Chapter 1.

Women and Girls in Science, Technology, Engineering, and Mathematics

Science, technology, engineering, and mathematics (STEM) are widely regarded as critical to the national economy. Concern about America's ability to be competitive in the global economy has led to a number of calls to action to strengthen the pipeline into these fields (National Academy of Sciences, Committee on Science, Engineering & Public Policy, 2007; U.S. Government Accountability Office, 2006; U.S. Department of Education, 2006). Expanding and developing the STEM workforce is a critical issue for government, industry leaders, and educators. Despite the tremendous gains that girls and women have made in education and the workforce during the past 50 years, progress has been uneven, and certain scientific and engineering disciplines remain overwhelmingly male. This report addresses why there are still so few women in certain scientific and engineering fields and provides recommendations to increase the number of women in these fields.

Definition of Science, Technology, Engineering, and Mathematics (STEM)

STEM is defined in many ways (for example, see U.S. government definitions at http://nces.ed.gov/pubs2009/2009161.pdf). In this report the term "STEM" refers to the physical, biological, and agricultural sciences; computer and information sciences; engineering and engineering technologies; and mathematics. The social and behavioral sciences, such as psychology and economics, are not included, nor are health workers, such as doctors and nurses. College and university STEM faculty are included when possible, but high school teachers in STEM subjects are not. While all of these workers are part of the larger scientific and engineering workforce, their exclusion is based on the availability of data. In this report the terms "STEM," "science, technology, engineering, and mathematics," and "scientific and engineering fields" are used interchangeably.

The National Science Foundation estimates that about five million people work directly in science, engineering, and technology—just over 4 percent of the workforce.[1] This relatively small group of workers is considered to be critical to economic innovation and productivity. Workers in science and engineering fields tend to be well paid and enjoy better job security than do other workers. Workforce projections for 2018 by the U.S. Department of Labor show that nine of the 10 fastest-growing occupations that require at least a bachelor's degree will require significant scientific or mathematical training. Many science and engineering occupations are predicted to grow faster than the average rate for all occupations, and

[1]Defined by occupation, the United States science and engineering workforce totaled between 4.3 and 5.8 million people in 2006. Those in science and engineering occupations who had bachelor's degrees were estimated at between 4.3 and 5.0 million. The National Science Foundation includes social scientists but not medical professionals in these estimates (National Science Board, 2010). Estimates of the size of the scientific, engineering, and technological workforce are produced using different criteria by several U.S. government agencies including the Census Bureau, the National Science Foundation, and the Bureau of Labor Statistics. Defined more broadly, the size of the STEM workforce has been estimated to exceed 21 million people.

some of the largest increases will be in engineering- and computer-related fields—fields in which women currently hold one-quarter or fewer positions (Lacey & Wright, 2009; National Science Board, 2010).

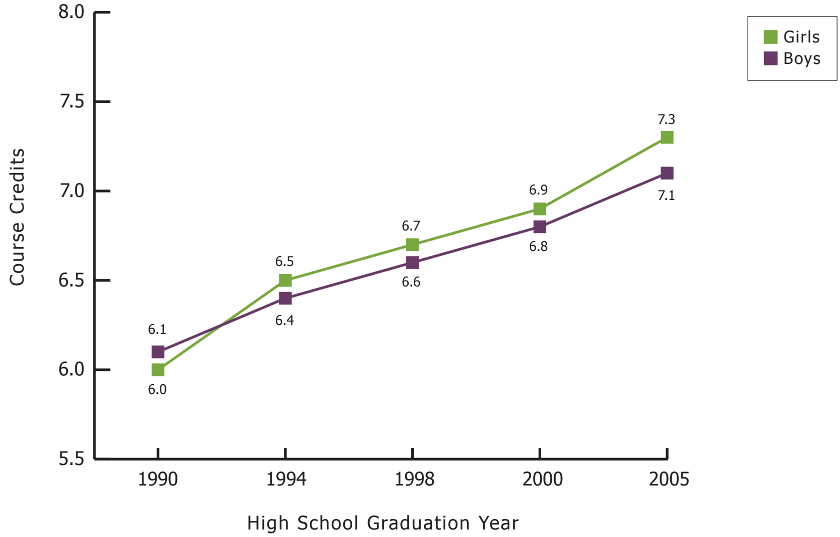
Attracting and retaining more women in the STEM workforce will maximize innovation, creativity, and competitiveness. Scientists and engineers are working to solve some of the most vexing challenges of our time—finding cures for diseases like cancer and malaria, tackling global warming, providing people with clean drinking water, developing renewable energy sources, and understanding the origins of the universe. Engineers design many of the things we use daily—buildings, bridges, computers, cars, wheelchairs, and X-ray machines. When women are not involved in the design of these products, needs and desires unique to women may be overlooked. For example, "some early voice-recognition systems were calibrated to typical male voices. As a result, women's voices were literally unheard. … Similar cases are found in many other industries. For instance, a predominantly male group of engineers tailored the first generation of automotive airbags to adult male bodies, resulting in avoidable deaths for women and children" (Margolis & Fisher, 2002, pp. 2–3). With a more diverse workforce, scientific and technological products, services, and solutions are likely to be better designed and more likely to represent all users.

The opportunity to pursue a career in science, technology, engineering, and mathematics is also a matter of pay equity. Occupational segregation accounts for the majority of the wage gap (AAUW Educational Foundation, 2007), and although women still earn less than men earn in science and engineering fields, as they do on average in the overall workforce, women in science and engineering tend to earn more than women earn in other sectors of the workforce. According to a July 2009 survey, the average starting salary for someone with a bachelor's degree in mechanical engineering, for example, was just over $59,000. By comparison, the average starting salary for an individual with a bachelor's degree in economics was just under $50,000 (National Association of Colleges and Employers, 2009).

PREPARATION OF GIRLS FOR STEM FIELDS

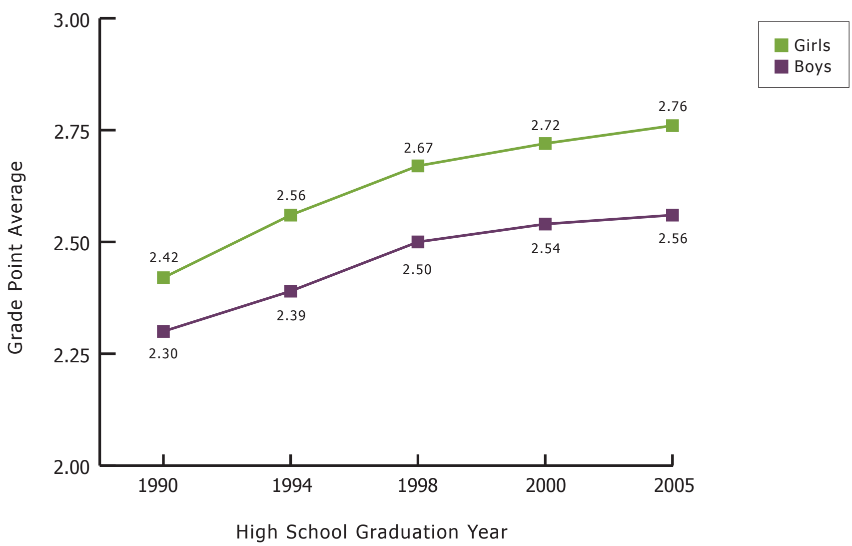
Math skills are considered essential to success in STEM fields. Historically, boys have outperformed girls in math, but in the past few decades the gender gap has narrowed, and today girls are doing as well as boys in math on average (Hyde et al., 2008). Girls are earning high school math and science credits at the same rate as boys and are earning slightly higher grades in these classes (U.S. Department of Education, National Center for Education Statistics, 2007) (see figures 1 and 2).

Figure 1. High School Credits Earned in Mathematics and Science, by Gender, 1990–2005



Source: U.S. Department of Education, National Center for Education Statistics, 2007, *The Nation's Report Card: America's high school graduates: Results from the 2005 NAEP High School Transcript Study*, by C. Shettle et al. (NCES 2007-467) (Washington, DC: Government Printing Office).

Figure 2. Grade Point Average in High School Mathematics and Science (Combined), by Gender, 1990–2005



Source: U.S. Department of Education, National Center for Education Statistics, 2007, *The Nation's Report Card: America's high school graduates: Results from the 2005 NAEP High School Transcript Study*, by C. Shettle et al. (NCES 2007-467) (Washington, DC: Government Printing Office).

On high-stakes math tests, however, boys continue to outscore girls, albeit by a small margin. A small gender gap persists on the mathematics section of the SAT and the ACT examinations (Halpern, Benbow, et al., 2007; AAUW, 2008). Fewer girls than boys take advanced placement (AP) exams in STEM-related subjects such as calculus, physics, computer science, and chemistry (see figure 3), and girls who take STEM AP exams earn lower scores than boys earn on average (see figure 4). Research on "stereotype threat," profiled in chapter 3, sheds light on the power of stereotypes to undermine girls' math test performance and may help explain the puzzle of girls' strong classroom performance and relatively weaker performance on high-stakes tests such as these.

