SOLVING THE EQUATION

The Variables for Women's Success in Engineering and Computing

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Foreword

During the 2014 White House Science Fair, President Barack Obama used a sports metaphor to explain why we must address the shortage of women in science, technology, engineering, and mathematics (STEM), particularly in the engineering and computing fields: "Half our team, we're not even putting on the field. We've got to change those numbers."

AAUW has been a leader in efforts to promote women in STEM since our founding in 1881. Through fellowships, programs, advocacy, and research, AAUW has inspired hundreds of thousands of girls to pursue science and math and helped thousands of women become scientists, engineers, and mathematicians. AAUW's 2010 research report, *Why So Few? Women in Science, Technology, Engineering, and Mathematics*, sparked nationwide interest in the shortage of women in STEM, leading to new initiatives in schools, colleges, and government. Indeed, significant progress has been made in fields such as biology and chemistry; yet in engineering and computing, women remain a distinct minority.

Solving the Equation: The Variables for Women's Success in Engineering and Computing focuses on the underrepresentation of women in engineering and computing and provides practical ideas for educators and employers seeking to foster gender diversity. From new ways of conceptualizing the fields for beginning students to good management practices, the report recommends large and small actions that can add up to real change.

Engineering and computing are too important for women to be less than fully represented. Diversity in these fields can contribute to creativity and productivity and, ultimately, to greater innovation. Join AAUW in our efforts to empower women and girls to succeed in every field of endeavor.

Patricia Fae Ho
AAUW President

Linda D. Hallman, CAE
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Acknowledgments

EXECUTIVE SUMMARY

More than ever before in history, girls are studying and excelling in science and mathematics. Yet the dramatic increase in girls' educational achievements in scientific and mathematical subjects has not been matched by similar increases in the representation of women working as engineers and computing professionals. Women made up just 26 percent of computing professionals in 2013, a substantially smaller portion than 30 years ago and about the same percentage as in 1960. In engineering, women are even less well represented, making up just 12 percent of working engineers in 2013.

The representation of women in engineering and computing occupations matters. Diversity in the workforce contributes to creativity, productivity, and innovation. Women's experiences—along with men's experiences—should inform and guide the direction of engineering and technical innovation. The United States simply can't afford to ignore the perspectives of half the population in future engineering and technical designs.

Advocates have long extolled the importance of advancing girls and women in science, technology, engineering, and mathematics (STEM). Engineering and computing stand out from the broader STEM category as the fields that offer the best opportunities for the greatest number of people. Accounting for more than 80 percent of the STEM workforce, engineering and computing occupations offer a higher return on investment and better prospects than jobs in other STEM fields offer. When women are not well represented in these fields, they lose out on these high-quality job opportunities.

Despite early similarities between girls and boys in math and science achievement, by high school, boys are more likely than girls to take the standardized exams most closely associated with the fields of engineering and computing. Among first-year college students, women are much less likely than men to say that they intend to major in engineering or computing. This disparity continues into the graduate level. In the workplace the discrepancy persists and in some cases worsens, as women leave engineering and computing jobs at higher rates than men do.

The issue of nonproportional representation in the number of engineering and computer science bachelor's degrees awarded is in large part an issue of women's underrepresentation, and some women of color are particularly underrepresented. Although black, Hispanic, American Indian, and Alaska Native women together made up 18 percent of the population ages 20 to 24 in 2013, they were awarded just 6 percent of computing and 3 percent of engineering bachelor's degrees conferred that year. In contrast, men from these demographic groups made up 19 percent of the population ages 20 to 24 and were awarded 18 percent of computing bachelor's degrees and 12 percent of engineering bachelor's degrees. Although men of some races and ethnicities are still underrepresented among those awarded degrees in these fields, particularly in engineering, men of every race and ethnicity are typically much closer to proportional representation than are their female counterparts.

Drawing on a large and diverse body of research, *Solving the Equation* highlights recent research that explores the factors underlying the underrepresentation of women in these fields, including stereotypes and biases, college curriculum, and workplace environment. The report argues for changes in the workplace and college environments as a necessary preamble to women's full participation in engineering and computing.

COMBATING STEREOTYPES AND BIASES

We all hold gender biases, shaped by cultural stereotypes in the wider culture, that affect how we evaluate and treat one another. While explicit gender bias—that is, self-reported bias—is declining, implicit or unconscious gender bias remains widespread.

