off so handsomely, to date.... While the recent Supreme Court decisions uphold diversity, they force us to come at things in a different way. We must come up with solutions for developing science and engineering talent—solutions that address the new and coming realities of the underrepresented minority becoming the underrepresented majority.[91]

Foreign Science and Engineering Students[92]

The increased presence of foreign students in graduate science and engineering programs has been and continues to be of concern to some in the scientific community.[93] Enrollment of U.S. citizens in graduate science and engineering programs has not kept pace with that of foreign students in those programs.[94] NSF data reveal found that first-time, full-time science and engineering graduate enrollment of foreign students in science and engineering disciplines increased by approximately 16.0% from 2005 to 2006. The increase for U.S. citizens and permanent resident students during this same academic year was slightly more than 1.0%. In addition to the number of foreign students in graduate science and engineering programs, a significant number of university faculty in the scientific disciplines are foreign, and foreign doctorates are employed in large numbers by industry.

NSF data reveal that in 2005, the foreign student population earned approximately 34.7% of the doctorate degrees in the sciences and approximately 63.1% of the doctorate degrees in engineering.[95] In 2005, foreign students on temporary resident[96] visas earned 20.6% of the doctorates in the sciences, and 48.6% of the doctorates in engineering. The participation rates in

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[90] More than half of the U.S. science and engineering workforce is over the age of 40.

[91] *Standing Our Ground, A Guidebook for STEM Educators in the Post-Michigan Era,* pp. 71-7 2.

[92] For an expanded discussion of foreign scientists and engineers, see CRS Report RL31146, *Foreign Students in the United States: Policies and Legislation,* by (name redacted), CRS Report RL30498, *Immigration: Legislative Issues on Nonimmigrant Professional Specialty (H-1B) Workers*, by (name redacted), and CRS Report 97-746, *Foreign Science and Engineering Presence in U.S. Institutions and the Labor Force,* by (name redacted).

[93] Scanlon, Cynthia, "The H-1B Visa Debate," *Area Development Site and Facility Plannin*g Online, October/November 2006, http://www.areadevelopment.com/laborEducation/oct06/h1bvisa.shtml.

[94] National Science Foundation, *First-Time, Full-Time Graduate Student Enrollment in Science and Engineering Increases in 2006, Especially Among Foreign Students*, InfoBrief, NSF08-302, Arlington, VA, December 2007, 6 pp., and McCormack, Eugene, "Number of Foreign Students Bounces Back to Near-Record High," *The Chronicle of Higher Education*, vol. 54, November 16, 2007, p. A1.

[95] National Science Foundation, *Science and Engineering Doctorate Awards:2005,* Detailed Statistical Tables, NSF07-305, Arlington, VA, December 2006, Table 3.

[96] A temporary resident is a person who is not a citizen or national of the United States and who is in this country on a temporary basis and can not remain indefinitely. The terms nonresident alien or nonimmigrant are used interchangeably.

2004 were 18.9% and 48.8%, respectively. In 2005, permanent resident[97] status students earned 3.8% of the doctorates in the sciences and 4.4% of the doctorates in engineering, an increase over the 2004 levels of 3.7% and 4.2%, respectively.[98] Trend data for science and engineering degrees for the years 1996-2005 reveal that of the non-U.S. citizen population, temporary resident status students consistently have earned the majority of the doctorate degrees.

There are divergent views in the scientific and academic community about the effects of a significant foreign presence in graduate science and engineering programs.[99] Some argue that U.S. universities benefit from a large foreign citizen enrollment by helping to meet the needs of the university and, for those students who remain in the United States, the Nation's economy.[100]

> Foreign students generate three distinct types of measurable costs and benefits. First, 13 percent of foreign students remain in the United States, permanently increasing the number of skilled workers in the labor force. Second, foreign students, while enrolled in schools, are an important part of the workforce at those institutions, particularly at large research universities. They help teach large undergraduate classes, provide research assistance to the faculty, and make up an important fraction of the bench workers in scientific labs. Finally, many foreign students pay tuition, and those revenues may be an important source of income for educational institutions.[101]

Some argue that the influx of immigrant scientists and engineers has resulted in depressed job opportunities, lowered wages, and declining working conditions for U.S. scientific personnel. While many businesses, especially high-tech companies, have recently downsized, the federal government issued thousands of H-1B visas to foreign workers. There are those in the scientific and technical community who contend that an over-reliance on H-1B visa workers to fill high-tech positions has weakened opportunities for the U.S. workforce.[102] Many U.S. workers argue that a number of the available positions are being filled by "less-expensive foreign labor."[103] Those critical of the influx of immigrant scientists have advocated placing restrictions on the

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[97] A permanent resident ("green card holder") is a person who is not a citizen of the United States but who has been lawfully accorded the privilege of residing permanently in the United States. The terms resident alien or immigrant apply.