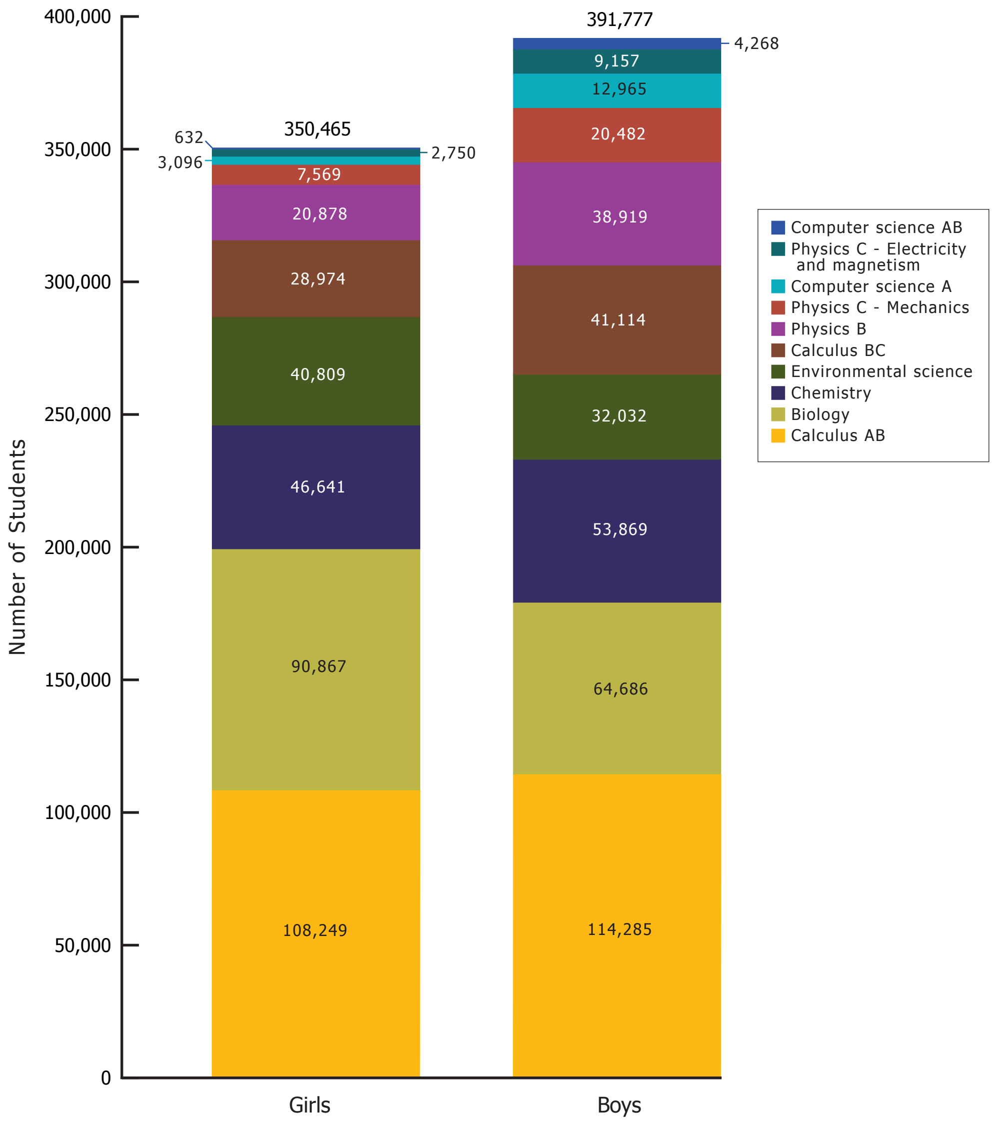
One notable gain is girls' increased representation in the ranks of the highest achievers in mathematics. Among students with very high scores on math tests, boys continue to outnumber girls (Lubinski & Benbow, 1992, 2006; Hedges & Nowell, 1995); however, the proportion of girls among the highest math achievers has greatly increased during the past few decades. The Study of Mathematically Precocious Youth identifies seventh and eighth graders who score greater than 700 on the SAT math section (the top 0.01 percent or 1 in 10,000 students). Since the early 1980s the ratio of boys to girls in this extremely select group has dramatically declined from 13:1 (Benbow & Stanley, 1983) to around 3:1 in recent years (Brody & Mills, 2005; Halpern, Benbow, et al., 2007).

Students from historically disadvantaged groups such as African American and Hispanic students, both female and male, are less likely to have access to advanced courses in math and science in high school, which negatively affects their ability to enter and successfully complete STEM majors in college (May & Chubin, 2003; Frizell & Nave, 2008; Tyson et al., 2007; Perna et al., 2009). In 2005, 31 percent of Asian American and 16 percent of white high school graduates completed calculus, compared with 6 percent and 7 percent of African American and Hispanic high school graduates, respectively. Additionally, one-quarter of Asian American and one-tenth of white high school graduates took either the AP or International Baccalaureate exam in calculus, compared with just 3.2 percent of African American and 5.6 percent of Hispanic graduates (National Science Board, 2008). Yet even among underrepresented racial-ethnic groups, a growing number of girls are leaving high school well prepared in math and science and capable of pursuing STEM majors in college.

WOMEN IN STEM IN COLLEGES AND UNIVERSITIES

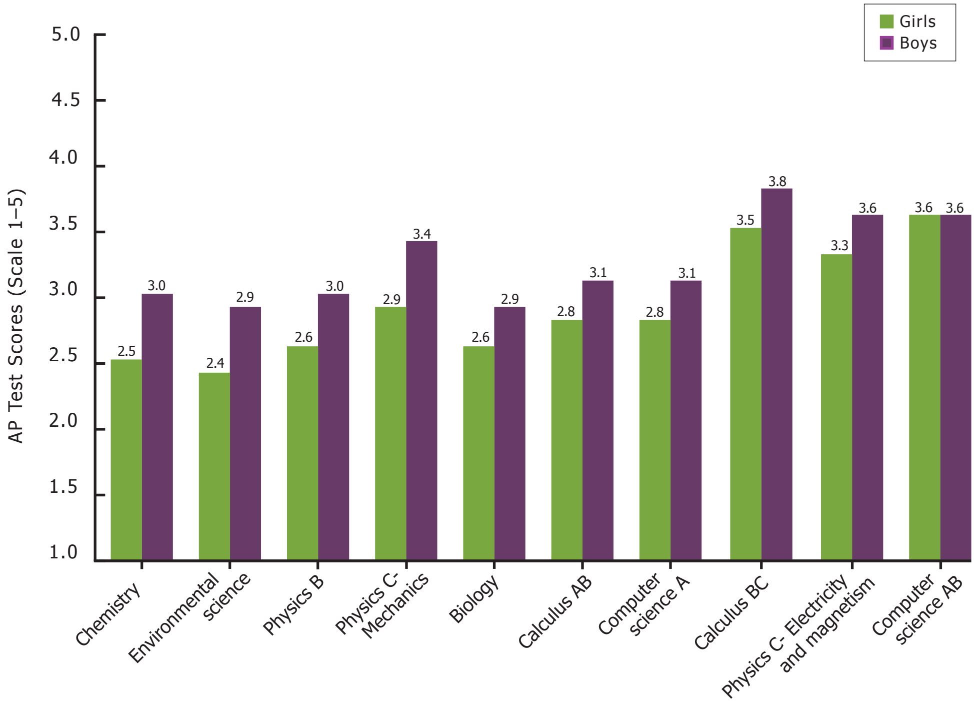
The transition between high school and college is a critical moment when many young women turn away from a STEM career path. Although women are the majority of college students, they are far less likely than their male peers to plan to major in a STEM field (see figure 5).

Figure 3. Students Taking Advanced Placement Tests in Mathematics and Science, by Gender, 2009



Source: Retrieved November 11, 2009, from the College Board website at www.collegeboard.com.

Figure 4. Average Scores on Advanced Placement Tests in Mathematics and Science Subjects, by Gender, 2009

