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CRS Report for Congress

Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action

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Prepared for Members and
Committees of Congress

Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action

Summary

There is growing concern that the United States is not preparing a sufficient number of students, teachers, and practitioners in the areas of science, technology, engineering, and mathematics (STEM). A large majority of secondary school students fail to reach proficiency in math and science, and many are taught by teachers lacking adequate subject matter knowledge.

When compared to other nations, the math and science achievement of U.S. pupils and the rate of STEM degree attainment appear inconsistent with a nation considered the world leader in scientific innovation. In a recent international assessment of 15-year-old students, the U.S. ranked 28th in math literacy and 24th in science literacy. Moreover, the U.S. ranks 20th among all nations in the proportion of 24-year-olds who earn degrees in natural science or engineering.

A 2005 study by the Government Accountability Office found that 207 distinct federal STEM education programs were appropriated nearly \$3 billion in FY2004. Nearly three-quarters of those funds and nearly half of the STEM programs were in two agencies: the National Institutes of Health and the National Science Foundation. Still, the study concluded that these programs are highly decentralized and require better coordination. Though uncovering many fewer individual programs, a 2007 inventory compiled by the American Competitiveness Council also put the federal STEM effort at \$3 billion and concurred with many of the GAO findings regarding decentralization and coordination.

STEM education (and competitiveness) issues have received a lot of attention in recent years. Several high-profile proposals were forwarded by the academic and business communities. In February of 2006, the President released the American Competitiveness Initiative. During the 109th Congress, three somewhat modest STEM education programs were passed and signed into law. Finally, in the spring and summer of 2007, some of the major STEM education legislative proposals were combined into the America Competes Act of 2007, passed by the 110th Congress and signed by the President on August 9, 2007.

This report provides the background and context to understand these legislative developments. The report first presents data on the state of STEM education in the United States. It then examines the federal role in promoting STEM education. The report concludes with a discussion of the legislative actions recently taken to address federal STEM education policy.

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Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action

Introduction

There is growing concern that the United States is not preparing a sufficient number of students, teachers, and professionals in the areas of science, technology, engineering, and mathematics (STEM).¹ Although the most recent National Assessment of Educational Progress (NAEP) results show improvement in U.S. pupils' knowledge of math and science, the large majority of students still fail to reach adequate levels of proficiency. When compared to other nations, the achievement of U.S. pupils appears inconsistent with the nation's role as a world leader in scientific innovation. For example, among the 40 countries participating in the 2003 Program for International Student Assessment (PISA), the U.S. ranked 28th in math literacy and 24th in science literacy.

Some attribute poor student performance to an inadequate supply of qualified teachers. This appears to be the case with respect to subject-matter knowledge: many U.S. math and science teachers lack an undergraduate major or minor in those fields — as many as half of those teaching in middle school math. Indeed, postsecondary degrees in math and physical science have steadily decreased in recent decades as a proportion of all STEM degrees awarded. Although degrees in some STEM fields (particularly biology and computer science) have increased in recent decades, the overall proportion of STEM degrees awarded in the United States has historically remained at about 17% of all postsecondary degrees awarded. Meanwhile, many other nations have seen rapid growth in postsecondary educational

¹ In 2005 and early 2006, at least six major reports were released by highly respected U.S. academic, scientific, and business organizations on the need to improve science and mathematics education: The Education Commission of the States, *Keeping America Competitive: Five Strategies To Improve Mathematics and Science Education*, July 2005; The Association of American Universities, *National Defense Education and Innovation Initiative, Meeting America's Economic and Security Challenges in the 21st Century*, January 2006; The National Academy of Sciences, Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, February 2006; The National Summit on Competitiveness, *Statement of the National Summit on Competitiveness: Investing in U.S. Innovation*, December 2005; The Business Roundtable, *Tapping America's Potential: The Education for Innovation Initiative*, July 2005; the Center for Strategic and International Studies, *Waiting for Sputnik*, 2005.

attainment — with particularly high growth in the number of STEM degrees awarded. According to the National Science Foundation, the United States currently ranks 20th among all nations in the proportion of 24-year-olds who earn degrees in natural science or engineering. Once a leader in STEM education, the United States is now far behind many countries on several measures.

What has been the federal role in promoting STEM education? A study by the Government Accountability Office (GAO) found 207 distinct federal STEM education programs that were appropriated nearly \$3 billion in FY2004.² A more recent study by the newly established Academic Competitiveness Council (ACC) found 105 STEM education programs that were appropriated just over \$3 billion in FY2006.³ The ACC report attributed the difference between the number of programs found by the two inventories to (1) programmatic changes, (2) differing definitions of what constitutes a “program,” and (3) GAO’s reliance on unverified, agency-reported data.⁴ Apart from these differences, both reports came to similar conclusions. Both found that federal STEM education programs had multiple goals, provided multiple types of assistance, and were targeted at multiple groups, but that the bulk of this effort supports graduate and post-doctoral study in the form of fellowships to improve the nation’s research capacity. Both studies concluded that the federal effort is highly decentralized and could benefit from stronger coordination, while noting that the creation of the National Science and Technology Council in 1993 was a step in the right direction.⁵ The ACC study also contained an evaluative portion and concluded that “there is a general dearth of evidence of effective practices and activities in STEM education.”⁶

Several pieces of legislation have been introduced in the 110th Congress that would support STEM education in the United States. Many of the proposals in these bills have been influenced by the recommendations of several reports recently issued by the scientific, business, and policy-making communities. Of particular influence has been a report issued by the National Academy of Sciences (NAS), *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* — also known as the “Augustine” report. Many of the recommendations appearing in the NAS report are also contained in the Administration’s *American*

² U.S. Government Accountability Office, *Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends*, GAO-06-114, October 2005.

³ The ACC was created by the Deficit Reduction Act of 2005 (P.L. 109-171) and charged with conducting a year-long study to identify all federal STEM education programs. U.S. Department of Education, *Report of the Academic Competitiveness Council*, Washington, D.C., 2007 [<http://www.ed.gov/about/inits/ed/competitiveness/acc-mathscience/index.html>].

⁴ U.S. Department of Education, *Report of the Academic Competitiveness Council*, Washington, D.C., 2007, p. 11.

⁵ These points were reiterated by Cornelia M. Ashby, Director of GAO’s Education, Workforce, and Income Security Team. Her testimony can be found on the GAO website at [<http://www.gao.gov/new.items/d06702t.pdf>].

⁶ U.S. Department of Education, *Report of the Academic Competitiveness Council*, Washington, D.C., 2007, p. 3.

*Competitiveness Initiative.*⁷ Among the report's many recommendations, five are targeted at improving STEM education. These five recommendations seek to increase the supply of new STEM teachers, improve the skills of current STEM teachers, enlarge the pre-collegiate pipeline, increase postsecondary degree attainment, and enhance support for graduate and early-career research.

The purpose of this report is to put these legislative proposals into a useful context. The first section analyzes data from various sources to build a more thorough understanding of the status of STEM education in the United States. The second section looks at the federal role in promoting STEM education, providing a broad overview of nearly all of the programs in federal agencies and a detailed look at a few selected programs. Finally, the third section discusses legislative options currently being considered to improve STEM education. This discussion focuses primarily on the proposals that have seen congressional action to date.

STEM Education in the United States

Elementary and Secondary Education

Assessments of Math and Science Knowledge. National-level assessment of U.S. students' knowledge of math and science is a relatively recent phenomenon, and assessments in other countries that provide for international comparisons are even more recent. Yet the limited information available thus far is beginning to reveal results that concern many individuals interested in the U.S. educational system and the economy's future competitiveness. The most recent assessments show improvement in U.S. pupils' knowledge of math and science; however, the large majority still fail to reach adequate levels of proficiency. Moreover, when compared to other nations, the achievement of U.S. students is seen by many as inconsistent with the nation's role as a world leader in scientific innovation.