Several research findings shed light on the effects of stereotypes and gender bias as they relate to women in engineering and computing. Chapter 3 highlights one study that found that scientists were more likely to choose a male candidate over an identical female candidate for a hypothetical job opening at a lab. Both female and male scientists

also offered a higher salary to the male candidate. Another study highlighted in chapter 3 found that potential employers systematically underestimated the mathematical performance of women compared with men, resulting in the hiring of lower-performing men over higher-performing women for mathematical work. Once objective past-performance information was introduced, however, the employers made less biased hiring decisions. Bias is prevalent, but its effects can be diminished with more comprehensive information.

Hundreds of studies have documented the power of stereotypes to influence performance through a phenomenon known as "stereotype threat." Stereotype threat occurs when individuals fear that they will confirm a negative stereotype about a group to which they belong. One such group is "women." When negative stereotypes about women's mathematical abilities are brought to test-takers' attention during tests, women's performance drops. Stereotype threat has been theorized not only to influence women's mathematical performance but also to contribute to disengagement from fields in which women are negatively stereotyped, such as engineering and computing.

Much research has been done on how stereotype threat can affect academic performance, but researchers are only recently beginning to examine how stereotype threat affects women in the workplace. One finding in this area, highlighted in chapter 5, showed that the more often female STEM faculty had research-related conversations with their male colleagues, the less engaged they felt with their work. In contrast, the more social conversations female STEM faculty had with their male colleagues, the more engaged they reported being with their work. One possible explanation for this finding is that research-related conversations with male colleagues may generate stereotype threat for female scientists. Social conversations with male colleagues, on the other hand, may lessen the threat by increasing a feeling of belonging in their work environment. Research suggests that stereotypes are activated for women more frequently when few women work in an organization. The presence of women at all levels of an organization has the potential to create environments that are less threatening for women.

Gender biases affect not only how we view and treat others but also how we view ourselves and what actions we take as a result. From early childhood we are exposed to stereotypes that guide our choices and behavior in powerful and often invisible ways, steering us toward certain careers and away from others. As early as first grade, children have already developed implicit biases associating math with boys. Studies suggest that girls who more strongly associate math with boys and men are less likely to perceive themselves as being interested in or skilled at math and less likely to spend time studying or engaging with math concepts.

A recent analysis of international differences in the composition of engineering and computing fields makes clear that the surrounding culture makes a difference in the gender makeup of these fields. Women in the United States earn approximately a fifth of all computing degrees, whereas in Malaysia women earn about half of all computing degrees. Similarly, in the United States women earn fewer than a fifth of engineering degrees. In Indonesia, however, women earn almost half of engineering degrees, and in a diverse group of countries women account for about a third of recent engineering graduates.

A study described in chapter 4 finds that most men who major in engineering and computing have relatively strong implicit biases associating men with science, whereas their female counterparts tend to have relatively weak science-male implicit biases. Engineering and computing workplaces have a wider gap in the gender-science bias among female and male employees relative to other fields. Female role models in engineering and computing can help shift implicit biases for both women and men.

EMPHASIZING SOCIAL RELEVANCE

One factor that may contribute to girls and women choosing to pursue fields other than engineering and computing is the small but well-documented gender difference in desire to work with and help

other people. Although communal goals are widely valued by both women and men, research described in chapter 6 finds that women are more likely than men to prioritize helping and working with other people over other career goals. Engineering and computing jobs clearly can provide opportunities for fulfilling communal goals, but jobs in these fields are not generally viewed that way. Rather, engineering and computing are often thought of as solitary occupations that offer few opportunities for social contribution. The perception and, in some cases, the reality that engineering and computing occupations lack opportunities to work with and help others may in part explain the underrepresentation of women in these fields. Incorporating communal aspects—both in messaging and in substance—into engineering and computing work will likely increase the appeal of these fields to communally oriented people, many of whom are women.

CULTIVATING A SENSE OF BELONGING

Perhaps because of this combination of stereotypes, biases, and values, women often report that they don't feel as if they belong in engineering and computing fields. A study highlighted in chapter 8 found that female engineering students were less likely than their male counterparts to feel a strong sense of fit with the idea of "being an engineer" as early as their first year in college. This more tenuous sense of fit with the professional role of an engineer was found to be associated with a greater likelihood of leaving the field. By emphasizing the wide variety of expertise necessary to be a successful engineer or computing professional—including less stereotypically masculine skills such as writing, communicating, and organizing—college engineering and computing programs can help young women see engineering and computing as fields in which they belong.