[98] *Science and Engineering Doctorate Awards: 2005*, Table 3.

[99] See for example The National Academies, Committee on Science, Engineering, and Public Policy, *Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States*, Washington, DC, 2005, pp. 17-65, Kalita, S. Mitra and Krissah Williams, "Help Wanted as Immigration Faces Overhaul," *The Washington Post*, March 27, 2006, p. A01, Clemons, Steven and Michael Lind, "How to Lose the Brain Race," *The New York Times*, April 10, 2006, Wertheimer, Linda K., "Visa Policy Hinders Research; Hurdles for Foreign Students Take Toll on Colleges' Scientific Work," *The Dallas Morning News*, November 24, 2002, p. A1, Stephan, Paula E. and Sharon G. Levin, "Exceptional Contributions to U.S. Science by the Foreign-Born and Foreign-Educated," *Population Research and Policy Review*, vol. 20, 2001, pp. 59-79.

[100] The Institute of International Education reports that for the 2006/2007 academic year, foreign students and their families contributed approximately $14.5 billion to the U.S. economy in money from tuition, living expenses and related costs. The Department of Commerce estimates that U.S. higher education is the nation's fifth largest service sector export. Institute of International Education, *Open Doors 2007: International Students in the United States*, November 13, 2007, http://opendoors.iienetwork.org/?p=113743.

[101] Borjas, George, Center for Immigration Studies, *An Evaluation of the Foreign Student Program*, June 2002, http://www.cis.org/articles/2002/back602.htm, pp.6-7.

[102] See for example Schwartz, Ephraim, "H-1B: Patriotic or Treasonous?," *InfoWorld*, vol. 27, May 6, 2005, http://www.infoworld.com/article/05/05/06/19NNh1b_1.html.

[103] Johnson, Carrie, "Hiring of Foreign Workers Frustrates Native Job-Seekers," *Washington Post*, February 27, 2002, p. E01.

hiring of foreign skilled employees in addition to enforcing the existing laws designed to protect workers. Those in support of the H-1B program maintain that there is no "clear evidence" that foreign workers displace U.S. workers in comparable positions and that it is necessary to hire foreign workers to fill needed positions, even during periods of slow economic growth.[104]

The debate on the presence of foreign students in graduate science and engineering programs and the workforce intensified following the terrorist attacks on September 11, 2001. It has been reported that foreign students in the United States are encountering "a progressively more inhospitable environment."[105] Concerns have been expressed about certain foreign students receiving education and training in sensitive areas.[106] There has been increased discussion about the access of foreign scientists and engineers to research and development (R&D) related to chemical and biological weapons. Also, there is discussion of the added scrutiny of foreign students from countries that sponsor terrorism.[107] The academic community is concerned that the more stringent requirements of foreign students may have a continued impact on enrollments in colleges and universities.[108] Others contend that a possible reduction in the immigration of foreign scientists may affect negatively on the competitiveness of U.S. industry and compromise commitments made in long-standing international cooperative agreements.[109]

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[104] See for example Clark, John, Nadine Jeserich, and Graham Toft, Hudson Institute, *Can Foreign Talent Fill Gaps in the U.S. Labor Force? The Contributions of Recent Literature*, September 2004, 33 pp., Baker, Chris, "Visa Restrictions Will Harm U.S. Technology, Gates Says; Microsoft Chief Calls For End to Caps On Workers," *The Washington Times*, April 29, 2005, p. C13, and Frauenheim, Ed, "Brain Drain in Tech's Future?," CNET Nets.com, August 6, 2004.

[105] Hudson, Audrey, "Foreign Students Labeled 'Threats'," *The Washington Times*, June 24, 2008, p. A1, and House Committee on the Judiciary, Subcommittee on Immigration, Border Security, and Claims, *Sources and Methods of Foreign Nationals Engaged in Economic and Military Espionage*, 109th, 1st Sess., September 15, 2005, Written testimony of William A. Wulf, President, National Academy of Engineering, p. 12, and Foroohar, Rana, "America Closes Its Doors," http://msnbc.msn.com/id/6038977/site/newsweek/print/1/displaymode/1098.

[106] See for example Lang, Les, "Commerce Department Withdraws Extra Restrictions on Foreign Scientists," *Gastroenterology*, vol. 131, October 2006, p. 988, and NAFSA: Association of International Educators, *Restoring U.S. Competitiveness for International Scholars*, June 2006, p. 6. The Bureau of Consular Affairs, Department of State, issues visas to foreign students and maintains a "technology alert list" that includes 16 sensitive areas of study. The list was produced in an effort to help the United States prevent the illegal transfer of controlled technology, and includes chemical and biotechnology engineering, missile technology, nuclear technology, robotics, and advanced computer technology.