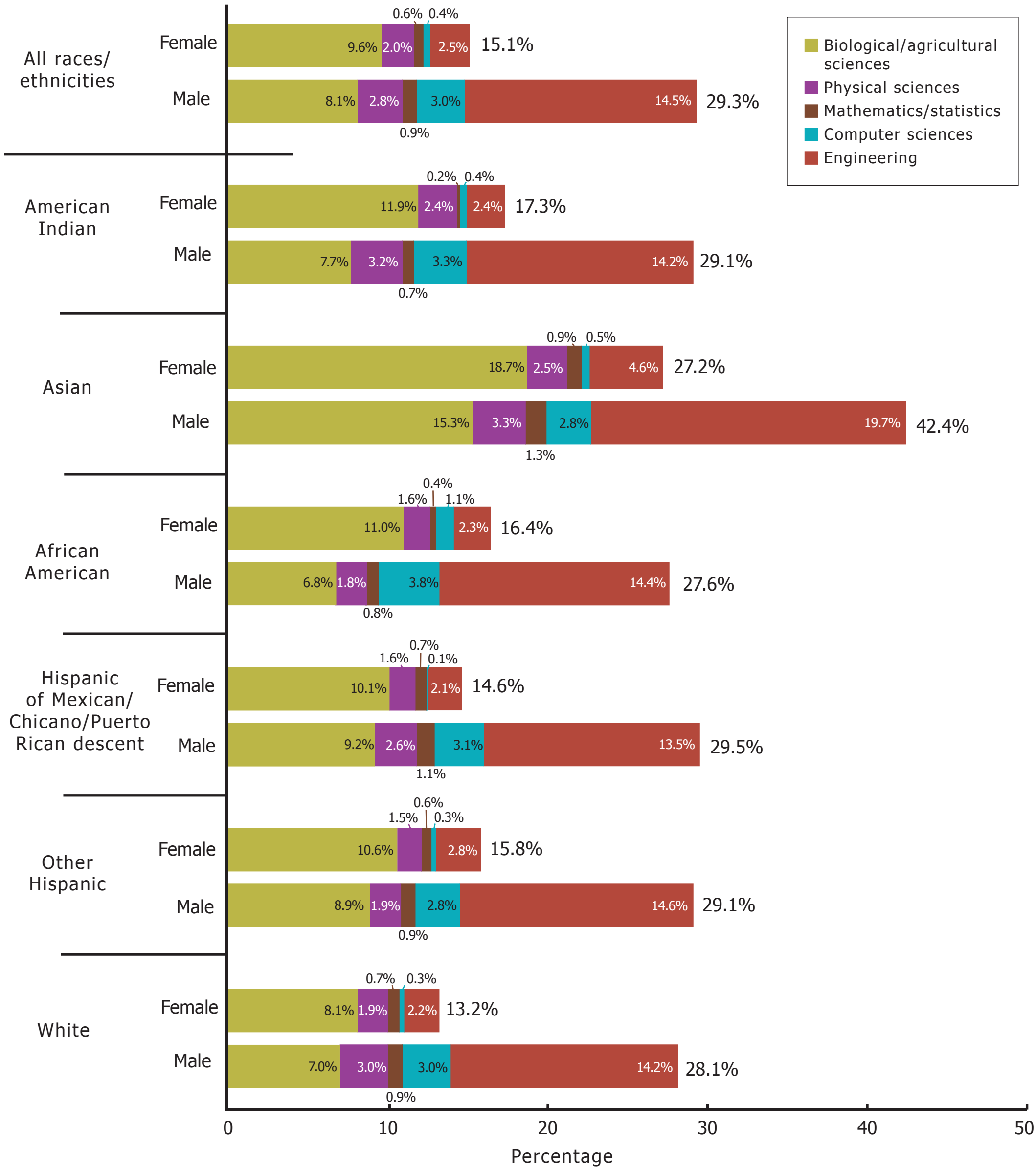


Source: Retrieved November 11, 2009, from the College Board website at www.collegeboard.com.

Almost one-third of all male freshmen (29 percent), compared with only 15 percent of all female freshmen, planned to major in a STEM field in 2006 (National Science Foundation, 2009b). The gender disparity in plans to major is even more significant when the biological sciences are not included. Just over one-fifth of male freshmen planned to major in engineering, computer science, or the physical sciences, compared with only about 5 percent of female freshmen (ibid.).

Women who enter STEM majors in college tend to be well qualified. Female and male first-year STEM majors are equally likely to have taken and earned high grades in the prerequisite math and science classes in high school and to have confidence in their math and science abilities (Brainard & Carlin, 1998; U.S. Department of Education, National Center for Education Statistics, 2000; Vogt et al., 2007). Nevertheless, many of these academically capable women

Figure 5. Intent of First-Year College Students to Major in STEM Fields, by Race-Ethnicity and Gender, 2006



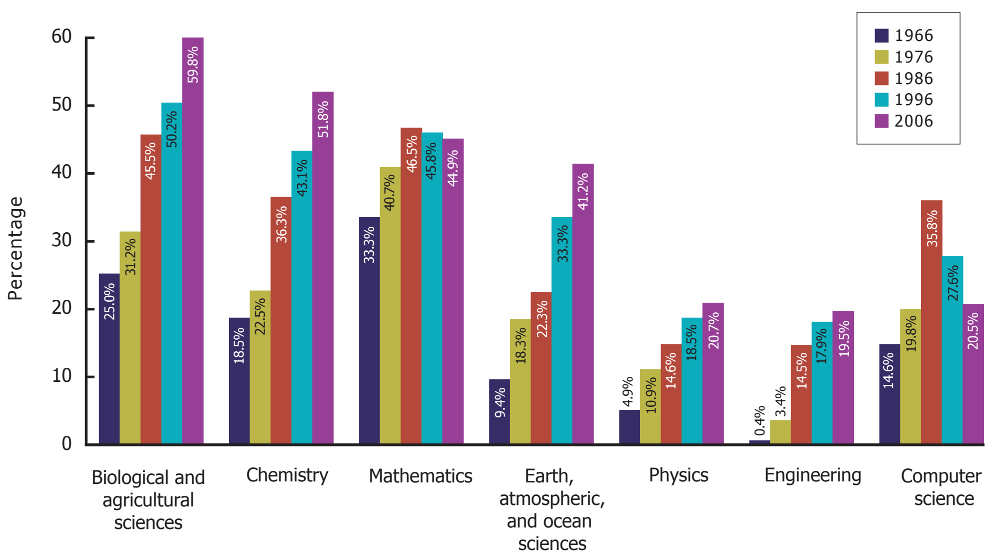
Source: Higher Education Research Institute, 2007, *Survey of the American freshman: Special tabulations* (Los Angeles, CA), cited in National Science Foundation, Division of Science Resources Statistics, 2009, *Women, minorities, and persons with disabilities in science and engineering: 2009* (NSF 09-305) (Arlington, VA), Table B-8.

leave STEM majors early in their college careers, as do many of their male peers (Seymour & Hewitt, 1997). For example, in engineering the national rate of retention from entry into the major to graduation is just under 60 percent for women and men (Ohland et al., 2008). Although the overall retention of female undergraduates in STEM is similar to the retention rate for men and has improved over time (U.S. Department of Education, National Center for Education Statistics, 2000; Xie & Shauman, 2003), understanding why women leave STEM majors is still an important area of research. Women make up a smaller number of STEM students from the start, so the loss of women from these majors is of special concern. Chapter 6 profiles the work of researchers Barbara Whitten, Jane Margolis, and Allan Fisher, showing the role of departmental culture in attracting and retaining female computer science and physics majors.

Despite the still relatively small percentages of women majoring in some STEM fields, the overall proportion of STEM bachelor's degrees awarded to women has increased dramatically during the past four decades, although women's representation varies by field.

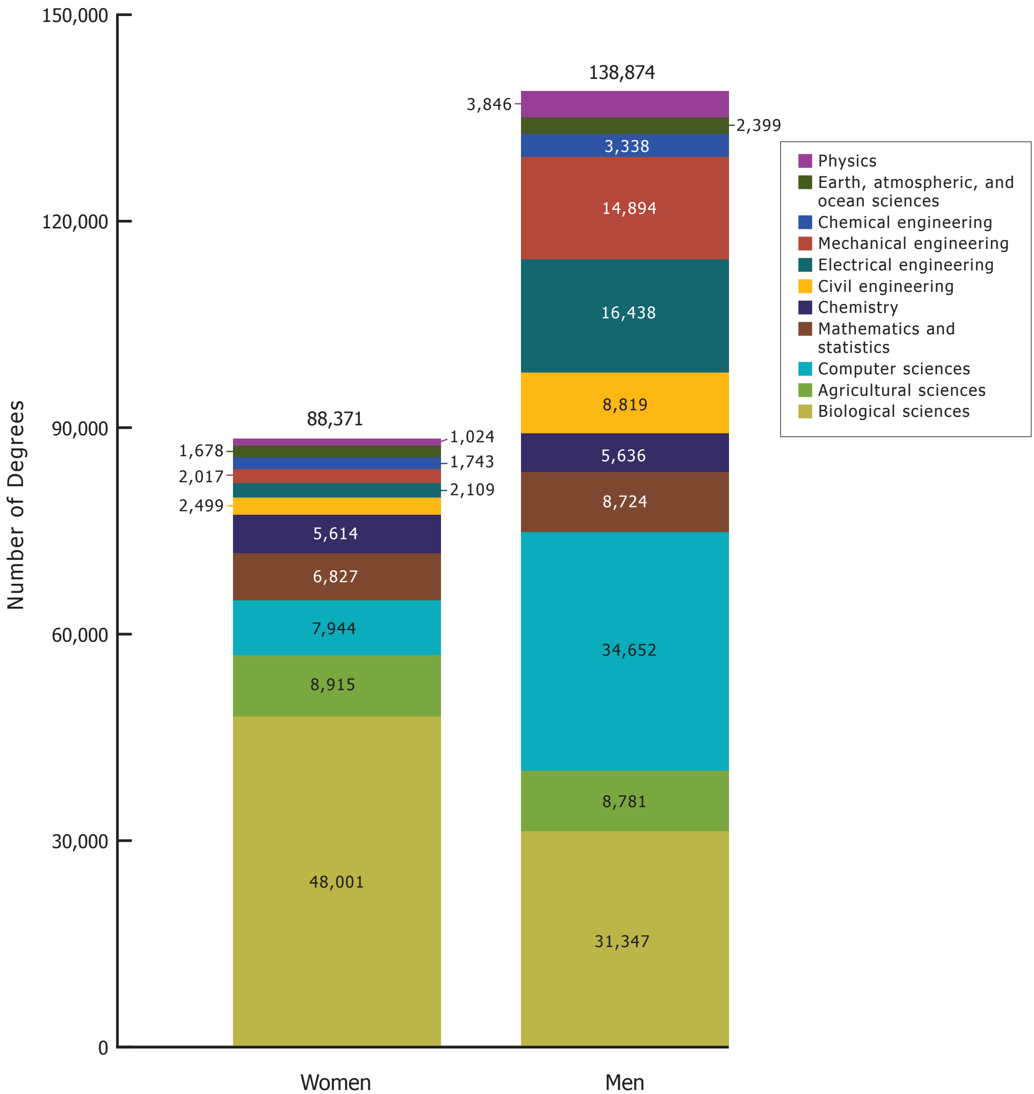
In 2006, women earned the majority of bachelor's degrees in biology, one-half of bachelor's degrees in chemistry, and nearly one-half in math. Women earned a much smaller proportion

Figure 6. Bachelor's Degrees Earned by Women in Selected Fields, 1966–2006



Source: National Science Foundation, Division of Science Resources Statistics, 2008, *Science and engineering degrees: 1966–2006* (Detailed Statistical Tables) (NSF 08-321) (Arlington, VA), Table 11, Author's analysis of Tables 34, 35, 38, & 39.