CHANGING THE ENVIRONMENT

Past decades have shown that simply trying to recruit girls and women into existing engineering and computing educational programs and workplaces has had limited success. Changing the environment in college and the workplace appears to be a prerequisite for fully integrating women into these fields.

COLLEGE

Harvey Mudd College is a prime example of how changing structures and environments can result in a dramatic increase in women's representation in computing. With leadership from the college president and college-wide support, Harvey Mudd increased the percentage of women graduating from its computing program from 12 percent to approximately 40 percent in five years. This dramatic increase was accomplished through three major changes: revising the introductory computing course and splitting it into two levels divided by experience, providing research opportunities for undergraduates after their first year in college, and taking female students to the Grace Hopper Celebration of Women in Computing conference. These changes can be modified and applied at other colleges and universities. Taken together, they provide a roadmap for reversing the downward trend in women's representation among bachelor's degree recipients in computing.

THE WORKPLACE

While many studies have focused on factors contributing to women entering STEM occupations, far fewer have looked at the arguably equally important question of why women leave these fields, often after years of preparation, and what factors support them in staying. The research featured in chapter 9 sheds light on why some women leave the engineering workforce and why others stay. Women who leave engineering are very similar to women who stay in engineering. The differences the researchers found were not in the women themselves but in their workplace environments.

Women who left engineering were less likely to have opportunities for training and development, support from co-workers or supervisors, and support for balancing work and nonwork roles than were women who stayed in the profession. Female engineers who were most satisfied with their jobs,

in contrast, worked for organizations that provided clear paths for advancement, gave employees challenging assignments that helped develop and strengthen new skills, and valued and recognized employees' contributions.

Women are making significant contributions to the fields of engineering and computing yet are still a distinct minority in these fields. Stereotypes and biases lie at the core of the challenges facing women in engineering and computing. Educational and workplace environments are dissuading women who might otherwise succeed in these fields. Expanding women's representation in engineering and computing will require concerted effort by employers, educational institutions, policy makers, and individuals to create environments that are truly welcoming for women.

CHAPTER 1.

WOMEN IN ENGINEERING AND COMPUTING

In recent years the fields of science, technology, engineering, and mathematics—collectively known as STEM—have received much attention for their critical role in maintaining our nation's competitive edge in the global economy. Although the STEM fields are often grouped together, important differences exist among them. In particular, engineering and computing stand out as the STEM fields that offer the best opportunities for the greatest number of people, accounting for more than 80 percent of STEM jobs (Landivar, 2013) as well as offering a higher return on educational investment. Yet women remain less well represented in engineering than in any other STEM field,[1] and computing has the dubious distinction of being the only STEM field in which women's representation has steadily declined throughout the past few decades. In 2013 just 12 percent of engineers and 26 percent of computing professionals were women (AAUW analysis of U.S. Department of Labor, Bureau of Labor Statistics, 2014b). Black and Hispanic women are even more underrepresented compared with their representation in the general population than are women overall, making up just 4 percent of computing professionals and fewer than 2 percent of engineers (AAUW analysis of U.S. Census Bureau, 2011a).

This set of circumstances motivated AAUW to examine the latest research on the factors behind the persistent underrepresentation of women in the U.S. engineering and computing workforce. AAUW chose to focus on engineering and computing together because of important commonalities between these two fields, including the quantitative nature of the work and the masculine culture in both fields. Reviewing research on the underrepresentation of women in engineering and computing allowed AAUW to draw on a larger body of research that is often relevant for both fields. This chapter explores the dimensions of women's underrepresentation in these fields, chapter 2 discusses the reasons behind women's underrepresentation, chapters 3 through 9 describe specific research findings in detail, and chapter 10 provides recommendations for change. Overall the report aims to increase understanding of women's underrepresentation and suggest ways in which women's participation can be increased.