The National Assessment of Educational Progress (NAEP) is the only nationally representative, continuing assessment of elementary and secondary students' math and science knowledge. Since 1969, NAEP has assessed students from both public and nonpublic schools at grades 4, 8, and 12. Students' performance on the assessment is measured on a 0-500 scale, and beginning in 1990 has been reported in terms of the percentages of students attaining three achievement levels: *basic*, *proficient*, and *advanced*.⁸

Proficient is the level identified by the National Assessment Governing Board as the degree of academic achievement that all students should reach, and "represents

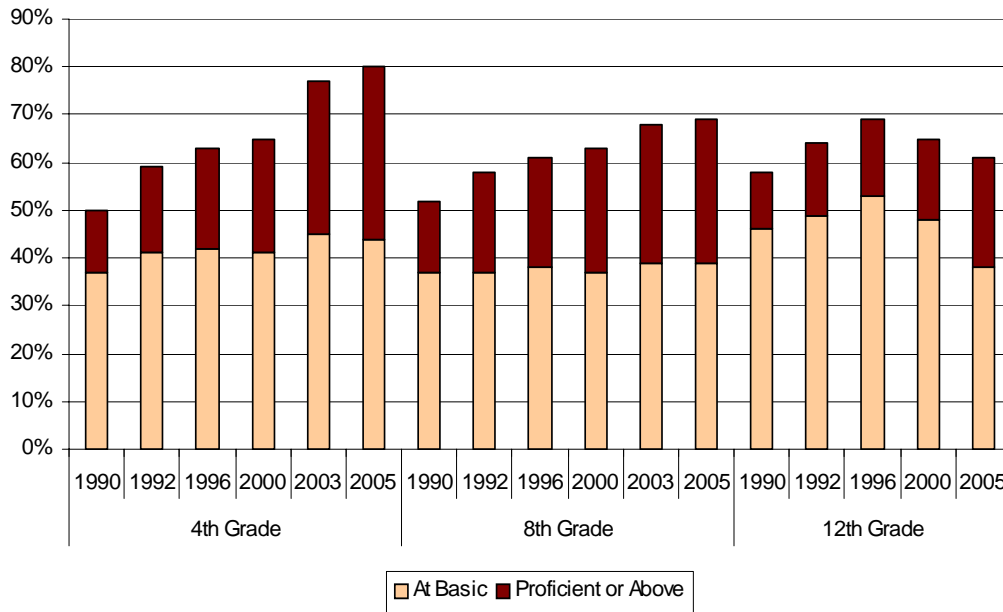
⁷ Office of Science and Technology Policy, Domestic Policy Council, *American Competitiveness Initiative — Leading the World In Innovation*, February 2006.

⁸ For more information on NAEP and other assessments, see CRS Report RL31407, *Educational Testing: Implementation of ESEA Title I-A Requirements Under the No Child Left Behind Act*, by Wayne C. Riddle.

solid academic performance. Students reaching this level have demonstrated competency over challenging subject matter.” In contrast, the board states that “Basic denotes partial mastery of the knowledge and skills that are fundamental for proficient work at a given grade.”⁹

The most recent NAEP administration occurred in 2005. **Figure 1** displays the available results from the NAEP math tests administered between 1990 and 2005. Although the proportion of 4th and 8th grade students achieving the proficient level or above has been increasing each year, overall math performance in these grades has been quite low. The percentage performing at the basic level has not improved in 15 years. About two in five students continue to achieve only partial mastery of math. In 2005, only about one-third of 4th and 8th grade students performed at the proficient level in math — 36% and 30%, respectively.¹⁰ The remainder of students — approximately 20% of 4th graders and just over 30% of 8th graders — scored below the basic level.

Figure 1. NAEP Math Scores, Selected Years: 1990-2005



Source: U.S. Department of Education, National Center for Education Statistics, *The Nation’s Report Card*, various years.

⁹ The National Assessment Governing Board is an independent, bipartisan group created by Congress in 1988 to set policy for the NAEP. More information on the board and NAEP achievement levels can be found at [<http://www.nagb.org/>].

¹⁰ U.S. Department of Education, National Center for Education Statistics, *The Nation’s Report Card: Mathematics 2005*, (NCES 2006-453), October 2005, p. 3.

The results among 12th grade students are mixed. Although the percent scoring at the basic level is higher among these students than among 4th and 8th grade students, the percent scoring proficient or above is smaller. Moreover, the results from recent years indicate that these percentages are in decline. [Note: changes in the testing instrument may account for much if not all of this drop.¹¹]

Similarly low levels of achievement have been found with regard to knowledge of science. Less than one-third of 4th and 8th grade students and less than one-fifth of 12th grade students score at or above proficient in science. In 2005, the percentage of 4th, 8th, and 12th grade students scoring proficient or above was 29%, 29%, and 18%, respectively; compared to 27%, 30%, and 18% in 2000 and 28%, 29%, and 21% in 1996.¹²

U.S. Students Compared to Students in Other Nations. Another relatively recent development in the area of academic assessment has been the effort by a number of nations to produce reliable cross-national comparison data.¹³ The Trends in International Mathematics and Science Study (TIMSS) assesses achievement in these subjects at grades 4 and 8 among students in several countries around the world. TIMSS has been administered to 4th grade students on two occasions (1995 and 2003) and to 8th grade students on three occasions (1995, 1999, and 2003). In the latest administration, 25 countries participated in assessments of their 4th grade students, and 45 countries participated in assessments of their 8th grade students. Unlike NAEP, TIMSS results are reported only in terms of numerical scores, not achievement levels.

U.S. 4th grade pupils outscored the international average on the most recent TIMSS assessment.¹⁴ The international average score for all countries participating in the 2003 4th grade TIMSS was 495 in math and 489 in science.¹⁵ The average score for U.S. students was 518 in math and 536 in science. U.S. 4th grade students

¹¹ The 2005 mathematics framework for grade 12 introduced changes from the previous framework in order to reflect adjustments in curricular emphases and to ensure an appropriate balance of content. For further information on these changes, go to [http://nationsreportcard.gov/reading_math_grade12_2005/s0413.asp].

¹² U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Science 2005* (NCES 2006-466) May 2006, Figures 4, 14, and 24.

¹³ More information on the development of this assessment can be found in archived CRS Report 86-683, *Comparison of the Achievement of American Elementary and Secondary Pupils with Those Abroad—The Examinations Sponsored by the International Association for the Evaluation of Educational Achievement (IEA)*, by Wayne C. Riddle (available on request).

¹⁴ Performance on the 1995 TIMSS assessment was normalized on a scale in which the average was set at 500 and the standard deviation at 100. Each country was weighted so that its students contributed equally to the mean and standard deviation of the scale. To provide trend estimates, subsequent TIMSS assessments are pegged to the 1995 average.

¹⁵ All the TIMSS results in this report were taken from, Patrick Gonzales, Juan Carlos Guzmán, Lisette Partelow, Erin Pahlke, Leslie Jocelyn, David Kastberg, and Trevor Williams, *Highlights From the Trends in International Mathematics and Science Study (TIMSS) 2003* (NCES 2005 — 005), December 2004.

outscored students in 13 of the 24 countries participating in the math assessment in 2003. In science, U.S. students outperformed students in 16 of the 24 countries. Among the 10 Organization for Economic Co-operation and Development (OECD) member states participating in the 2003 TIMSS, U.S. 4th grade students ranked fourth in math and tied for second in science.

U.S. 8th grade pupils also outscored the international average. Among 8th grade students, the international average on the 2003 TIMSS was 466 in math and 473 in science. The average score for U.S. students was 504 in math and 527 in science. Among the 44 countries participating in the 8th grade assessments in 2003, U.S. students outscored students in 25 countries in math and 32 countries in science. Twelve OECD countries participated in the 8th grade TIMSS in 2003 — five outscored the United States in math and three outscored the United States in science.

TIMSS previously assessed students at grade 4 in 1995 and grade 8 in 1995 and 1999. Although there was no measurable difference between U.S. 4th graders' average scores in 1995 and 2003, the standing of the United States declined relative to that of the 14 other countries participating in both math and science assessments. In math, U.S. 4th graders outperformed students in nine of these countries in 1995, on average, compared to six countries in 2003. In science, U.S. 4th graders outperformed students in 13 of these countries in 1995, on average, compared to eight countries in 2003.

Among 8th graders, U.S. scores increased on both the math and science assessments between 1995 and 2003. The increase in scores translated into a higher ranking of the United States relative to other countries. In math, 12 of the 21 participating countries outscored U.S. 8th graders in 1995, while seven did so in 2003. In science, 15 of the 21 participating countries outscored U.S. 8th graders in 1995, while 10 did so in 2003. **Table 1** displays the 2003 TIMSS math and science scores of 4th and 8th grade students by country (scores in **bold** are higher than the U.S. score).

Table 1. TIMSS Scores by Grade and Country/Jurisdiction, 2003

	4 th Grade		8 th Grade	
	Math	Science	Math	Science
International Average	495	489	466	473
United States	518	536	504	527
United Kingdom	531	540	—	—
Tunisia	339	314	410	404
Sweden	—	—	499	524
South Africa	—	—	264	244
Slovenia	479	490	493	520
Slovak Republic	—	—	508	517
Singapore	594	565	605	578
Serbia	—	—	477	468
Scotland	490	502	498	512
Saudi Arabia	—	—	332	398

	4 th Grade		8 th Grade	
	Math	Science	Math	Science
Russian Federation	532	526	508	514
Romania	—	—	475	470
Philippines	358	332	378	377
Palestinian National Authority	—	—	390	435
Norway	451	466	461	494
New Zealand	493	520	494	520
Netherlands	540	525	536	536
Morocco	347	304	387	396
Moldova, Republic of	504	496	460	472
Malaysia	—	—	508	510
Macedonia, Republic of	—	—	435	449
Lithuania	534	512	502	519
Lebanon	—	—	433	393
Latvia	536	532	508	512
Korea, Republic of	—	—	589	558
Jordan	—	—	424	475
Japan	565	543	570	552
Italy	503	516	484	491
Israel	—	—	496	488
Iran, Islamic Republic of	389	414	411	453
Indonesia	—	—	411	420
Hungary	529	530	529	543
Hong Kong SAR	575	542	586	556
Ghana	—	—	276	255
Estonia	—	—	531	552
Egypt	—	—	406	421
Cyprus	510	480	459	441
Chinese Taipei	564	551	585	571
Chile	—	—	387	413
Bulgaria	—	—	476	479
Botswana	—	—	366	365
Belgium-Flemish	551	518	537	516
Bahrain	—	—	401	438
Australia	499	521	505	527
Armenia	456	437	478	461

Source: U.S. Department of Education, National Center for Education Statistics, *Highlights From the Trends in International Mathematics and Science Study (TIMSS) 2003*, NCES 2005-005, Dec. 2004.