Figure 7. Bachelor's Degrees Earned in Selected Science and Engineering Fields, by Gender, 2007

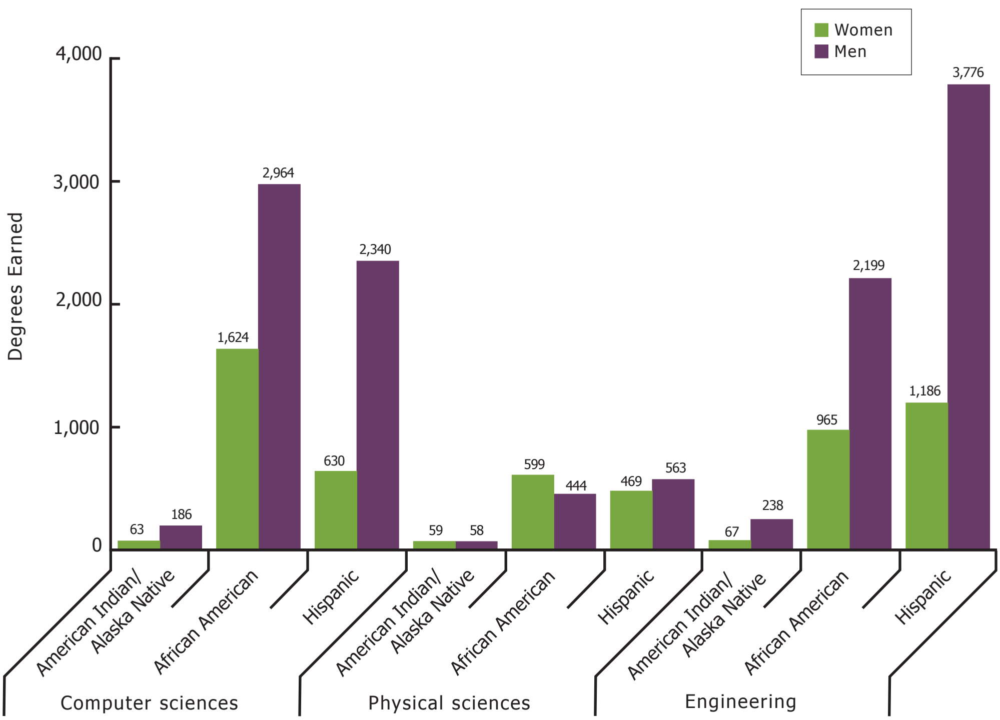


Source: National Science Foundation, Division of Science Resources Statistics, 2009, *Women, minorities, and persons with disabilities in science and engineering: 2009* (NSF 09-305) (Arlington, VA), Tables C-4 and C-5.

of bachelor's degrees awarded in physics, engineering, and computer science. In fact, as figure 6 shows, women's representation in computer science is actually declining—a stark reminder that women's progress cannot be taken for granted. In the mid-1980s women earned slightly more than one-third (36 percent) of the bachelor's degrees in computer science; by 2006 that number had dropped to 20 percent.

The size of the STEM disciplines, and, therefore, the number of degrees awarded, varies dramatically. As figure 7 shows, women earned 48,001 biological science degrees in 2007, compared with only 7,944 computer science degrees, 2,109 electrical engineering degrees, and 1,024 physics degrees. In comparison, men earned 31,347 biological science degrees, 34,652 computer science degrees, 16,438 electrical engineering degrees, and 3,846 physics degrees.

Figure 8. Bachelor's Degrees Earned by Underrepresented Racial-Ethnic Groups in Selected STEM Fields, by Gender, 2007

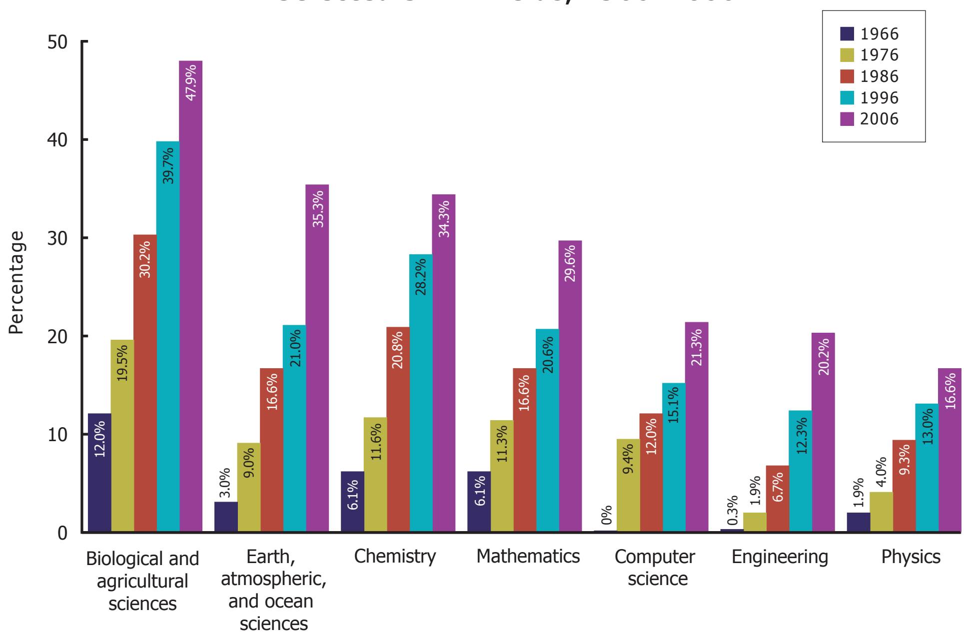


Note: Racial-ethnic groups include U.S. citizens and permanent residents only. Data based on degree-granting institutions eligible to participate in Title IV federal financial aid programs.
Source: National Science Foundation, Division of Science Resources Statistics, 2009, *Women, minorities, and persons with disabilities in science and engineering: 2009* (NSF 09-305) (Arlington, VA), Table C-14.

Trends in bachelor's degrees earned by women from underrepresented racial-ethnic groups (African American, Hispanic, and Native American/Alaskan Native) generally mirror the overall pattern; however, in some cases the gender gap in degrees earned by African American and Hispanic women and men is much smaller or even reversed (see figure 8). For example, African American women earned 57 percent of physical science degrees awarded to African Americans in 2007; still, the overall number of African American women earning physical science bachelor's degrees was less than 600.

Women's representation among doctoral degree recipients in STEM fields also has improved in the last 40 years (see figure 9). In 1966, women earned about one-eighth of the doctorates in the biological and agricultural sciences, 6 percent of the doctorates in chemistry and mathematics, and 3 percent or less of the doctorates in earth, atmospheric, and ocean sciences; physics; engineering; and computer science. Forty years later, in 2006, women earned almost one-half of the doctorates in the biological and agricultural sciences; around one-third of the doctorates in earth, atmospheric, and ocean sciences, chemistry, and math; and approximately one-fifth of the doctorates in computer science, engineering, and physics.

Figure 9. Doctorates Earned by Women in Selected STEM Fields, 1966–2006



Source: National Science Foundation, Division of Science Resources Statistics, 2008, *Science and engineering degrees: 1966–2006* (Detailed Statistical Tables) (NSF 08-321) (Arlington, VA), Table 25, Author's analysis of Tables 34, 35, 38, & 39.

Title IX and Gender Equity in STEM

Title IX of the Education Amendments of 1972 prohibits sex discrimination in education programs and activities that receive federal financial assistance. The law states, "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any educational program or activity receiving federal financial assistance" (20 U.S. Code § 1681). Title IX covers nearly all colleges and universities. To ensure compliance with the law, Title IX regulations require institutions that receive any form of federal education funding to evaluate their current policies and practices and adopt and publish grievance procedures and a policy against sex discrimination.

When Congress enacted Title IX, the law was intended to help women achieve equal access to all aspects of education at all levels. During the last 37 years, however, Title IX has been applied mostly to sports. Recent efforts by Congress have brought attention to how Title IX could be used to improve the climate for and representation of women in STEM fields.

Critics argue that women do not face discrimination in STEM fields but rather that women are less interested than men in certain STEM fields and that enforcement of Title IX could lead to a quota system in the sciences (Tierney, 2008; Munro, 2009). Title IX requires neither quotas nor proportionality, and it cannot address gender gaps in participation due to personal choices; however, Title IX reviews can help identify institutional policies and practices that negatively, and in some cases inadvertently, affect personal choices in gender-specific ways (Pieronek, 2005). Simply put, Title IX can help create a climate where women and men of similar talent who want to be scientists or engineers have equal opportunity to do so.