WOMEN'S PERSISTENT UNDERREPRESENTATION IN ENGINEERING AND COMPUTING
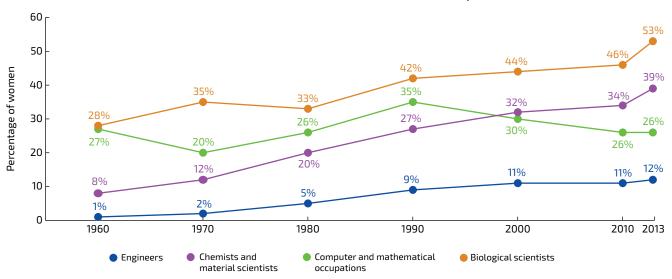
In the past 50 years women have entered the workforce in record numbers, making their way into many fields previously dominated by men. But women's gains have been more modest in engineering and computing than in other historically male professions, such as law, business, and medicine. Women made up just 3 percent of lawyers and judges in 1960, but women's representation in those jobs had increased to 33 percent by 2013. Likewise among physicians and surgeons, women made up just 7 percent of professionals in 1960, but that number had grown to 36 percent by 2013. In management occupations women held 14 percent of jobs in 1960 and 38 percent in 2013 (AAUW analysis of U.S. Census Bureau, 1963, and U.S. Department of Labor, Bureau of Labor Statistics, 2014d).

Women have also made substantial gains in many STEM disciplines. For instance, women made up 8 percent of chemists in 1960 but accounted for 39 percent of the chemistry workforce by 2013 (see figure 1). In biology, women's representation increased from just over a quarter to just over half of the workforce during this period. On the other hand, women's representation in computing *declined* from just over a third of workers in 1990 to just over a quarter in 2013, about the same as it was in 1960. In engineering, women made up less than 1 percent of workers in 1960, growing to 12 percent of the workforce by 2013. Indeed, engineering has been described as the most sex-segregated nonmilitary profession in the world (Cech, Rubineau et al., 2011; Charles & Bradley, 2009).

Figure 2 shows that, in recent years, white women have made up 8 percent, Asian and Pacific Islander women have made up 2 percent, and black and Hispanic women have each made up 1 percent of the U.S. engineering workforce (see figure A1 in the appendix for the list of occupations included in the engineering workforce). Overall, for both women and men, more than three-fourths of engineering workers in the United States were non-Hispanic white, 13 percent were Asian and
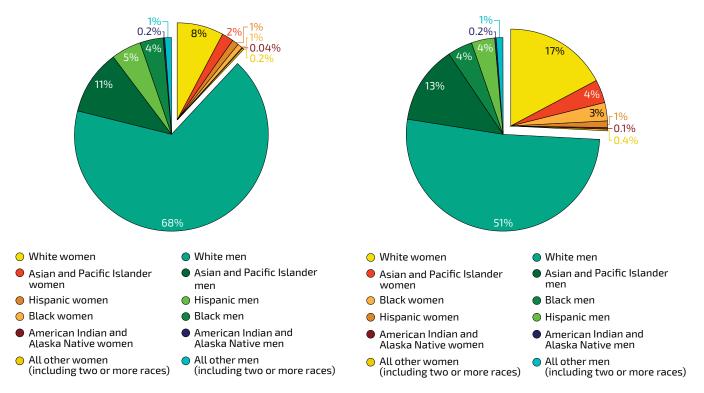
FIGURE 1. WOMEN IN SELECTED STEM OCCUPATIONS, 1960–2013

● Engineers   ● Chemists and material scientists   ● Computer and mathematical occupations   ● Biological scientists

Notes: Postsecondary teachers are not included. For biological scientists in the 1980 and 1990 censuses, data include life scientists as well as biological scientists. For chemical and material scientists in the 1960 and 1970 censuses, the category was titled "chemists"; in the 1980 and 1990 censuses, the category was titled "chemists except biochemists." For computer and mathematical occupations in the 1960 census, no category for computer scientists was included; in the 1970 census, the category was titled "mathematicians and computer specialists"; and in the 1980, 1990, and 2000 censuses, the category was titled "mathematical and computer scientists."
Sources: AAUW analysis of data from U.S. Census Bureau (1960, 1970, 1980, 1990, 2000); L. M. Frehill analysis of data from U.S. Department of Labor, Bureau of Labor Statistics (2011, 2014b).

FIGURE 2. ENGINEERING WORKFORCE, BY GENDER AND RACE/ETHNICITY, 2006–2010

○ White women   ● White men
● Asian and Pacific Islander women   ● Asian and Pacific Islander men
○ Hispanic women   ● Hispanic men
○ Black women   ● Black men
● American Indian and Alaska Native women   ● American Indian and Alaska Native men
○ All other women (including two or more races)   ● All other men (including two or more races)

Source: AAUW analysis of U.S. Census Bureau (2011a).