The Program for International Student Assessment (PISA) is an OECD-developed effort to measure, among other things, mathematical and scientific literacy among students 15 years of age, that is, roughly at the end of their compulsory education.¹⁶ In 2003, U.S. students scored an average of 483 on math literacy — behind 23 of the 29 OECD member states that participated and behind four of the 11 non-OECD countries. The average U.S. student scored 491 on science literacy — behind 19 of the 29 OECD countries and behind three of the 11 non-OECD countries. **Table 2** displays the 2003 PISA scores on math and science literacy by country (scores in **bold** are higher than the U.S. score).

¹⁶ Like the TIMSS, PISA results are normalized on a scale with 500 as the average score, and results are not reported in terms of achievement levels. In 2003, PISA assessments were administered in just over 40 countries.

Table 2. PISA Math and Science Scores, 2003

	2003	
	Math	Science
OECD Average	500	500
United States	483	491
Turkey	423	434
Switzerland	527	513
Sweden	509	506
Spain	485	487
Slovak Republic	498	495
Portugal	466	468
Poland	490	498
Norway	495	484
New Zealand	524	521
Netherlands	538	524
Mexico	385	405
Luxembourg	493	483
Korea, Republic of	542	538
Japan	534	548
Italy	466	487
Ireland	503	505
Iceland	515	495
Hungary	490	503
Greece	445	481
Germany	503	502
France	511	511
Finland	544	548
Denmark	514	475
Czech Republic	517	523
Canada	533	519
Belgium	529	509
Austria	506	491
Australia	524	525
Non-OECD Countries		
Uruguay	422	438
United Kingdom	508	518
Tunisia	359	385
Thailand	417	429
Serbia and Montenegro	437	436
Russian Federation	468	489
Macao SAR	527	525
Liechtenstein	536	525
Latvia	483	489
Indonesia	360	395
Hong Kong SAR	550	540

Source: U.S. Department of Education, National Center for Education Statistics, *International Outcomes of Learning in Mathematics Literacy and Problem Solving*, NCES 2005-003, Dec. 2004.

Math and Science Teacher Quality

Many observers look to the nation's teaching force as a source of national shortcomings in student math and science achievement. A recent review of the research on teacher quality conducted over the last 20 years revealed that, among those who teach math and science, having a major in the subject taught has a significant positive impact on student achievement.¹⁷ Unfortunately, many U.S. math and science teachers lack this credential. The Schools and Staffing Survey (SASS) is the only nationally representative survey that collects detailed data on teachers' preparation and subject assignments.¹⁸ The most recent administration of the survey for which public data are available took place during the 1999-2000 school year. That year, there were just under 3 million teachers in U.S. schools, about evenly split between the elementary and secondary levels. Among the nation's 1.4 million public secondary school teachers, 13.7% reported math as their main teaching assignment and 11.4% reported science as their main teaching assignment.¹⁹

Nearly all public secondary school math and science teachers held at least a baccalaureate degree (99.7%), and most had some form of state teaching certification (86.2%) at the time of the survey.²⁰ However, many of those who taught middle school (classified as grades 5-8) math and science lacked an undergraduate or graduate major or minor in the subject they taught. Among middle-school teachers, 51.5% of those who taught math and 40.0% of those who taught science did not have a major or minor in these subjects. By contrast, few of those who taught high school (classified as grades 9-12) math or science lacked an undergraduate or graduate major or minor in that subject. Among high school teachers, 14.5% of those who taught math and 11.2% of those who taught science did not have a major or minor in these subjects.²¹ **Table 3** displays these statistics for teachers in eight subject areas.

¹⁷ Michael B. Allen, *Eight Questions on Teacher Preparation: What Does the Research Say?*, Education Commission of the States, July 2003.

¹⁸ The sample is drawn from the Department of Education Common Core of Data, which contains virtually every school in the country.

¹⁹ U.S. Department of Education, *Digest of Education Statistics, 2004*, NCES 2005-025, October 2005, Table 67.

²⁰ CRS analysis of Schools and Staffing Survey data, March 29, 2006.

²¹ U.S. Department of Education, *Qualifications of the Public School Teacher Workforce*, May 2002, Tables B-11 and B-12.

Table 3. Teachers Lacking a Major or Minor in Subject Taught, 1999-2000

	Middle School	High School
English	44.8%	13.3%
Foreign language	27.2%	28.3%
Mathematics	51.5%	14.5%
Science	40.0%	11.2%
Social science	29.6%	10.5%
ESL/bilingual education	57.6%	59.4%
Arts and music	6.8%	6.1%
Physical/health education	12.6%	9.5%

Source: U.S. 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, May 2002.

Given the link between teachers' undergraduate majors and student achievement in math and science, these data appear to comport with some of the NAEP findings discussed earlier. Recall that those assessments revealed that only about one-third of 4th and 8th grade students performed at the proficient or higher level in math and science. On the other hand, at the high school level, the data seem to diverge. While four-fifths of math and science teachers at this level have a major in the subject, only two-fifths of high school students scored proficient or above on the NAEP in those subjects.

Postsecondary Education

STEM Degrees Awarded in the United States. The number of students attaining STEM postsecondary degrees in the U.S. more than doubled between 1960 and 2000; however, as a proportion of degrees in all fields, STEM degree awards have stagnated during this period.²² In the 2002-2003 academic year, more than 2.5 million degrees were awarded by postsecondary institutions in the United States.²³ That year, just under 16% (399,465) of all degrees were conferred in STEM fields; all STEM degrees comprised 14.6% of associate degrees, 16.7% of baccalaureate degrees, 12.9% of master's degrees, and 34.8% of doctoral degrees.²⁴ **Table 4** displays the distribution of degrees granted by academic level and field of study.

At the associate and baccalaureate levels, the number of STEM degrees awarded was roughly equivalent to the number awarded in business. In 2002-2003, 92,640

²² Through various "completions" surveys of postsecondary institutions administered annually since 1960, ED enumerates the number of degrees earned in each field during the previous academic year.

²³ U.S. Department of Education, National Center for Education Statistics, *Digest of Education Statistics, 2004*, NCES 2005-025, October 2005, Table 169.

²⁴ Includes Ph.D., Ed.D., and comparable degrees at the doctoral level, but excludes first-professional degrees, such as M.D., D.D.S., and law degrees.

associate degrees and 224,911 baccalaureate degrees were awarded in STEM fields, compared to 102,157 and 293,545, respectively, in business. However, nearly twice as many master's degrees were granted in business (127,545) as in STEM (65,897), and an even larger number of master's degrees were awarded in education (147,448). At the doctoral level, STEM plays a larger role. Doctoral degrees awarded in STEM fields account for more than one-third of all degrees awarded at this level. Education is the only field in which more doctoral degrees (6,835) were awarded than in the largest three STEM fields — biology, engineering, and the physical sciences (5,003, 5,333, and 3,858, respectively).

Specialization within STEM fields also varies by academic level. Engineering was among the most common STEM specialties at all levels of study in 2002-2003. Biology was a common specialization at the baccalaureate and doctoral levels, but not at the master's level. Computer science was common at all but the doctoral level. Physical sciences was a common specialization *only* at the doctoral level.