[107] The State Department publishes a list annually of state sponsors of terrorism. Currently, the countries include Cuba, Iran, Sudan, and Syria. On October 11, 2008, the Bush Administration removed North Korea from the list of state sponsors of terrorism.

[108] See for example Cohen, David, "Middle Eastern Students Shut Out of the U.S. Turn to Australia and New Zealand," *The Chronicle of Higher Education*, vol. 53, August 17, 2007, p. A37, Strauss, Valerie, "Competition Worries Graduate Programs," *The Washington Post*, April 18, 2006, p. A06, and The National Academies, *Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States*, pp. 26-42.

[109] "Current Visa Restrictions Interfere with U.S. Science and Engineering Contributions to Important National Needs," Statement from Bruce Alberts, President National Academy of Sciences, Wm. A. Wulf, President, National Academy of Engineering, and Harvey Fineberg, President, Institute of Medicine, December 13, 2002 http://www.nationalacademies.org. See also Southwick, Ron, "Agriculture Department Draws Fire for Decision to Stop Hiring Foreign Scientists," *The Chronicle of Higher Education*, vol. 48, May 13, 2002.

Congressional Activity

On August 9, 2007, President Bush signed into law P.L. 110-69, The America COMPETES Act (H.R. 2272).[110] The legislation was directed at increasing research investment, improving economic competitiveness, developing an innovation infrastructure, and strengthening and expanding science and mathematics programs at all points on the educational pipeline. This legislation included components of other competitiveness bills introduced during the 110th Congress.[111] The COMPETES Act authorized $33.6 billion for FY2008 through FY2010 for science, mathematics, engineering, and technology programs across the federal government. Among other things, it directed the NSF to expand the Integrative Graduate Education and Research Traineeship and the Graduate Research Fellowship programs, and to establish a clearinghouse of programs related to improving the professional science master's degree. To address the need to expand the participation of underrepresented groups in the sciences, the COMPETES Act supported a program for mentoring to women interested in pursing degrees in science, mathematics, and engineering. In addition, it required the NSF to establish teacher institutes that are focused on science, technology, engineering, and mathematics. These are to be summer institutes and are to provide professional development for teachers at the precollege level teaching in high-need subjects and in high-need schools.

Legislation during the 111th Congress includes H.R. 1709, STEM Education Coordination Act of 2009. This bill would establish a committee under the National Science and Technology Council with the responsibility of coordinating STEM activities and programs for all federal agencies. The committee would provide a five-year STEM education strategic plan for the participating agencies that includes annual and long-term objectives, and the metrics used to assess progress in obtaining the objectives. In addition, the committee would provide a description for the role of each agency in supporting programs and activities designed to achieve the objectives. H.R. 461, 10,000 Trained by 2010 Act, would authorize funding for competitive grants to generate innovative approaches in the health care information fields. The bill would establish or improve undergraduate and master's degree health care information programs, attract students to such programs, and provide students with discipline-related experiences in the private sector or at the federal level. H.R. 1144, Fulfilling the Potential of Women in Academic Science and Engineering Act, would, among other things, increase awareness of and overcome gender bias in academic science and engineering through research and training. The bill would develop a uniform policy for each federal science agency to conduct workshops directed at educating program officers, grant review panel members, and others about methods that reduce the effects of gender biases in evaluation of research grants. Other policies to be explored would include those of hiring, tenure, and promotion practices, and the selection for honors determined primarily on the recipient's research record. H.R. 1791, Stopping Trained in America PhDs from Leaving the Economy Act of 2009 (STAPLE Act) would exempt from the numerical limits on H-1B visas, foreign students who have earned a doctorate in a scientific or technical discipline from a U.S. institution. In

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110 COMPETES—Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science. For expanded discussion of science and mathematics programs in the COMPETES Act, see CRS Report RL34396, *The America COMPETES Act and the FY2009 Budget*, by (name redacted), and CRS Report RL34328, *America COMPETES Act: Programs, Funding, and Selected Issues*, by (name redacted), *America COMPETES Act: Programs, Funding, and Selected Issues*.

111 For expanded discussion of legislative action related to science and engineering education issues during the 110th Congress see CRS Report RL33434, *Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action*, by (name redacted).

addition, these degree earners in science, technology, engineering, and mathematics would be admitted for permanent residence.

Oversight by the 111th Congress may touch on some of the following questions: Can our system of education and training achieve its stated goal of being first in science and mathematics? Can underrepresented minorities be encouraged to pursue scientific careers in larger numbers? Can the U.S. continue to produce successive generations of scientists, engineers, and technicians to meet the demands of the nation's changing economy and workplace?

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