FIGURE 3. COMPUTING WORKFORCE, BY GENDER AND RACE/ETHNICITY, 2006–2010

○ White women   ● White men
● Asian and Pacific Islander women   ● Asian and Pacific Islander men
○ Black women   ● Black men
○ Hispanic women   ● Hispanic men
● American Indian and Alaska Native women   ● American Indian and Alaska Native men
○ All other women (including two or more races)   ● All other men (including two or more races)

Source: AAUW analysis of U.S. Census Bureau (2011a).

Pacific Islander, 5 percent were Hispanic, and 4 percent were black (some of these percentages do not match figure 2 exactly because of rounding corrections).

Figure 3 shows that in computing, white women made up 17 percent, Asian and Pacific Islander women made up 4 percent, black women made up 3 percent, and Hispanic women made up 1 percent of the workforce (see figure A2 in the appendix for the list of occupations included in computing). Overall, for both women and men, 69 percent of computing workers were non-Hispanic whites, 17 percent were Asian and Pacific Islander, 7 percent were black, and 6 percent were Hispanic (some of these percentages do not match figure 3 exactly because of rounding corrections).

DIVERSITY IN HIGH-TECH COMPANIES

Some technology companies have for years made public the gender and racial/ethnic makeup of their workforce (see Intel Corporation, 2014, for example). Other prominent companies, such as Google, Apple, and Facebook, recently made public for the first time the racial/ethnic diversity of their employees as well as the percentage of their technical employees who are women. With 17 percent of its technical workforce made up of women, Google (2014a) freely admitted, "We are not where we want to be when it comes to diversity." Apple (2014) reported that women account for 20 percent of its technical workforce. At Facebook (2014), women make up just 15 percent of technical workers, and at Twitter (2014) only 10 percent of technical workers are women. Other prominent high-tech companies report similar numbers. These recent efforts toward transparency are an important step in addressing the problem and tracking future progress.

WHY WOMEN'S REPRESENTATION MATTERS

Why does women's representation in engineering and computing fields matter? The answer can be summed up in one word: innovation. Finding solutions to many of the big problems of this century, including climate change, universal access to water, disease, and renewable energy, will require the skills of engineers and computer scientists. When women are not well represented in these fields, everyone misses out on the novel solutions that diverse participation brings. Moreover, a recent experiment showed that lower-performing men are frequently selected over higher-performing women for mathematical work (Reuben et al., 2014a). With so few women working in these fields, U.S. engineering and technology companies are losing out on a massive talent pool and are less globally competitive than they could be because they may not be hiring the best people for the jobs.

In addition, when women are so dramatically underrepresented, many technical decisions are based on the experiences, opinions, and judgments of only men (Williams, 2014), and needs unique to women may be overlooked. Schiebinger and Schraudner (2011) call for including sex and gender in all phases of research to avoid costly retrofits and spur innovation. As Margolis and Fisher (2002, pp. 2–3) point out,

> 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.

THE DIVERSITY ADVANTAGE

Usually defined in terms of race, ethnicity, gender, disability status, age, or sexual orientation, diversity is a popular topic in the business community. Business leaders' current attention to diversity is rooted in the civil rights laws of the 1960s. In the 1980s and 1990s, some companies

A HIGHER RETURN ON A COLLEGE DEGREE

Engineering and computing typically offer a higher return on educational investment than do other STEM fields. In general, engineering and computing jobs are less likely than other scientific jobs to require education beyond a bachelor's degree. Only 1 percent of jobs in engineering and computing fields,[2] compared with just under 30 percent of science and math jobs,[3] require more education than a bachelor's degree for an entry-level position. This means that engineering and computing occupations require less investment of time and money in education compared with many other STEM occupations. At the same time, engineering and computing jobs tend to pay better than other STEM jobs. In fact, nearly all of the highest-paid STEM workers—94

percent of workers in the 25 highest-paying STEM occupations—are engineers or computing professionals (AAUW analysis of U.S. Department of Labor, Bureau of Labor Statistics, 2014e).

Job opportunities are also more numerous in engineering and computing than in other STEM fields, numbering approximately 5.5 million jobs in 2013. Because engineering and computing jobs make up 80 percent of the STEM labor market (Landivar, 2013) and computing jobs in particular are predicted to grow dramatically over the next decade, many more engineering and computing jobs than other types of STEM jobs are expected to be available in the near future.

began promoting tolerance and multiculturalism in the workplace, having recognized the need to advance working relationships among co-workers of diverse backgrounds (Anand & Winters, 2008). More recently, discussions about diversity focus on enhancing business performance (Catalyst, 2013).