A report by the U.S. Government Accountability Office (2004) focused on Title IX in STEM disciplines and concluded that federal agencies need to do more to ensure that colleges and universities receiving federal funds comply with Title IX. In response to these findings, federal agencies, including NASA and the Department of Energy in conjunction with the Department of Education and the Department of Justice, have begun to conduct Title IX compliance reviews more regularly (Pieronek, 2009).

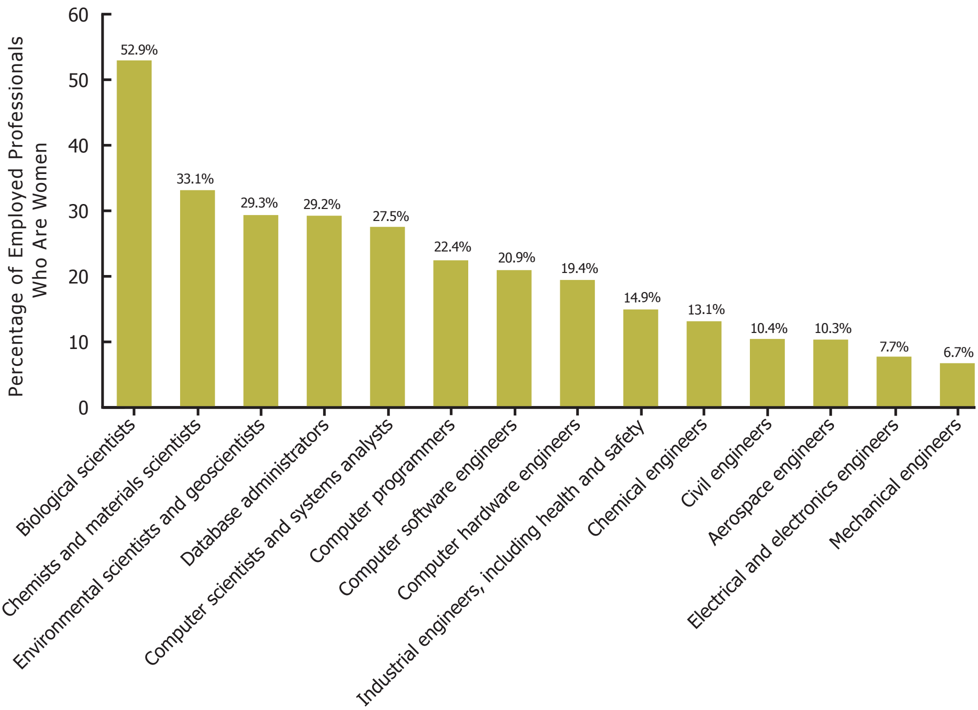
In general the number of doctoral degrees in STEM disciplines earned by women from underrepresented racial-ethnic backgrounds also increased during the past four decades but still remains a small proportion of the total. For example, in 2007, African American women earned 2.2 percent of the doctorates awarded in the biological sciences and less than 2 percent of those awarded in engineering, computer sciences, the physical sciences, and mathematics and statistics. The proportions were similar for Hispanic women and even smaller for Native American women (National Science Foundation, 2009b). Although women have clearly made great progress in earning doctorates in STEM fields, at the doctoral level women remain underrepresented in every STEM field except biology.

WOMEN IN THE STEM WORKFORCE

Consistent with the increased representation of women among STEM degree recipients, women's representation in the STEM workforce has also improved significantly in recent decades; yet, as figure 10 shows, women are still underrepresented in many STEM professions.

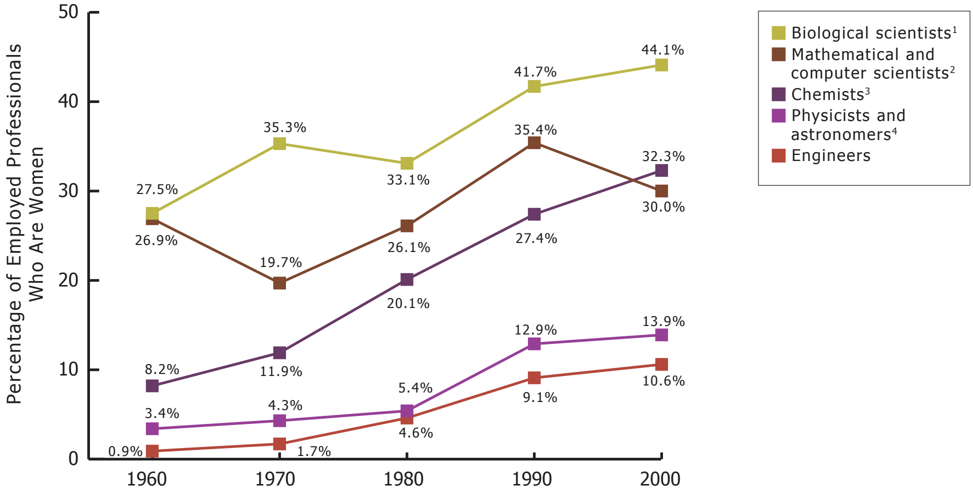
In fields such as the biological sciences, women have had a sizeable presence as far back as 1960, when women made up about 27 percent of biologists. Forty years later, in 2000, women made up about 44 percent of the field. On the other end of the spectrum, women made up a mere 1 percent of engineers in 1960 and only about 11 percent of engineers by 2000 (see figure 11). This is an impressive increase, but women still make up only a small minority of working engineers. Overall, progress has been made, but women remain vastly outnumbered in many STEM fields, especially engineering and physics.

Figure 10. Women in Selected STEM Occupations, 2008



Note: Occupations are self-reported.
Source: U.S. Department of Labor, Bureau of Labor Statistics, 2009, *Women in the labor force: A databook* (Report 1018) (Washington, DC), Table 11.

Figure 11. Women in Selected STEM Occupations, 1960–2000



Notes: Data on postsecondary teachers by field of instruction were not gathered in the 2000 census, so postsecondary teachers are not included here. When postsecondary teachers were included from 1960 to 1990, the general trends remained the same.

[1] In the 1980 and 1990 censuses, data include life scientists as well as biological scientists.

[2] In the 1960 census, no category for computer scientists was included; in the 1970 census, the category was titled "mathematicians and computer specialists."

[3] In the 1980 and 1990 censuses, the category was titled "chemists except biochemists"; in the 2000 census, the category was titled "chemists and material scientists."

[4] In the 1960 census, the category was titled "physicists."

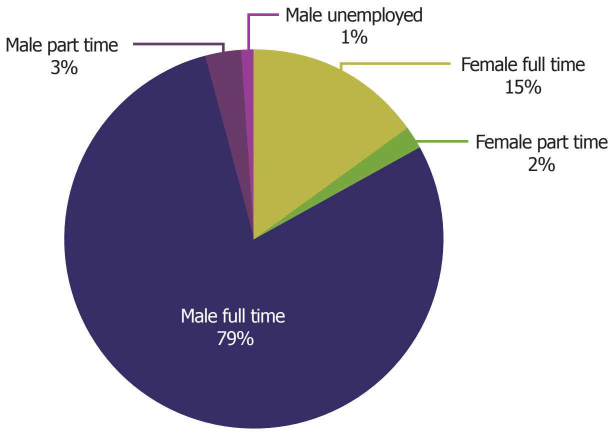
Source: U.S. Census Bureau, 1960, 1970, 1980, 1990, & 2000, *Census of the population* (Washington, DC).

Among workers who hold doctorates, men represent a clear majority in all STEM fields. Figures 12a and 12b show that men far outnumber women, even in the biological sciences.

In the academic workforce, women's representation varies by discipline as well as tenure status. Forty percent of the full-time faculty in degree-granting colleges and universities in the United States in 2005 were women; however, women's representation in STEM disciplines was significantly lower. Women made up less than one-quarter of the faculty in computer and information sciences (22 percent), math (19 percent), the physical sciences (18 percent), and engineering (12 percent). In the life sciences, an area in which many people assume that women have achieved parity, women made up only one-third (34 percent) of the faculty. In all cases women were better represented in lower faculty ranks than in higher ranks among STEM faculty in four-year colleges and universities (Di Fabio et al., 2008).

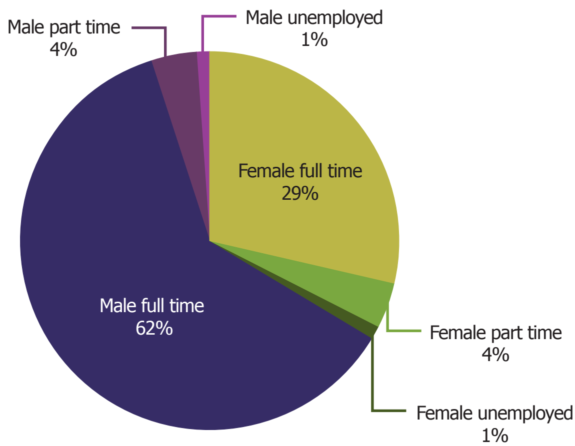
The situation is even more severe for women from underrepresented racial-ethnic backgrounds. Of the more than 7,000 computer-science doctoral faculty in 2006, only 60 were

Figure 12a. Workers with Doctorates in the Computer and Information Sciences Workforce, by Gender and Employment Status, 2006



Note: The number of female unemployed workers was not available due to small sample size.
Source: National Science Foundation, Division of Science Resources Statistics, 2009, *Characteristics of doctoral scientists and engineers in the United States: 2006* (Detailed Statistical Tables) (NSF 09-317) (Arlington, VA), Authors' analysis of Table 2.