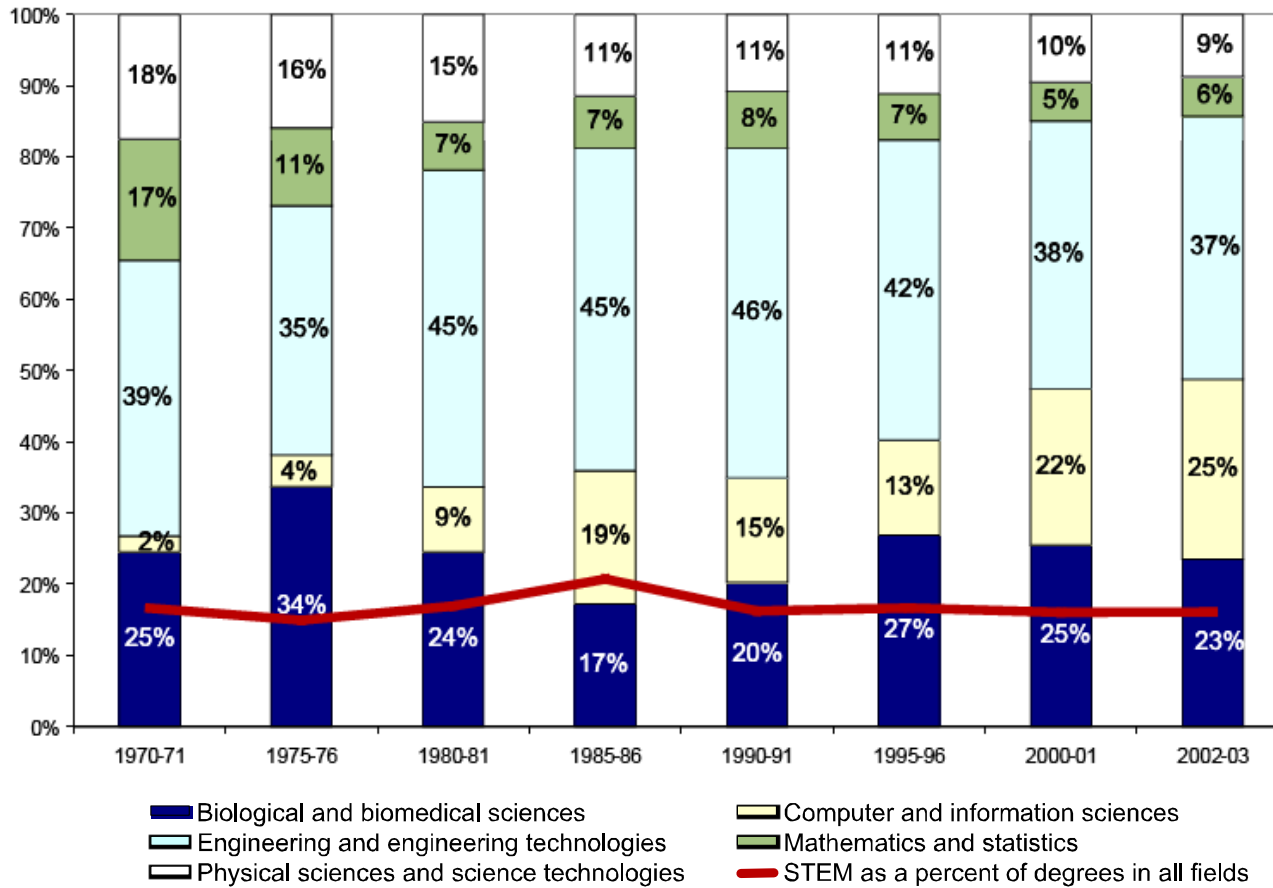
Figure 2 displays the trends in STEM degrees awarded over the last three decades (excluding associate degrees). The solid line represents the number of STEM degrees awarded as a proportion of the total number of degrees awarded in all fields of study. The flat line indicates that the ratio of STEM degrees to all degrees awarded has historically hovered at around 17%. The bars represent the number of degrees awarded in each STEM sub-field as a proportion of all STEM degrees awarded. The top two segments of each bar reveal a consistent decline, since 1970, in the number of degrees awarded in math and the physical sciences. The bottom segment of each bar shows a history of fluctuation in the number of degrees awarded in biology over the last 30 years. The middle two segments in the figure represent the proportion of degrees awarded in engineering and computer science. The figure reveals a steady decline in the proportion of STEM degrees awarded in engineering since 1980, and a steady increase in computer science degrees (except for a contraction that occurred in the late 1980s following a rapid expansion in the early 1980s).

Table 4. Degrees Conferred by Level and Field of Study, 2002-2003

	Associate	Baccalaureate	Master's	Doctoral	Total
All fields	632,912	1,348,503	512,645	46,024	2,540,084
STEM fields, total	92,640	224,911	65,897	16,017	399,465
STEM, percentage of all fields	14.6%	16.7%	12.9%	34.8%	15.7%
Biological and biomedical sciences	1,496	60,072	6,990	5,003	73,561
Computer and information sciences	46,089	57,439	19,503	816	123,847
Engineering and engineering technologies	42,133	76,967	30,669	5,333	155,102
Mathematics and statistics	732	12,493	3,626	1,007	17,858
Physical sciences and science technologies	2,190	17,940	5,109	3,858	29,097
Non-STEM fields, total	540,272	1,123,592	446,748	30,007	2,140,619
Business	102,157	293,545	127,545	1,251	524,498
Education	11,199	105,790	147,448	6,835	271,272
English language and literature/letters	896	53,670	7,413	1,246	63,225
Foreign languages and area studies	1,176	23,530	4,558	1,228	30,492
Liberal arts and sciences, general studies, and humanities	216,814	40,221	3,312	78	260,425
Philosophy, theology, and religious studies/vocations	804	18,270	6,677	1,983	27,734
Psychology	1,784	78,613	17,123	4,831	102,351
Social sciences	5,422	115,488	12,109	2,989	136,008
History	316	27,730	2,525	861	31,432
Other	199,704	366,735	118,038	8,705	693,182

Source: U.S. Department of Education, National Center for Education Statistics, *Digest of Education Statistics, 2004*, NCES 2005-025, Oct. 2005, Table 249-252..

Figure 2. STEM Degrees Awarded, 1970-2003



U.S. Degrees Awarded to Foreign Students. The increased presence of foreign students in graduate science and engineering programs and in the scientific workforce has been and continues to be of concern to some in the scientific community. Enrollment of U.S. citizens in graduate science and engineering programs has not kept pace with that of foreign students in these programs. According to the National Science Foundation (NSF) Survey of Earned Doctorates, foreign students earned one-third of all doctoral degrees awarded in 2003.

Doctoral degrees awarded to foreign students were concentrated in STEM fields. The NSF reports that foreign students earned “more than half of those [awarded] in engineering, 44% of those in mathematics and computer science, and 35% of those in the physical sciences.”²⁵ Many of these degree recipients remain in the United States to work. The same NSF report indicates that 53% of those who earned a doctorate in 1993 remained in the U.S. as of 1997, and 61% of the 1998 cohort were still working in the United States in 2003. 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.²⁶

International Postsecondary Educational Attainment. The United States has one of the highest rates of postsecondary educational attainment in the world. In 2003, the most recent academic year for which international data are available, 38% of the U.S. population aged 25-64 held a postsecondary degree — 9% at the *tertiary-type B* (vocational level) and 29% at the *tertiary-type A* (university level) or above. The OECD compiled comparison data from 30 OECD member states and 13 other nations. Three countries (Canada, Israel, and the Russian Federation) had larger shares at the two tertiary levels combined; however, all three had lower rates at the tertiary-type A level. At the tertiary-type A level, only one country (Norway) had a rate as high as the United States. The average for OECD member states was 16% at tertiary-type A and 8% at tertiary-type B.²⁷

China and India were not included in the OECD data. Reliable information on postsecondary educational attainment is very difficult to obtain for these countries.

²⁵ National Science Board, *Science and Engineering Indicators, 2006*, (NSB 06-1). Arlington, VA: National Science Foundation, January 2006, p. O-15.

²⁶ For more information on issues related to foreign students and foreign technical workers, see the following: CRS Report 97-746, *Foreign Science and Engineering Presence in U.S. Institutions and the Labor Force*, by Christine M. Matthews; CRS Report RL31973, *Programs Funded by the H-1B Visa Education and Training Fee and Labor Market Conditions for Information Technology (IT) Workers*, by Linda Levine; and CRS Report RL30498, *Immigration: Legislative Issues on Nonimmigrant Professional Specialty (H-1B) Workers*, by Ruth Ellen Wasem.