Diversity is widely linked to positive outcomes, such as greater innovation and productivity. A common theme among researchers boils down to the advantages of combining ideas among individuals in a group. Indeed, scholars have found that diverse people working together can outperform the "lone genius with a high IQ" (Page, 2007). One study found that gender diversity contributed to the "collective intelligence" of the group (Woolley et al., 2010). The intellectual process of resolving differences itself is seen as important. Though people often feel more comfortable with others like themselves, homogeneity can hamper the exchange of different ideas (Phillips et al., 2009). Studies specifically focusing on gender diversity have demonstrated a strong connection with corporate performance (Catalyst, 2004, 2011). Numerous studies have connected a higher representation of women at all levels of organizations, from board members to employees, with better outcomes (National

Center for Women and Information Technology, 2014b).

Of course, diversity does not always result in better outcomes. Diversity can have negative effects, such as decreased cooperation, reduced cohesiveness, and increased turnover, largely stemming from social categorization—in other words, an "us-versus-them" mentality (Roberge & van Dick, 2010). One study of women's representation on executive boards in the United States found that diversity could inhibit or propel strategic change, depending on the economic circumstances of the company (Triana et al., 2013).

While the benefits of diversity are not automatic, the rewards are attainable (Campbell et al., 2013). To achieve a benefit, researchers call for a "diversity mindset," defined as learning and building from diversity (van Knippenberg et al., 2013). A diversity mindset is especially valuable for work involving exploration, creativity, and complex thinking. By adopting a diversity mindset, organizational leaders can help cement the positive effects of diversity and minimize the negative effects by implementing fair employment practices and integrating excluded groups into the workplace culture (Nishii, 2013).

HIGH-QUALITY JOBS

In addition to encouraging innovation, increasing women's representation in engineering and computing also promotes gender equity. Both fields offer good salaries. Especially among workers without graduate and professional degrees, earnings in engineering and computing outpace other fields (Carnevale et al., 2011). The average starting salary for individuals with a bachelor's degree in engineering or computing was approximately $62,000 in 2014, tens of thousands of dollars higher than annual salaries among other recent college graduates (National Association of Colleges and Employers, 2014; AAUW, 2012). When women aren't well represented in these fields, women and their families miss out on the good salaries that engineering and computing occupations can provide.

WORKPLACE FLEXIBILITY

Some evidence shows that engineering and computing jobs tend to offer more-flexible hours and work locations than many other jobs. A recent analysis found that engineering, technology, and science occupations offer greater time flexibility and more independence in determining tasks, priorities, and goals compared with business, health, and law professions (Goldin, 2014). Another analysis found that women in STEM fields, predominantly information technology and engineering, worked slightly fewer hours than did women in other professional occupations, such as management, financial operations, and nursing, and were more likely to have flexible schedules than those other professionals had (Glass et al., 2013).

Another indicator of flexibility is the option to work from home. Computer and engineering workers are increasingly likely—and more likely than workers in many other fields—to work from home. The U.S. Census Bureau (Mateyka et al., 2012) reports that in 2010, more than 400,000 computing, engineering, and science workers usually worked from home, a 69 percent increase since 2000—and a faster rate of growth than seen in any other occupational field. The only workers who were more likely to work from home were those in management, business, and financial fields. In addition to workers who usually work from home, many more work from home some of the time.[4]

JOB SATISFACTION

Many people appear to find engineering and computing jobs to be very satisfying. In a recent analysis of 25,000 volunteer respondents, CareerBliss (2014), a job listings website focused on helping workers find "happiness in the workplace," reported that the "happiest job" of 2014 (out of 169 jobs) was database administrator and the second happiest job was quality assurance engineer. All told, this survey found that four of the top 10 happiest jobs were engineering or computing jobs.

THE GENDER PAY GAP

Finally, while women in engineering and computing, like women in virtually all occupations, are paid less than men, the gender gap in earnings tends to be substantially narrower in engineering and computing occupations than in the overall labor force. In the overall population of full-time workers, a typical woman is paid 78 cents for every dollar paid to a typical man (U.S. Census Bureau, 2014b). In fields such as mechanical engineering and computer programming, women are paid more than 90 cents for every dollar paid to men for full-time work. In engineering and many other occupations, this gap is largely associated with seniority, with little gap among early-career engineers, a slight gap for mid-career, and a larger gap for late-career engineers (Frehill, 2011; AAUW, 2014). See figure A3 in the appendix for more information.