Figure 12b. Workers with Doctorates in the Biological, Agricultural, and Environmental Life Science Workforce, by Gender and Employment Status, 2006



Note: The percentages do not equal 100 due to rounding.
Source: National Science Foundation, Division of Science Resources Statistics, 2009, *Characteristics of doctoral scientists and engineers in the United States: 2006* (Detailed Statistical Tables) (NSF 09-317) (Arlington, VA), Authors' analysis of Table 2.

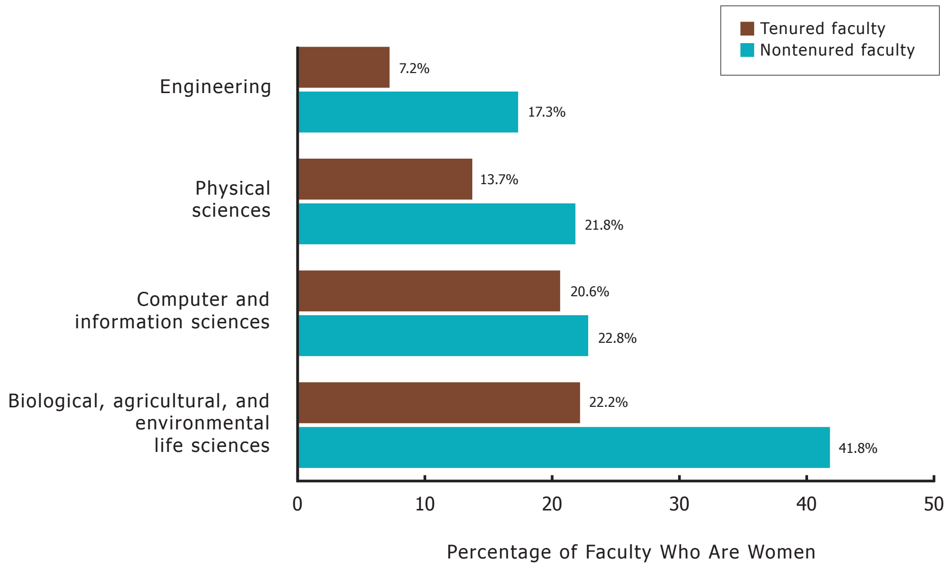
African American women; numbers for Hispanic and Native American women were too low to report. African American women also made up less than 1 percent of the 17,150 postsecondary teachers in engineering. Even in the biological sciences the number of African American and Hispanic female faculty was low. Of the nearly 25,000 postsecondary teachers in the biological sciences, 380 were African American women and 300 were Hispanic women (ibid.).

Women's representation among tenured faculty is lower than one would expect based on the supply of female science and engineering doctoral degree recipients in recent decades (Kulis et al., 2002). The path from elementary school to a STEM career has often been compared to a pipeline. This metaphor suggests that as the number of girls who study STEM subjects in elementary, middle, and secondary school increases (more girls go into the pipeline), the number of women who become scientists and engineers will also increase (more women come out of the pipeline), and gender disparities in representation will disappear. This has not happened at the expected rate, especially at the tenured faculty level in science and engineering. If we compare the percentage of tenured female faculty in 2006 with the percentage of STEM doctorates awarded to women in 1996 (allowing 10 years for an individual to start an academic job and earn tenure), in most STEM fields the drop-off is pronounced. For example, women earned 12 percent of the doctorates in engineering in 1996 but were only 7 percent of the tenured faculty in engineering in 2006. Even in fields like biology, where women now receive about one-half of doctorates and received 42 percent in 1996, women made up less than one-quarter of tenured faculty and only 34 percent of tenure-track faculty in 2006 (National Science Foundation, 2008, 2009a). Women make up larger percentages of the lower-paying, nontenured STEM faculty positions (see figure 13).

Several studies have found a gender difference in hiring in STEM academic disciplines (Bentley & Adamson, 2003; Nelson & Rogers, n.d.; Ginther & Kahn, 2006). Although recent research found that when women do apply for STEM faculty positions at major research universities they are more likely than men to be hired, smaller percentages of qualified women apply for these positions in the first place (National Research Council, 2009). Improving women's position among STEM faculty will apparently require more than simply increasing the pool of female STEM degree holders (Valian, 1998; Kulis et al., 2002).

Cathy Trower and her colleagues at the Collaborative on Academic Careers in Higher Education (COACHE) at Harvard University found that female STEM faculty express lower job satisfaction than do their male peers. Lower satisfaction leads to higher turnover and a loss of talent in science and engineering. Trower's research, profiled in chapter 7, suggests that the climate of science and engineering departments is closely related to satisfaction of female faculty and that providing effective mentoring and work-life policies can help improve job satisfaction and, hence, the retention of female STEM faculty.

Figure 13. Female STEM Faculty in Four-Year Educational Institutions, by Discipline and Tenure Status, 2006



Source: National Science Foundation, Division of Science Resources Statistics, 2009, *Characteristics of doctoral scientists and engineers in the United States: 2006* (Detailed Statistical Tables) (NSF 09-317) (Arlington, VA), Author's analysis of Table 20.

Women working in STEM fields tend to have higher earnings than do other women in the workforce, although a gender pay gap exists in STEM occupations as in other fields. For example, in 2009 the average starting salary for bachelor's degree recipients in marketing was just over $42,000 a year, and bachelor's degree recipients in accounting received starting salaries averaging around $48,500 a year. In comparison, starting salaries for bachelor's degree holders in computer science averaged around $61,500, and average starting salaries were just under $66,000 for individuals holding bachelor's degrees in chemical engineering (National Association of Colleges and Employers, 2009). As these numbers indicate, many STEM careers can provide women increased earning potential and greater economic security.

Recent studies of scientists, engineers, and technologists in business and the high-tech industry have found that women in these fields have higher attrition rates than do both their male peers and women in other occupations (Hewlett et al., 2008; Simard et al., 2008). The studies highlight midcareer as a critical time for these women. Hewlett et al. (2008) at the Center for Work-Life Policy at Harvard University found that female scientists, engineers, and technologists are fairly well represented at the lower rungs on corporate ladders

(41 percent). More than half (52 percent), however, quit their jobs by midcareer (about 10 years into their careers). High-tech companies in particular lost 41 percent of their female employees, compared with only 17 percent of their male employees. In engineering, women have higher attrition rates than their male peers have, despite similar levels of stated satisfaction and education. The Society of Women Engineers (2006) conducted a retention study of more than 6,000 individuals who earned an engineering degree between 1985 and 2003. One-quarter of female engineers surveyed were either not employed at all or not employed in engineering or a related field, while only one-tenth of men surveyed had left the engineering field.

WHY SO FEW?

Academic research on this topic is prolific, with three themes emerging from the literature. First, the notion that men are mathematically superior and innately better suited to STEM fields than women are remains a common belief, with a large number of articles addressing cognitive gender differences as an explanation for the small numbers of women in STEM. A second theme revolves around girls' lack of interest in STEM. A third theme involves the STEM workplace, with issues ranging from work-life balance to bias. The remainder of this chapter summarizes and examines these themes and concludes with an introduction to the research projects profiled in chapters 2 through 9.

Methodology

Using multiple databases, including Web of Science, ProQuest, Social Science Citation Index, and J-Stor, AAUW reviewed hundreds of academic articles written during the past 25 years on the topic of women in science and engineering. Articles from the fields of psychology, sociology, education, economics, neuroscience, and endocrinology were examined. The literature review informed this chapter, and it was used to help identify the eight research findings profiled in chapters 2 through 9. These projects were chosen because they each address an important issue with the potential to influence public understanding. The profiled findings are well respected in the research community, as measured by publication in peer-reviewed journals, number of citations, and other forms of public recognition. These projects were conducted within the past 15 years.

Cognitive Sex Differences

As noted earlier, a difference in average math performance between girls and boys no longer exists in the general school population (Hyde et al., 2008). Nevertheless, the issue of cognitive sex differences, including mathematical ability, remains hotly contested. Lynn and Irwing (2004) found small or no differences in average IQ between the sexes; that is, neither girls nor boys are the "smarter sex."[2] Other researchers have found, however, that girls and boys tend to have different cognitive strengths and weaknesses. Generally, boys perform better on tasks using spatial orientation and visualization and on certain quantitative tasks that

[2]Some research suggests that women and men achieve similar IQ results using different parts of the brain (Haier et al., 2005).

rely on those skills. Girls outperform boys on tests relying on verbal skills, especially writing, as well as some tests involving memory and perceptual speed (Hedges & Nowell, 1995; Kimura, 2002; Halpern, Aronson, et al., 2007).