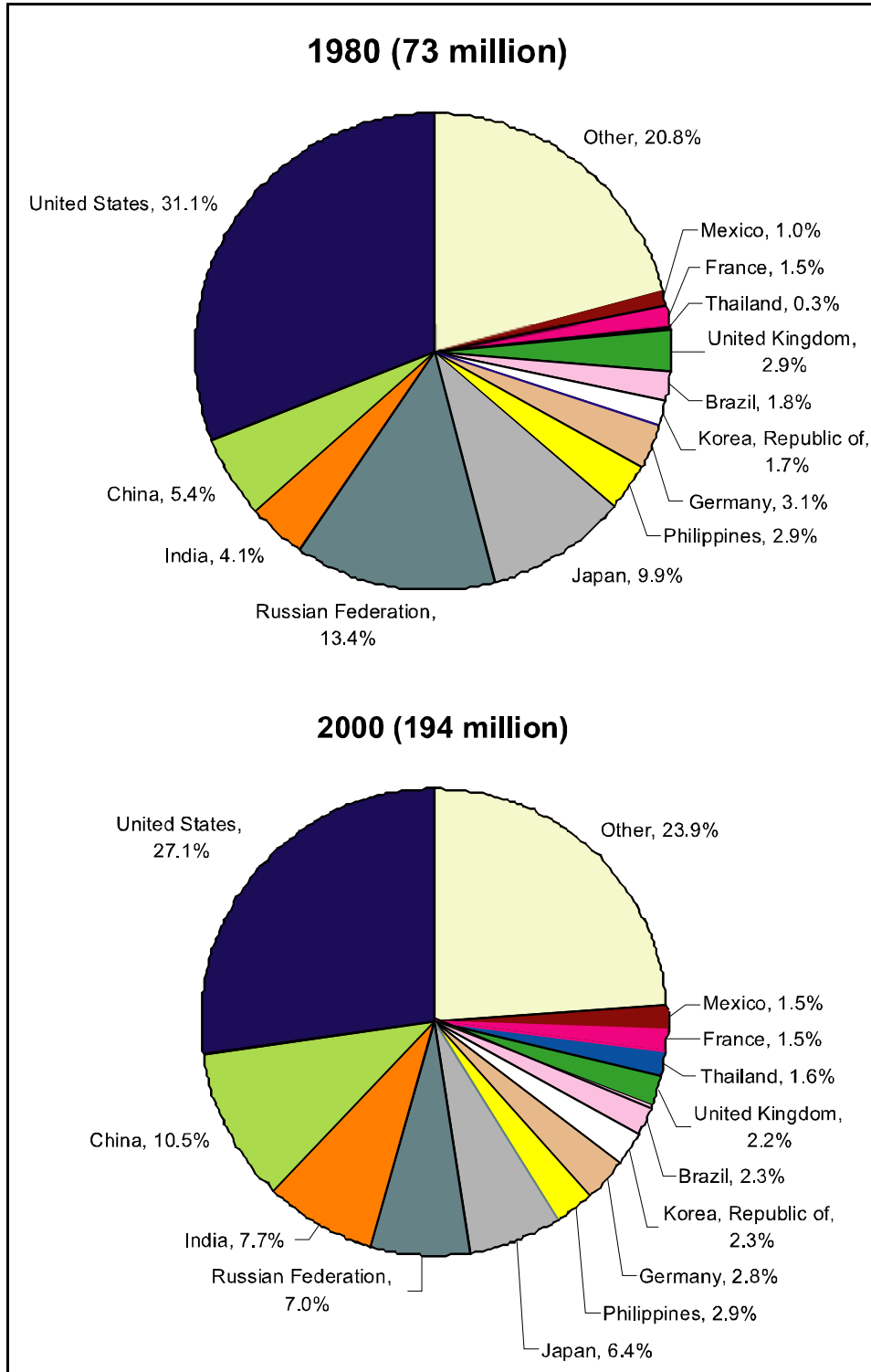
²⁷ Organization for Economic Co-operation and Development, *Education at a Glance, OECD Indicators 2005*, Paris, France, September 2005. The OECD compiles annual data from national labor force surveys on educational attainment for the 30 OECD member countries, as well as 13 non-OECD countries that participate in the World Education Indicators (WEI) program. More information on sources and methods can be found at [<http://www.oecd.org/dataoecd/36/39/35324864.pdf>].

The World Bank estimates that, in 1998, tertiary enrollment of the population between 18 and 24 years old was 6% in China and 8% in India, up from 1.7% and 5.2%, respectively, in 1980.²⁸ Based on measures constructed by faculty at the Center for International Development (CID), the National Science Foundation (NSF) has generated an estimate of the distribution of the world's population that possesses a tertiary education.²⁹ The NSF estimates that the number of people in the world who had a tertiary education more than doubled from 73 million in 1980 to 194 million in 2000. Moreover, the two fastest-growing countries were China and India. China housed 5.4% of the world's tertiary degree holders in 1980, and India had 4.1%; by 2000, the share in these countries was 10.5% and 7.7%, respectively. Indeed, as **Figure 3** indicates, China and India were the only countries to substantially increase their share of the world's tertiary degree-holders during that period.

²⁸ The World Bank, *Constructing Knowledge Societies: new challenges for tertiary education*, Washington, D.C., October 2002. Available at [<http://siteresources.worldbank.org/EDUCATION/Resources/278200-1099079877269/547664-1099079956815/ConstructingKnowledgeSocieties.pdf>].

²⁹ Unlike the OECD data, which are based on labor-force surveys of households and individuals, the CID data are based on the United Nations Educational, Scientific and Cultural Organization (UNESCO) census and survey data of the entire population. Documentation describing methodology as well as data files for the CID data is available at [<http://www.cid.harvard.edu/ciddata/ciddata.html>].

Figure 3. Tertiary Education by Country, 1980 and 2000



Source: National Science Foundation, *Science and Engineering Indicators, 2006, Volume 1*, Arlington, VA, NSB 06-01, Jan. 2006.

International Comparisons in STEM Education. The NSF has compiled data for many countries on the share of *first university* degrees awarded in STEM fields.³⁰ According to these data, the United States has one of the lowest rates of STEM to non-STEM degree production in the world. In 2002, STEM degrees accounted for 16.8% of all first university degrees awarded in the United States (the same NCES figure reported at the outset of this section). The international average for the ratio of STEM to non-STEM degrees was 26.4% in 2002. **Table 5** displays the field of first university degrees for regions and countries that award more than 200,000 university degrees annually. Among these nations, only Brazil awards a smaller share (15.5%) of STEM degrees than the United States. By contrast, the world leaders in the proportion of STEM degrees awarded are Japan (64.0%) and China (52.1%). Although the U.S. ranks near the bottom in the proportion of STEM degrees, it ranks third (behind Japan and China) in the absolute number of STEM degrees awarded.

Table 5. Field of Study, by Selected Region and Country, 2002
(or the Most Recent Year Available)

Region/Country	All Fields	STEM Fields	Percent STEM
All Regions	9,057,193	2,395,238	26.4%
Asia	3,224,593	1,073,369	33.3%
China	929,598	484,704	52.1%
India	750,000	176,036	23.5%
Japan	548,897	351,299	64.0%
South Korea	239,793	97,307	40.6%
Middle East	445,488	104,974	23.6%
Europe	2,682,448	713,274	26.6%
France	309,009	83,984	27.2%
Spain	211,979	55,418	26.1%
United Kingdom	282,380	72,810	25.8%
Central/Eastern Europe	1,176,898	319,188	27.1%
Russia	554,814	183,729	33.1%
North/Central America	1,827,226	341,526	18.7%
Mexico	321,799	80,315	25.0%
United States	1,305,730	219,175	16.8%
South America	543,805	96,724	17.8%
Brazil	395,988	61,281	15.5%

Source: National Science Foundation, *Science and Engineering Indicators, 2006, Volume 1*, Arlington, VA, NSB 06-01, January 2006, Table 2-37.

³⁰ *First university* degrees are those designated Level 5A by the International Standard Classification of Education (ISCED 97), and usually require less than five years to complete. More information on this classification and the ISCED is available at [http://www.unesco.org/education/information/nfsunesco/doc/isced_1997.htm].

Federal Programs that Promote STEM Education

Government Accountability Office Study

According to a 2005 Government Accountability Office (GAO) survey of 13 federal civilian agencies, in FY2004 there were 207 federal education programs designed to increase the number of students studying in STEM fields and/or improve the quality of STEM education.³¹ About \$2.8 billion was appropriated for these programs that year, and about 71% (\$2 billion) of those funds supported 99 programs in two agencies. In 2004, the National Institutes of Health (NIH) received \$998 million that funded 51 programs, and the National Science Foundation (NSF) received \$997 million that funded 48 programs. Seven of the 13 agencies had more than five STEM-related education programs. In addition to the NIH and NSF, only three other agencies received more than \$100 million for STEM-related education programs. In FY2004, the National Aeronautics and Space Administration (NASA) received \$231 million that funded five programs, the Department of Education (ED) received \$221 million that funded four programs, and the Environmental Protection Agency (EPA) received \$121 million that funded 21 programs.

The GAO study found that most of the 207 programs had multiple goals, provided multiple types of assistance, and were targeted at multiple groups. The analysis identified six major program goals, four main types of assistance, and 11 target groups. The findings revealed that federal STEM education programs are heavily geared toward attracting college graduates into pursuing careers in STEM fields by providing financial assistance at the graduate and postdoctoral levels. Moreover, improving K-12 teacher education in STEM areas was the least frequent of the major goals, improving infrastructure was the least frequent of the main types of assistance, and elementary and secondary students were the least frequent group targeted by federal STEM education programs.³²

The major goals of these programs were found by GAO to be the following (the number of programs with this goal is shown in parentheses):

- attract and prepare students at all educational levels to pursue coursework in STEM areas (114),
- attract students to pursue STEM postsecondary degrees (two-year through Ph.D.) and postdoctoral appointments (137),

³¹ U.S. Government Accountability Office, *Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends*, GAO-06-114, October 2005. The GAO study does not include programs in the Department of Defense because the department decided not to participate. Other programs were omitted from the report for various reasons; typically because they did not meet the GAO criteria for a STEM-related educational program (according to an April 26, 2006 conversation with the report's lead author, Tim Hall).

³² Attrition rates among college students majoring in STEM fields combined with the growth of foreign students in U.S. graduate STEM programs suggest that pre-college STEM education may be a major source of the nation's difficulty in this area.

- provide growth and research opportunities for college and graduate students in STEM fields (103),
- attract graduates to pursue careers in STEM fields (131),
- improve teacher education in STEM areas (73), and
- improve or expand the capacity of institutions to promote STEM fields (90).

The four main types of assistance provided by these programs were as follows (the number of programs providing this service is shown in parentheses):

- financial support for students or scholars (131),
- institutional support to improve educational quality (76),
- support for teacher and faculty development (84), and
- institutional physical infrastructure support (27).