ENGINEERING

Engineers design, build, and test products. Merriam-Webster defines engineering as "the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people." Branches of engineering include aerospace, biomedical, chemical, civil, electrical, environmental, industrial, mechanical, and systems, and within these branches, subdisciplines exist.[5]

As Vassar, Bryn Mawr, and other women's colleges began teaching physics, biology, and chemistry in the late 1800s, the idea of an engineering department for female students was never considered. A handful of women earned U.S. engineering degrees in the late 1800s and early 1900s, but they remained outliers (Bix, 2014). By the 1950s women made up fewer than 1 percent of engineering students in colleges and universities. Changing this situation required all-male engineering programs to admit women, which institutions began to do during World War II and through the 1960s. Even after women were officially allowed into engineering programs, however, historic ties to male-dominated apprenticeships and powerful cultural norms marked engineering as "male." As Bix argues, "Women's engineering ambitions were of a more deeply transgressive nature (than women's scientific ambitions) because technical knowledge—with its ties to industry, heavy manual labor, and the military—was a far more masculine domain than science." As an indication of just how masculine the field of engineering has been, one review found that in 1920, "the U.S. Census Bureau reported that the 41 women who were enumerated as engineers were most likely mistaken about their jobs" (Frehill, 2004, p. 384).

While men make up the majority of all types of engineers, some engineering fields are more male-dominated than others. For example, women make up just 6 to 8 percent of petroleum, mechanical, and electrical and electronics engineers. In industrial, biomedical, and environmental engineering, on the other hand, women make up 17 to 21 percent of working engineers (see figure 4).

ENGINEERING FOR BOYS, HOME ECONOMICS FOR GIRLS
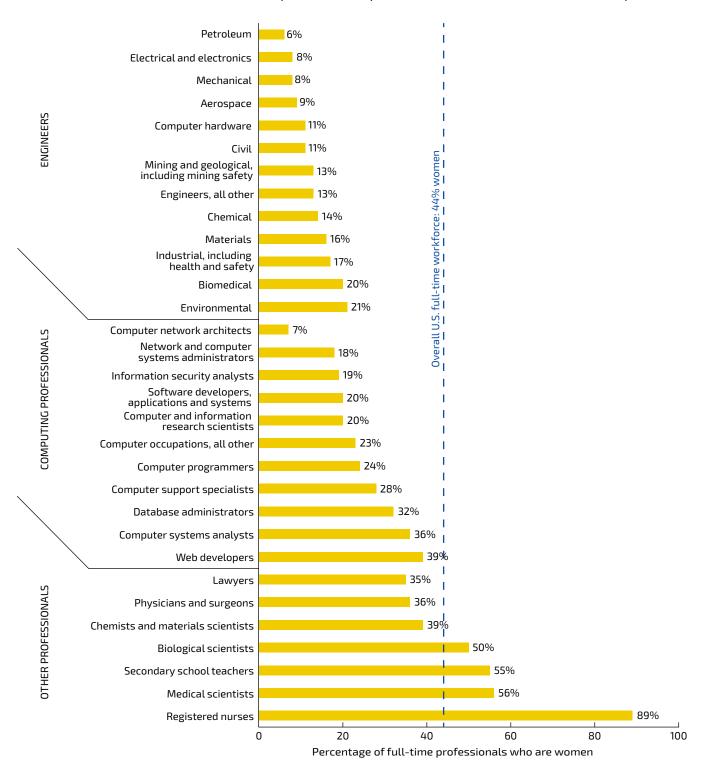
Historically, many engineering-minded women were encouraged to study home economics rather than engineering (Bix, 2002). Ellen Swallow Richards, the founder of the American Home Economics Association (as well as a co-founder of the Association of Collegiate Alumnae, the predecessor organization to AAUW), was trained as a chemist at Vassar and MIT (Stage, 1997) and conducted important water-quality research that led to the first modern U.S. municipal sewage treatment plant.

Describing the history of the development of the home economics discipline, Alice Pawley (2012, p. 63) wrote,

> The founders of home economics wanted women to apply the logic of scientific management to domestic contexts to develop better, more effective, and more efficient ways of operating the home. Improved health, hygiene, and sanitation, improved knowledge of nutrition, more efficient technologies for lighting, heating, and cleaning, and management techniques for supervising servants and raising children, all organized around the home, constituted the realm of a new, science-oriented understanding of the domestic sphere, created and maintained by women. What is crucial about this history with respect to the construction of engineering is the realization that the actual tasks awarded to home economics could easily have been considered "science" or "engineering" tasks had they been in a different context.