One of the largest gender gaps in cognitive skills is seen in the area of spatial skills and specifically on measures of mental rotation, with boys consistently outscoring girls (Linn & Petersen, 1985; Voyer et al., 1995). Many people consider spatial skills to be important for success in fields like engineering, although the connection between spatial abilities and success in STEM careers is not definitive (Ceci et al., 2009). Whether or not well-developed spatial skills are necessary for success in science and engineering, research shows that spatial skills can be improved fairly easily with training (Baenninger & Newcombe, 1989; Vasta et al., 1996). Among the most promising research findings in this field are those of Sheryl Sorby, whose work is profiled in chapter 5. Sorby and Baartmans (2000) and their colleagues designed and implemented a successful course to improve the spatial-visualization skills of first-year engineering students who had poorly developed spatial skills. More than three-quarters of female engineering students who took the course remained in the school of engineering, compared with about one-half of the female students who did not take the course. Poor or underdeveloped spatial skills may deter girls from pursuing math or science courses or careers, but these skills can be improved fairly easily.

Biology is not destiny

Ceci et al. (2009) reviewed more than 400 articles exploring the causes of women's underrepresentation in STEM fields, including biological as well as social factors, and concluded that the research on sex differences in brain structure and hormones is inconclusive. Female and male brains are indeed physically distinct, but how these differences translate into specific cognitive strengths and weaknesses remains unclear. Likewise, evidence for cognitive sex differences based on hormonal exposure is mixed. Ceci et al. found that hormonal exposure, especially in gestation, does have a role in cognitive sex differences. Overall, however, the researchers concluded, "Evidence for a hormonal basis of the dearth of female scientists" is "weaker than the evidence for other factors," such as gender differences in preferences and sociocultural influences on girls' performance on gatekeeper tests (p. 224).

Differences in the representation of women in science and math fields cross-culturally and over time also support the role of sociocultural factors for explaining gender gaps in these fields (Andreescu et al., 2008). As discussed earlier, the ratio of boys to girls among children identified as mathematically precocious has decreased dramatically in the last 30 years, far faster than it would take a genetic change to travel through the population. Also, while in the vast majority of countries more boys than girls scored above the 99th percentile in mathema-

tics on the 2003 Program for International Student Assessment, in Iceland and Thailand more girls than boys scored above the 99th percentile (Guiso et al., 2008). Differences between countries and over time illustrate the importance of culture in the development of mathematical skills.

Scientists and engineers are not necessarily the highest math achievers

Boys outnumber girls at the very high end of the math test score distribution. Some researchers have suggested that this gender difference accounts for the small number of women in certain STEM fields. This logic has two main flaws. First, as mentioned above, girls have made rapid inroads into the ranks of children identified as "mathematically gifted" in the past 30 years, while women's representation in mathematically demanding fields such as physics, computer science, and engineering has grown slowly. That is, fewer women pursue STEM careers than would be expected based on the number of girls who earn very high math scores. Second, Weinberger (2005) found that the science and engineering workforce is not populated primarily by the highest-scoring math students, male or female. Less than one-third of college-educated white men in the engineering, math, computer science, and physical science workforce scored higher than 650 on the SAT math exam, and more than one-third had SAT math scores below 550—the math score of the average humanities major. Even though a correlation exists between high school math test scores and later entry into STEM education and careers, very high math scores are not necessarily a prerequisite for success in STEM fields.

"Just Not Interested"

Many girls and women report that they are not interested in science and engineering. In a 2009 poll of young people ages 8–17 by the American Society for Quality, 24 percent of boys but only 5 percent of girls said they were interested in an engineering career. Another recent poll found that 74 percent of college-bound boys ages 13–17 said that computer science or computing would be a good college major for them compared with 32 percent of their female peers (WGBH Education Foundation & Association for Computing Machinery, 2009). From early adolescence, girls express less interest in math or science careers than boys do (Lapan et al., 2000; Turner et al., 2008). Even girls and women who excel in mathematics often do not pursue STEM fields. In studies of high mathematics achievers, for example, women are more likely to secure degrees in the humanities, life sciences, and social sciences than in math, computer science, engineering, or the physical sciences; the reverse is true for men (Lubinski & Benbow, 2006).

Interest in an occupation is influenced by many factors, including a belief that one can succeed in that occupation (Eccles [Parsons] et al., 1983; Correll, 2004; Eccles, 2006). The work of

Shelley Correll, profiled in chapter 4, shows that girls assess their mathematical ability lower than do boys with equivalent past mathematical achievement. At the same time, girls hold themselves to a higher standard in subjects like math, where boys are considered to excel. Because of this, girls are less likely to believe that they will succeed in a STEM field and, therefore, are less likely to express interest in a STEM career.

Pajares (2005) found that gender differences in self-confidence in STEM subjects begin in middle school and increase in high school and college, with girls reporting less confidence than boys do in their math and science ability. In part, boys develop greater confidence in STEM through experience developing relevant skills. A number of studies have shown that gender differences in self-confidence disappear when variables such as previous achievement or opportunity to learn are controlled (Lent et al., 1986; Zimmerman & Martinez-Pons, 1990; Cooper & Robinson, 1991; Pajares, 1996, 2005). Students who lack confidence in their math or science skills are less likely to engage in tasks that require those skills and will more quickly give up in the face of difficulty. Girls and women may be especially vulnerable to losing confidence in STEM areas. The research of Carol Dweck, profiled in chapter 2, has implications for improving self-confidence. Dweck's research shows that when a girl believes that she can become smarter and learn what she needs to know in STEM subjects—as opposed to believing that a person is either born with science and math ability or not—she is more likely to succeed in a STEM field.

A belief that one can succeed in a STEM field is important but is not the only factor in establishing interest in a STEM career. Culturally prescribed gender roles also influence occupational interest (Low et al., 2005). A review of child vocational development by Hartung et al. (2005) found that children—and girls especially—develop beliefs that they cannot pursue particular occupations because they perceive them as inappropriate for their gender.

Jacquelynne Eccles, a leading researcher in the field of occupational choice, has spent the past 30 years developing a model and collecting evidence about career choice. Her work suggests that occupational choice is influenced by a person's values as well as expectancy for success (Eccles [Parsons] et al., 1983; Eccles, 1994, 2006). Well-documented gender differences exist in the value that women and men place on doing work that contributes to society, with women more likely than men to prefer work with a clear social purpose (Jozefowicz et al., 1993; Konrad et al., 2000; Margolis et al., 2002; Lubinski & Benbow, 2006; Eccles, 2006). The source of this gender difference is a subject of debate: Some claim that the difference is innate, while others claim that it is a result of gender socialization. Regardless of the origin of the difference, most people do not view STEM occupations as directly benefiting society or individuals (National Academy of Engineering, 2008; Diekman et al., 2009). As a result, STEM careers often do not appeal to women (or men) who value making a social contribution

(Eccles, 1994; Sax, 1994). Certain STEM subdisciplines with a clearer social purpose, such as biomedical engineering and environmental engineering, have succeeded in attracting higher percentages of women than have other subdisciplines like mechanical or electrical engineering (Gibbons, 2009).

Despite girls' lower stated interest in science and engineering compared with boys, recent research suggests that there are ways to increase girls' interest in STEM areas (Turner & Lapan, 2005; Eisenhart, 2008; Plant et al., 2009). Plant et al. (2009) reported an increase in middle school girls' interest in engineering after the girls were exposed to a 20-minute narrative delivered by a computer-generated female agent describing the lives of female engineers and the benefits of engineering careers. The narrative included positive statements about students' abilities to meet the demands of engineering careers and counteracted stereotypes of engineering as an antisocial, unusual career for women while emphasizing the people-oriented and socially beneficial aspects of engineering. Another ongoing study and outreach project is focusing on educating high-achieving, mostly minority, high school girls about what scientists and engineers actually do and how they contribute to society. Although the girls knew almost nothing about engineering at the start of the study, of the 66 percent of girls still participating after two years, 80 percent were seriously considering a career in engineering (Eisenhart, 2008). The Engineer Your Life website (www.engineeryourlife.com), a project of the WGBH Educational Foundation and the National Academy of Engineering, has also been shown to increase high school girls' interest in pursuing engineering as a career. In a survey by Paulsen and Bransfield (2009), 88 percent of 631 girls said that the website made them more interested in engineering as a career, and 76 percent said that it inspired them to take an engineering course in college. Although these studies generally relied on small samples and in a number of cases no long-term follow-up has been done with participants, the results are promising.

Research on interest in science and engineering does not usually consider gender, race, and ethnicity simultaneously. Of course, gender and race do interact to create different cultural roles and expectations for women (and men) from different racial-ethnic backgrounds. Assumptions about the mismatch between women's interests and STEM often are based on the experiences of white women. In the African American community, for example, many of the characteristics that are considered appropriate for African American women, such as high self-esteem, independence, and assertiveness, can lead to success in STEM fields (Hanson, 2004). Young African American women express more interest in STEM fields than do young white women (Hanson, 2004; Fouad & Walker, 2005). The number of African American women in STEM remains low, however, suggesting that other barriers are important for this community (ibid.).

Workplace Environment, Bias, and Family Responsibilities

As mentioned above, women leave STEM fields at a higher rate than do their male peers (Society of Women Engineers, 2006; Hewlett et al., 2008; Frehill et al., 2009). Workplace environment, bias, and family responsibilities all play a role.