The 11 target groups served by these programs were the following (the number of programs targeting them is shown in parentheses):

- elementary school students (28),
- middle school students (34),
- high school students (53),
- two-year college students (58),
- four-year college students (96),
- graduate students (100),
- postdoctoral scholars (70),
- elementary school teachers (39),
- secondary school teachers (50),
- college faculty or instructional staff (79), and
- institutions (82).

Academic Competitiveness Council Study

The Academic Competitiveness Council (ACC) was created by the Deficit Reduction Act of 2005 (P.L. 109-171). Section 401A(a)(2)(B) of the act charged the ACC with conducting a year-long study to

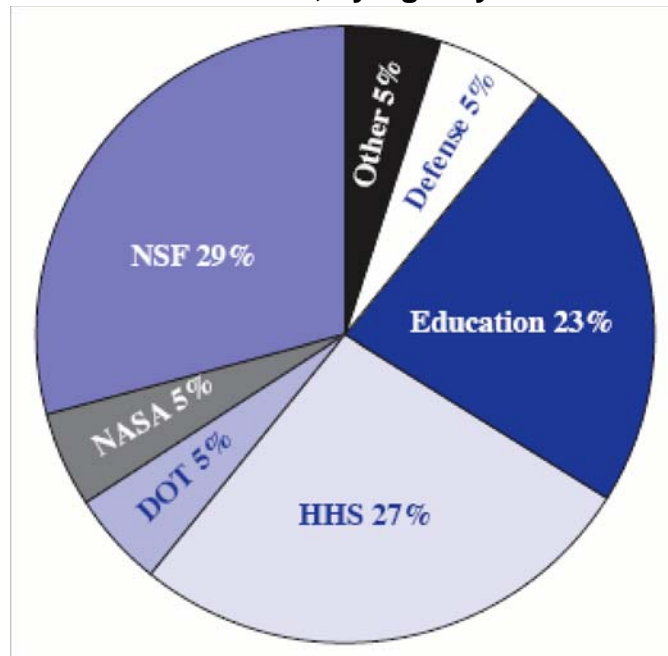
- (i) identify all federal programs with a mathematics or science focus;
- (ii) identify the target populations being served by such programs;
- (iii) determine the effectiveness of such programs;
- (iv) identify areas of overlap or duplication in such programs; and
- (v) recommend ways to efficiently integrate and coordinate such programs.

The ACC found 105 STEM education programs that were appropriated just over \$3 billion in FY2006.³³ The authors of the ACC report attributed the difference between the number of programs found by the GAO and ACC inventories to have occurred for three reasons:

First, programmatic changes occurred between the time of the GAO study and the time of the ACC effort. Second, the ACC program inventory and GAO report used different definitions and guidelines for program inclusion. Specifically, the ACC effort included all federal agencies that supported STEM education programs while the GAO report did not. Lastly, differences in the program inventories arose because the GAO report was based solely on agency-reported data, whereas the ACC program inventory was also verified by the Office of Management and Budget.³⁴

According to the ACC inventory, three agencies account for nearly 80% of all federal STEM education spending in FY2006. **Figure 4** displays total federal spending for that year by agency. According to the ACC, 29% (\$924 million) of total federal STEM funds went to NSF, 27% (\$855 million) went to NIH (through the Department of Health and Human Services (HHS)), and 23% (\$706 million) went to ED.

Figure 4. Federal STEM Education Funding FY2006, by Agency



Source: U.S. Department of Education, *Report of the Academic Competitiveness Council*, Washington, D.C., 2007

³³ U.S. Department of Education, *Report of the Academic Competitiveness Council*, Washington, D.C., 2007, at [<http://www.ed.gov/about/inits/ed/competitiveness/acc-math-science/index.html>].

³⁴ U.S. Department of Education, *Report of the Academic Competitiveness Council*, Washington, D.C., 2007, p. 11.

Apart from these differences, both the GAO and ACC studies came to similar findings and conclusions about the state of the federal effort to promote STEM education. Both found that federal STEM education programs had multiple goals, provided multiple types of assistance, and were targeted at multiple groups. Both concluded that the federal effort is highly decentralized and could benefit from stronger coordination, while noting that the creation of the National Science and Technology Council in 1993 was a step in the right direction.³⁵ The ACC report states that these programs

support activities in a wide variety of areas, including STEM curriculum development; teacher professional development, recruitment, and retention; institutional support (including programs to strengthen the educational capabilities of minority-serving or similar institutions); mentoring; student financial assistance; outreach and recognition to motivate interest in or continued work in STEM fields; and research aimed at improving STEM education.³⁶

Like the GAO results, the ACC study found that much of the federal effort in this area comes through NSF and NIH support for graduate and post-doctoral study in the form of fellowships to improve the nation's research capacity. The ACC identified 27 federally funded STEM graduate and post-doctoral fellowship and traineeship programs with a total funding of \$1.46 billion in FY2006, which is 47% of the total FY2006 federal funding in STEM education. The ACC found an additional 43 STEM programs in nine agencies primarily focused on improving undergraduate education that received 30% (\$943 million) of the total FY2006 funds. The remaining 23% of federal STEM education funds went to 24 K-12 programs (\$574 million) and 11 STEM "informal education and outreach" programs (\$137 million).³⁷

Program Effectiveness. The ACC study went beyond the scope of the GAO study in one key area: the ACC was asked to evaluate the effectiveness of federal STEM education programs. Due to the short time frame allotted to the study, the ACC could not conduct its own evaluations and, instead, had to solicit examples of evaluations from the agencies administering the programs. After a review of the examples submitted, the ACC concluded that "there is a general dearth of evidence of effective practices and activities in STEM education."³⁸

In particular, the report states that, "Of the 115 examples submitted: 10 evaluations were scientifically rigorous evaluations that produced preliminary

³⁵ These points were reiterated by Cornelia M. Ashby, Director of GAO's Education, Workforce, and Income Security Team. Her testimony can be found on the GAO website at [<http://www.gao.gov/new.items/d06702t.pdf>].

³⁶ Ibid.

³⁷ Ibid, pp. 21-29.

³⁸ U.S. Department of Education, *Report of the Academic Competitiveness Council*, Washington, D.C., 2007, p. 3.

findings about a program or project’s impact on education outcomes.”³⁹ Of the ten evaluations that were considered to be “scientifically rigorous,” only three had been completed, were found to have a “meaningful positive impact,” and had published results in academic journals. The report’s critique continued by stating that, “even these well-designed studies with seemingly positive impacts would require additional replication and validation before they could be useful” in determining what policies and programs to promote.⁴⁰

Description of Selected Federal STEM Programs

The GAO and ACC reports did not provide much detail on specific federal STEM programs.⁴¹ This section describes the major federal STEM education programs including the kinds of activities they support and how they operate at the federal, state, and/or local levels. These are the largest STEM education programs administered by the agencies with the largest STEM education budgets, including NIH, NSF, and ED.

NIH Ruth L. Kirschstein National Research Service Awards. First funded in 1975, the Kirschstein National Research Service Awards (KNRSA) constitute the large majority of HHS/NIH’s spending on STEM education.⁴² Most of these funds are used to support the Kirschstein Training Grants that provide graduate and postdoctoral fellowships in health-related fields. About 15-20% of the funds support the Kirschstein Postdoctoral Fellowships and Kirschstein Predoctoral Fellowships. The Training Grants are awarded to institutions to develop or enhance research training opportunities for individuals, selected by the institution, who are training for careers in specified areas of interest to the institution or principal investigator. The Fellowship Grants are awarded directly to individuals from various organizations within the NIH (e.g., the National Institute on Aging) to support the particular research interests of the individual receiving the award.

Kirschstein Award applicants must be U.S. citizens or nationals, or permanent resident aliens of the United States — individuals on temporary or student visas are not eligible. Predoctoral trainees must have received a baccalaureate degree by the starting date of their appointment, and must be training at the postbaccalaureate level and be enrolled in a program leading to a Ph.D. in science or in an equivalent research doctoral degree program. Health-profession students who wish to interrupt their studies for a year or more to engage in full-time research training before completing their professional degrees are also eligible. Postdoctoral trainees must have received, as of the beginning date of their appointment, a Ph.D., M.D., or comparable doctoral degree from an accredited domestic or foreign institution.

³⁹ Ibid, p. 26.

⁴⁰ Ibid, p. 28.

⁴¹ Appendix III of the GAO report provides very brief descriptions of programs funded at \$10 million or more and the ACC report briefly describes the five largest programs in its inventory.

⁴² More information on the NRSA program is available at [<http://grants.nih.gov/training/nrsa.htm>].

Institutional grants are made for a five-year period. Trainee appointments are normally made in 12-month increments, although short-term (two- to three-month) awards are available. No individual trainee may receive more than five years of aggregate Kirschstein support at the predoctoral level or three years of support at the postdoctoral level, including any combination of support from institutional training grants and individual fellowship awards. The annual stipend for predoctoral trainees in 2005 was about \$12,000, and the postdoctoral stipend was between \$20,000 and \$32,000 (depending on years of experience).

In FY2004, Training Grants were awarded to 293 institutions in all but six states. A total of 2,356 grants were awarded, which funded nearly 9,000 predoctoral fellowships and nearly 5,500 postdoctoral fellowships. The Fellowship Grant programs supported around 2,500 pre- and postdoctoral students in 2004. The large majority of the Training Grants were awarded through the National Institute of General Medical Sciences.

NSF Graduate Research Fellowships. The NSF Graduate Research Fellowships is the largest of that agency's STEM education programs. These fellowships also represent one of the longest-running federal STEM programs (enacted in 1952). The purpose of this program is to increase the size and diversity of the U.S. workforce in science and engineering. The program provides three years of support to approximately 1,000 graduate students annually in STEM disciplines who are pursuing research-based master's and doctoral degrees, with additional focus on women in engineering and computer and information sciences. In 2006, 907 awards were given to graduate students studying in nine major fields at 150 institutions.

Applicants must be U.S. citizens or nationals, or permanent resident aliens of the United States; must have completed no more than twelve months of full-time graduate study at the time of their application; and must be pursuing an advanced degree in a STEM field supported by the National Science Foundation.⁴³ The fellows' affiliated institution receives a \$40,500 award — \$30,000 for a 12-month stipend and \$10,500 for an annual cost-of-education allowance. These awards are for a maximum of three years and usable over a five-year period, and provide a one-time \$1,000 International Research Travel Allowance. All discipline-based review panels, made up of professors, researchers, and others respected in their fields, convene for three days each year to read and evaluate applications in their areas of expertise. In 2005, there were 29 such panels made up of more than 500 experts.

NSF Mathematics and Science Partnerships. The Mathematics and Science Partnerships program is among the NSF's largest STEM education programs. Since its inception in 2002, this program has awarded grants that support four types of projects (the number of awards is shown in parentheses):

⁴³ A list of NSF-supported fields of study can be found at [<http://www.nsf.gov/pubs/2005/nsf05601/nsf05601.htm#study>].

- Comprehensive Partnership projects (12) to implement change in mathematics and science education across the K-12 continuum;
- Targeted Partnership projects (28) to improve K-12 student achievement in a narrower grade range or disciplinary focus in mathematics and/or science;
- Institute Partnership projects (8) to focus on improving middle and high school mathematics and science through the development of school-based intellectual leaders and master teachers; and
- Research, Evaluation & Technical Assistance projects (22) to build research, evaluation, and infrastructure capacity for the MSP.

One of the Comprehensive Partnership projects is between the Baltimore County Public Schools (BCPS) and the University of Maryland, Baltimore County (UMBC). The two main goals of the UMBC-BCPS STEM Partnership are to (1) facilitate the implementation, testing, refinement, and dissemination of promising practices for improving STEM student achievement, and (2) improve teacher quality and retention in selected high-need elementary, middle, and high schools in Baltimore County Public Schools. Centered on creating and evaluating performance-based pre-service (internship) teacher education programs and sustainable professional development programs for teachers and administrators, the project is designed to increase K-12 student achievement in STEM areas by increasing teacher and administrator knowledge. Ongoing assessments of student work and the differentiation of instruction based upon these assessments serve to evaluate and refine instruction, curricula and assessments, professional development programs, administrative leadership strategies, and directions for overall school improvement in STEM areas. UMBC and BCPS collaboration is facilitated by the creation of the Center for Excellence in STEM Education, where UMBC faculty and BCPS teachers and administrators develop projects to serve the needs of the BCPS district and the university. At the center, faculty and teachers work together to simultaneously improve the university's STEM and teacher education departments and the teaching and learning culture in the BCPS.

One of the Targeted Partnership grants supports the Promoting Reflective Inquiry in Mathematics Education Partnership, which includes Black Hills State University, Technology and Innovations in Education (TIE) of the Black Hills Special Services Cooperative, and the Rapid City School District in South Dakota. The overall goal of the partnership is aimed at improving achievement in mathematics for all students in Rapid City schools, with a particular goal of reducing the achievement gap between Native American and non-Native American students. The project seeks to improve the professional capacity and sustain the quality of K-12 in-service teachers of mathematics in the Rapid City School District, and student teachers of mathematics from Black Hills State University in order to provide effective, inquiry-based mathematics instruction. Objectives include reducing the number of high school students taking non-college preparatory mathematics, increasing the number of students taking upper level mathematics, and increasing student performance on college entrance exams. To accomplish these goals, the project provides 100 hours of professional development in combination with content-based workshops at the district level, and building-based activities involving modeling of effective lessons, peer mentoring and coaching, and lesson study. Mathematics education and discipline faculty from Black Hills State University are

involved in district-wide professional development activities. A cadre of building-based Mathematics Lead Teachers convenes learning teams composed of mathematics teachers, mathematics student teachers, school counselors, and building administrators to identify key issues in mathematics curriculum and instruction.

NSF Research Experiences for Undergraduates. The Research Experiences for Undergraduates (REU) program is the largest of the NSF STEM education programs that supports active research participation by *undergraduate* students. REU projects involve students in research through two avenues. REU Sites are based on independent proposals to initiate and conduct projects that engage a number of students in research. *REU Supplements* are requested for ongoing NSF-funded research projects or are included as a component of proposals for new or renewal NSF grants or cooperative agreements. REU projects may be based in a single discipline or academic department, or on interdisciplinary or multi-department research opportunities with a coherent intellectual theme. Undergraduate student participants in either Sites or Supplements must be citizens or permanent residents of the United States or its possessions. Students apply directly to REU Sites (rather than to the NSF) to participate in the program.

One of the grantees under this program is the REU Site in Microbiology at the University of Iowa. The goals of this project are to (1) recruit and select bright students, including women, individuals with diverse backgrounds with respect to geographic origin and ethnicity, and students from non-Ph.D.-granting institutions where research possibilities are limited; (2) involve students in basic, experimental research in microbiology; (3) expose students to a broad range of bioscience research; (4) develop each student's critical-thinking skills; and (5) develop each student's ability to record, analyze, and present scientific information. The student participants are integrated into faculty research programs and expected to perform like beginning graduate students. Informal faculty-student discussions and weekly seminars supplement laboratory research. Weekly informal lunches, two picnics, and a banquet facilitate social and scientific interactions. At the end of each summer's program, the students prepare oral presentations to be given at a Summer Program Symposium. Each student also prepares a written research report under the guidance of a mentor.

ED Science and Mathematics Access to Retain Talent Grants. The establishment of the Science and Mathematics Access to Retain Talent (SMART) Grants through the Deficit Reduction Act of 2005 (P.L. 109-171) nearly doubled the STEM education effort under ED. In its first year of funding, FY2006, the SMART Grants accounted for over half of ED's STEM education spending. The SMART Grant provides up to \$4,000 for each of the third and fourth years of undergraduate study and is in addition to the student's Pell Grant award.

To be eligible to receive a SMART Grant a student must be a citizen, eligible to receive a Pell Grant, have a 3.0 cumulative grade point average, and enrolled as a full-time third or fourth year student in a science-related baccalaureate degree program.

ED Mathematics and Science Partnerships. Prior to creation of the SMART Grants, the Mathematics and Science Partnership (MSP) program was the

ED's largest STEM program. The MSP is intended to increase the academic achievement of students in mathematics and science by enhancing the content knowledge and teaching skills of classroom teachers. These partnerships — between state education agencies, high-need school districts, and STEM faculty in institutions of higher education — are supported by state-administered formula grants and carried out in collaboration with the NSF-MSP program. Partnerships must use their grants for one or more of several specific activities. Among them are the following:

- professional development to improve math and science teachers' subject knowledge;
- activities to promote strong teaching skills among these teachers and teacher educators;
- math and science summer workshops or institutes with academic-year followup;
- recruitment of math, science, and engineering majors to teaching jobs through signing and performance incentives, stipends for alternative certification, and scholarships for advanced course work;
- development and redesign of more rigorous, standards-aligned math and science curricula;
- distance-learning programs for math and science teachers;
- and opportunities for math and science teachers to have contact with working mathematicians, scientists, and engineers.

A review of projects funded in FY2004 revealed that most grantees focus on math (as opposed to science) instruction in middle schools, and provide professional development to roughly 46 teachers over a period of about 21 months.⁴⁴ The survey found that most projects link content to state standards, and that algebra, geometry, and problem-solving are the top three math topics addressed by professional development activities. Most projects administer content knowledge tests to teachers, conduct observations, and make pre-and post-test comparisons. About half of the projects develop their own tests for teachers, and most rely on state tests of academic achievement to measure student knowledge.

Recommendations to Improve Federal STEM Education Policy

Many prominent reports from the scientific community have received serious consideration and their recommendations have been incorporated into legislative proposals that have ultimately gained passage. These recommendations concern every aspect of the educational pipeline. All of the recent reports issuing STEM education policy recommendations focus on five areas: improving elementary and secondary preparation in math and science, recruiting new elementary and secondary math and science teachers, retooling current math and science teachers, increasing the number of undergraduate STEM degrees awarded, and supporting graduate and early-career research.

⁴⁴ Analysts at the Brookings Institution conducted a survey of 266 winning MSP projects from 41 states. Results of the survey are available at [<http://www.ed.gov/programs/mathsci/proposalreview.doc>].