Workplace environment

In the study of STEM professionals in the private sector described earlier, Hewlett et al. (2008) found that many women appear to encounter a series of challenges at midcareer that contribute to their leaving careers in STEM industries. Women cited feelings of isolation, an unsupportive work environment, extreme work schedules, and unclear rules about advancement and success as major factors in their decision to leave. Although women and men in industry and business leave STEM careers at significantly different rates, the situation in academia is somewhat more nuanced. In a recent study on attrition among STEM faculty, Xu (2008) showed that female and male faculty leave at similar rates; however, women are more likely than men to consider changing jobs within academia. Women's higher turnover intention in academia (which is the best predictor of actual turnover) is mainly due to dissatisfaction with departmental culture, advancement opportunities, faculty leadership, and research support. Goulden et al. (2009) compared men and women in the sciences who are married with children and found that the women were 35 percent less likely to enter a tenure-track position after receiving a doctorate.

Bias

Women in STEM fields can experience bias that negatively influences their progress and participation. Although instances of explicit bias may be decreasing, implicit bias continues to have an adverse effect. Implicit biases may reflect, be stronger than, or in some cases contradict explicitly held beliefs or values. Therefore, even individuals who espouse a belief of gender equity and equality may harbor implicit biases about gender and, hence, negative gender stereotypes about women and girls in science and math (Valian, 1998). Nosek et al. (2002a) found that majorities of both women and men of all racial-ethnic groups hold a strong implicit association of male with science and female with liberal arts. This research is profiled in chapter 8.

Research has also pointed to bias in peer review (Wenneras & Wold, 1997) and hiring (Steinpreis et al., 1999; Trix & Psenka, 2003). For example, Wenneras and Wold found that a female postdoctoral applicant had to be significantly more productive than a male applicant to receive the same peer review score. This meant that she either had to publish at least three more papers in a prestigious science journal or an additional 20 papers in lesser-known specialty journals to be judged as productive as a male applicant. The authors concluded that the

systematic underrating of female applicants could help explain the lower success rate of female scientists in achieving high academic rank compared with their male counterparts.

Trix and Psenka (2003) found systematic differences in letters of recommendation for academic faculty positions for female and male applicants. The researchers concluded that recommenders (the majority of whom were men) rely on accepted gender schema in which, for example, women are not expected to have significant accomplishments in a field like academic medicine. Letters written for women are more likely to refer to their compassion, teaching, and effort as opposed to their achievements, research, and ability, which are the characteristics highlighted for male applicants. While nothing is wrong with being compassionate, trying hard, and being a good teacher, arguably these traits are less valued than achievements, research, and ability for success in academic medicine. The authors concluded, "Recommenders unknowingly used selective categorization and perception, also known as stereotyping, in choosing what features to include in their profiles of the female applicants" (p. 215).

Research profiled in chapter 9 shows that when women are acknowledged as successful in arenas that are considered male in character, women are less well liked and more personally derogated than are equivalently successful men. Being disliked can affect career outcomes, leading to lower evaluations and less access to organizational rewards. These results suggest that gender stereotypes can prompt bias in evaluative judgments of women in male-dominated environments, even when these women have proved themselves to be successful and demonstrated their competence (Heilman et al., 2004).

Biases do change. Today the fields viewed as stereotypically male have narrowed considerably compared with even 30 years ago. Life and health sciences are seen as more appropriate for women, while the physical or hard sciences and engineering fields are still considered masculine domains (Farenga & Joyce, 1999).

Family responsibilities

Many people think that women leave STEM academic careers because they cannot balance work and family responsibilities (Mason et al., 2009; Xie & Shauman, 2003); however, research evidence by Xu (2008) points to a more nuanced relationship between family responsibilities and academic STEM careers. Research shows that being single is a good predictor that a woman will be hired for a tenure-track job and promoted. Research also shows, however, that marriage is a good predictor for both women and men of being hired as an assistant professor (Xie & Shauman, 2003; Ginther & Kahn, 2006). Married women in STEM appear to have a disadvantage compared with married men in relation to tenure and promotion decisions only if the married women have children (Xie & Shauman, 2003).

So while marriage does not appear to hurt women, having young children does affect their chances for advancement. Having young children in the home may affect women's productivity since child-care responsibilities fall disproportionately on women (Stack, 2004).

Some telling statistics point to the difficulties that mothers still face in an academic environment. Mason and Goulden (2002) found that among tenured faculty in the sciences 12 to 14 years after earning a doctorate, 70 percent of the men but only 50 percent of the women had children living in their home. The same study found that among science professors who had babies within the first five years after receiving a doctorate, 77 percent of the men but only 53 percent of the women had achieved tenure 12 to 14 years after earning a doctorate. These disparities were not unique to, and not always worse in, STEM fields. In another Mason and Goulden study (2004), more than twice as many female academics (38 percent) as male academics (18 percent) indicated that they had fewer children than they had wanted.

In business and industry both women and men identify family responsibilities as a possible barrier to advancement, but women are affected differently than men by this "family penalty" (Simard et al., 2008, p. 5). Although both women and men feel that having a family hinders their success at work, women are more likely than men to report foregoing marriage or children and delaying having children. Among women and men with families, women are more likely to report that they are the primary caregiver and have a partner who also works full time. A recent retention study found that most women and men who left engineering said that interest in another career was a reason, but women were far more likely than men to also cite time and family-related issues (Society of Women Engineers, 2006; Frehill et al., 2008). Additionally, women in STEM are more likely to have a partner who is also in STEM and faces a similarly demanding work schedule. In a situation where a "two body problem" exists, the man's career is often given priority (Hewlett et al., 2008).

WHERE DO WE GO FROM HERE?

Multiple factors contribute to the underrepresentation of women and girls in STEM and, therefore, multiple solutions are needed to correct the imbalance. The remainder of this report profiles eight research findings, each of which offers practical ideas for helping girls and women reach their potential in science, technology, engineering, and mathematics. Selected for their relevance to public debate and their scientific credibility, these case studies provide important insights into the question of why so few women study and work in many STEM fields.

These findings provide evidence on the nurture side of the nature-nurture debate, demonstrating that social and environmental factors clearly contribute to the underrepresentation of women in science and engineering. The findings are organized into three areas: social and environmental factors that shape girls' achievements and interest in math and science; the college environment; and the continuing importance of bias, often operating at an unconscious level, as an obstacle to women's success in STEM fields.

Girls' Achievements and Interest in Math and Science Are Shaped by the Environment around Them

This report profiles four research projects that demonstrate the effects of societal beliefs and the learning environment on girls' achievements and interest in science and math. Chapter 2 profiles research showing that when teachers and parents tell girls that their intelligence can expand with experience and learning, girls do better on math tests and are more likely to want to continue to study math.

Chapter 3 examines research showing that negative stereotypes about girls' abilities in math are still relevant today and can lower girls' test performance and aspirations for science and engineering careers. When test administrators tell students that girls and boys are equally capable in math, the difference in performance disappears, illustrating the importance of the learning environment for encouraging girls' achievement and interest in math.

Chapter 4 profiles research on self-assessment, or how we view our own abilities. This research finds that girls assess their mathematical abilities lower than do boys with similar past mathematical achievements. At the same time, girls hold themselves to a higher standard than boys do in subjects like math, believing that they have to be exceptional to succeed in "male" fields. One result of girls' lower self-assessment of their math ability—even in the face of good grades and test scores—and their higher standard for performance is that fewer girls than boys aspire to STEM careers.

One of the most consistent, and largest, gender differences in cognitive abilities is found in the area of spatial skills, with boys and men consistently outperforming girls and women. Chapter 5 highlights research documenting that individuals' spatial skills consistently improve dramatically in a short time with a simple training course. If girls are in an environment that enhances their success in science and math with spatial skills training, they are more likely to develop their skills as well as their confidence and consider a future in a STEM field.

At Colleges and Universities, Little Changes Can Make a Big Difference in Attracting and Retaining Women in STEM

As described earlier, many girls graduate from high school well prepared to pursue a STEM career, but few of them major in science or engineering in college. Research profiled in chapter 6 demonstrates how small improvements in the culture of computer science and physics departments, such as changing admissions requirements, presenting a broader overview of the field in introductory courses, and providing a student lounge, can add up to big gains in female student recruitment and retention.

Likewise, colleges and universities can attract more female science and engineering faculty if they improve the integration of female faculty into the departmental culture. Research profiled in chapter 7 provides evidence that women are less satisfied with the academic workplace and more likely to leave it earlier in their careers than their male counterparts are. College and university administrators can recruit and retain more women by implementing mentoring programs and effective work-life policies for all faculty members.

Bias, Often Unconscious, Limits Women's Progress in Scientific and Engineering Fields

Research profiled in chapter 8 shows that most people continue to associate science and math fields with "male" and humanities and arts fields with "female," including individuals who actively reject these stereotypes. Implicit bias may influence girls' likelihood of identifying with and participating in math and science and also contributes to bias in education and the workplace—even among people who support gender equity. Taking the implicit bias test at https://implicit.harvard.edu can help people identify and understand their own implicit biases so that they can work to compensate for them.

Research profiled in chapter 9 shows that people not only associate math and science with "male" but also often hold negative opinions of women in "masculine" positions, like scientists or engineers. This research shows that people judge women to be less competent than men in "male" jobs unless women are clearly successful in their work. When a woman is clearly competent in a "masculine" job, she is considered to be less likable. Because both likability and competence are needed for success in the workplace, women in STEM fields can find themselves in a double bind.

Women have made impressive gains in science and engineering but are still a distinct minority in many science and engineering fields. The following eight research findings, taken together, suggest that creating environments that support girls' and women's achievements and interest in science and engineering will encourage more girls and women to pursue careers in these vital fields.