As mentioned at the outset of this report, one report that has been of particular influence in the STEM debate is from the National Academy of Sciences (NAS) — *Rising Above the Gathering Storm*. This influence is perhaps due to the clear targets and concrete programs laid out in the report. The NAS report's five recommendations to improve STEM education are to

- quadruple middle- and high-school math and science course-taking by 2010,
- recruit 10,000 new math and science teachers per year,
- strengthen the skills of 250,000 current math and science teachers,
- increase the number of STEM baccalaureate degrees awarded, and
- support graduate and early-career research in STEM fields.

To *enlarge the pipeline* of future STEM degree recipients, NAS sets a goal of quadrupling the number of middle and high school students taking Advanced Placement (AP) or International Baccalaureate (IB) math or science courses, from the current 1.1 million to 4.5 million by 2010. NAS further sets a goal of increasing the number of students who pass either the AP or IB tests to 700,000 by 2010. To enlarge the pipeline, NAS also supports the expansion of programs such as *statewide specialty high schools* for STEM immersion and *inquiry-based learning* through laboratory experience, summer internships, and other research opportunities.

To *recruit 10,000 new STEM teachers*, NAS advocates the creation of a competitive grant program to award merit-based scholarships to obtain a four-year STEM degree in conjunction with certification as a K-12 mathematics or science teacher. These \$10,000 to \$20,000 awards could be used only for educational expenses and would require a five-year service commitment. An additional \$10,000 annual bonus would be awarded to participating teachers in underserved schools in inner cities and rural areas. In further support of this scholarship program, NAS recommends that five-year, \$1 million matching grants be awarded to postsecondary institutions to encourage the creation of programs that integrate the obtainment of a STEM bachelor's degree with teacher certification.

NAS proposes four approaches to achieving the goal of *strengthening the skills of 250,000 current STEM teachers*. First, NAS proposes that matching grants be awarded to support the establishment of state and regional summer institutes for STEM teachers modeled after the Merck Institute for Science Education. Second, NAS proposes that additional grants go to postsecondary institutions that support STEM master's degree programs for current STEM teachers (with or without STEM bachelor's degrees) modeled after the University of Pennsylvania Science Teachers Institute. Third, NAS proposes that programs be created to train current teachers to provide AP, IB, and pre-AP or pre-IB instruction modeled after the Advanced Placement Initiative and the Laying the Foundation programs. Fourth, NAS proposes the creation of a national panel to collect, evaluate, and develop rigorous K-12 STEM curricula modeled after Project Lead the Way.

To *increase STEM bachelor's degree attainment*, NAS proposes providing 25,000 new scholarships each year. These Undergraduate Scholar Awards in Science, Technology, Engineering, and Mathematics (USA-STEM) would be distributed to each state in proportion with its population, and awarded to students

based on competitive national exams. The \$20,000 scholarships could only go to U.S. citizens, and could only be used for the payment of tuition and fees in pursuit of a STEM degree at a U.S. postsecondary institution.

To increase graduate study in areas of national need, including STEM, NAS proposes the creation of 5,000 new fellowships each year to U.S. citizens pursuing doctoral degrees. The fellowships would be administered by the National Science Foundation, which would also draw on the advice of several federal agencies in determining the areas of need. An annual stipend of \$30,000 would be accompanied by an additional \$20,000 annually to cover the cost of tuition and fees. These fellowships would also be portable, so that students could choose to study at a particular institution without the influence of faculty research grants.

Legislation Action on STEM Education Policy

In recent years, several pieces of legislation have been introduced with the purpose of improving STEM education in the United States. As has been noted, many of the proposals in these bills have been influenced by the recommendations of several reports recently issued by leading academic, scientific, and business organizations.⁴⁵ These recommendations, particularly those from the business community, are not limited to the educational system. This report does not discuss these non-educational policy recommendations (e.g., immigration policies that affect the supply of foreign workers to fill U.S. demand in STEM occupations or policies designed to incent private-sector research and development). Rather, this concluding section reviews proposals that have gained passage in the 109th and 110th Congresses that seek to improve the various STEM education outcomes discussed at the outset of this report.

Major Legislative Actions in the 109th Congress

Three bills containing STEM education-related proposals were passed in the 109th Congress and signed into law. The National Aeronautics and Space Administration Authorization Act of 2005 (P.L. 109-155) directed the Administrator to develop, expand, and evaluate educational outreach programs in science and space that serve elementary and secondary schools. The National Defense Authorization Act of 2006 (P.L. 109-163) made permanent the Science, Mathematics and Research for Transformation pilot program initiated by the Defense Act of 2005 to address

⁴⁵ The Education Commission of the States, *Keeping America Competitive: Five Strategies To Improve Mathematics and Science Education*, July 2005; The Association of American Universities, *National Defense Education and Innovation Initiative, Meeting America's Economic and Security Challenges in the 21st Century*, January 2006; The National Academy of Sciences, Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, February 2006; The National Summit on Competitiveness, *Statement of the National Summit on Competitiveness: Investing in U.S. Innovation*, December 2005; The Business Roundtable, *Tapping America's Potential: The Education for Innovation Initiative*, July 2005; The Center for Strategic and International Studies, *Waiting for Sputnik*, 2005.

deficiencies of scientists and engineers in the national security workforce. The Deficit Reduction Act of 2005 (P.L. 109-171) established the Academic Competitiveness Grants and the National Science and Mathematics Access to Retain Talent Grants programs, which supplement Pell Grants for students studying mathematics, technology, engineering, critical foreign languages, and physical, life, and computer sciences. The act also established the Academic Competitiveness Council, chaired by the Secretary of Education and charged with identifying and evaluating all federal STEM programs, and recommending reforms to improve program integration and coordination. The Council released the findings of its study in May 2007 (discussed earlier in this report).

The America COMPETES Act

The 110th Congress passed the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (known as the America COMPETES Act) which was signed into law on August 9, 2007 (P.L. 110-69). The act expands existing STEM education programs and establishes several new programs under the Department of Energy (DOE), Department of Education (ED), and the National Science Foundation (NSF). A brief discussion of the major provisions of the act follows.

Department of Energy. Title V of the act establishes several STEM education programs under the DOE. In an effort to draw middle and secondary school students into the STEM educational pipeline, the act creates (1) a pilot program that awards grants to states to help establish or expand statewide Specialty Schools for Mathematics and Science and (2) a program to provide internships to support Experiential-Based Learning Opportunities for middle and high-school students at the national labs, with priority given to students from high-needs schools. To improve K-12 teaching, the act creates (1) a program to establish a Center of Excellence in each national laboratory region in order to develop and disseminate best practices in STEM education and (2) a program to support Summer Institutes at the national labs and partner universities in order to improve the STEM content knowledge of current teachers. To encourage the pursuit of STEM fields among advanced students and young scholars, the act creates (1) grants to promote the establishment of Talent Expansion academic programs in nuclear and hydrocarbon studies, (2) PACE Graduate Fellowships for those studying a “mission area of the Department,” and (3) Early Career Awards for new STEM research scientists. The act also appoints a new Director for STEM Education at the Department who would coordinate DOE education activities and serve as an interagency liaison for K-12 STEM education.

Education Department. Title VI of the act authorizes several new grant programs in ED to enhance STEM education. Subtitle A authorizes three new programs to improve K-12 teaching: (1) a Baccalaureate Degrees program that encourages STEM majors to concurrently obtain teaching certification, (2) a Master’s Degrees program to upgrade the skills of current teachers through two to three years of part-time study or to support one-year programs to bring STEM professionals into teaching, and (3) a program to increase the number of Advanced Placement and International Baccalaureate teachers by 70,000. Subtitle B establishes three new programs specifically directed at improving students’ math achievement. These

programs award competitive grants to LEAs (through states) and include the Math Now program to improve math instruction at elementary schools with low math performance, the Summer Term Education program to provide additional instruction in high-need LEAs, and the Secondary School program that funds the hiring of math coaches. Subtitle D authorizes a new competitive state grant program to improve the Alignment of Secondary School Graduation Requirements with postsecondary and workforce demands and develop P-16 Data Systems. Subtitle E provides Mathematics and Science Partnership Bonus Grants for high-poverty elementary and secondary schools in each state.

National Science Foundation. Title VII of the act seeks to double spending on NSF STEM education programs in seven years. Most of these funds are directed at a number of existing STEM education programs at NSF. These programs include the Robert Noyce Teacher Scholarship program that recruits and trains math and science teachers, the Math and Science Education Partnerships program, the STEM Talent Expansion program to increase the number of students receiving associate or baccalaureate degrees, the Advanced Technological Education program to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels, the Graduate Research Fellowship program that provides three years of support for graduate study in STEM fields leading to research-based master's or doctoral degrees, and the Integrative Graduate Education and Research Traineeship program that supports collaborative research that transcends traditional disciplinary boundaries. The act amends the MSP program to add a new Teacher Institutes for the 21st Century program that provides additional professional development to STEM teachers in high-need schools and amends the Noyce Scholarship program to add a new Teaching Fellowships program that provides salary supplements. The act further creates a Laboratory Science Pilot program to award grants to improve laboratories at the secondary school level and a program to award grants to institutions of higher education to develop Professional Science Master's Degree programs.