According to one analysis of the study of home economics at Iowa State University, engineering majors and home economics majors learned very similar concepts but related them to different applications (Bix, 2002). Whereas agricultural engineering majors took apart and inspected tractors, home economics majors disassembled and evaluated stoves. While mechanical engineering majors learned the thermodynamics behind diesel engines, home economics majors learned about the physics of refrigeration. This historical context of intentional segregation of women and men into different fields, despite the similar technical underpinnings of their work, helps explain why progress in increasing the representation of women in engineering has been slow.

FIGURE 4. WOMEN IN ENGINEERING, COMPUTING, AND SELECTED OTHER OCCUPATIONS, 2013

ENGINEERS

Occupation	Percentage
Petroleum	6%
Electrical and electronics	8%
Mechanical	8%
Aerospace	9%
Computer hardware	11%
Civil	11%
Mining and geological, including mining safety	13%
Engineers, all other	13%
Chemical	14%
Materials	16%
Industrial, including health and safety	17%
Biomedical	20%
Environmental	21%

COMPUTING PROFESSIONALS

Occupation	Percentage
Computer network architects	7%
Network and computer systems administrators	18%
Information security analysts	19%
Software developers, applications and systems	20%
Computer and information research scientists	20%
Computer occupations, all other	23%
Computer programmers	24%
Computer support specialists	28%
Database administrators	32%
Computer systems analysts	36%
Web developers	39%

OTHER PROFESSIONALS

Occupation	Percentage
Lawyers	35%
Physicians and surgeons	36%
Chemists and materials scientists	39%
Biological scientists	50%
Secondary school teachers	55%
Medical scientists	56%
Registered nurses	89%

Overall U.S. full-time workforce: 44% women

Percentage of full-time professionals who are women

Notes: Occupations are self-reported. All occupations designated as computer and engineering occupations by the U.S. Department of Labor, Bureau of Labor Statistics, that employed at least 500 men and 500 women in 2013 are shown. Occupations shown in "other professionals" are selected professions shown for reference.
Source: L. M. Frehill analysis of data from U.S. Department of Labor, Bureau of Labor Statistics (2014c).

COMPUTING

Like engineering, computing is all around us, influencing how we work, play, and communicate. Computing professionals work with computer systems, including hardware, software, and networking technology. They design and produce hardware components such as computer chips and hard drives, design computer systems and networks, develop and test software, perform maintenance on technology, provide support to users of information technology products, and design video games.[6] Computing professionals are employed not only by technology companies but across nearly every sector of the workforce. In the modern world, in which society depends on technology and computers, most workplaces employ computing professionals in some form.

Women's representation in computing has taken a different path than women's representation in any other field. While today fewer than one in five computer science degrees is awarded to a woman, and women make up around a quarter of the computing workforce, women were not always so sparsely represented in computing.

Women were a significant presence in the early decades of computing. Ada Lovelace, considered the first computer programmer, was an early pioneer who lived in the mid-1800s. Women made up the majority of programmers during World War II (Abbate, 2012). Kay McNulty, Betty Snyder, Marlyn Wescoff, Ruth Lichterman, Jean Jennings, and Frances Bilas were the first programmers of the first programmable electronic computer, ENIAC (Electronic Numerical Integrator and Computer). Graduates of a University of Pennsylvania course to train women to perform ballistics calculations, the women were originally hired as "subprofessional" workers but were later promoted to professional status as a result of their innovative work in developing programming procedures for the ENIAC, which consisted of 18,000 vacuum tubes (Abbate, 2012; Light, 1999). Rear Admiral Grace Hopper, another early pioneer, created the first compiler in 1952.

With a few notable exceptions, however, women working in computing in the mid-1900s were viewed as low-status clerical employees. Computer operators inherited their positions and status from the clerical, administrative, data-processing work of key punch operators, as well as from women who had been employed as "human computers" to do calculations by hand (Misa, 2010; Abbate, 2012; Schlombs, 2010). Koput and Gutek (2010, p. 92) describe women moving into the computer and information technology sector, often in "basement jobs" in "the bowels of large corporations." These jobs were not part of any career ladders; therefore, workers were not well compensated and were usually overlooked for career advancement.

Throughout the mid-1900s, computing was still a new field that lacked a gender identity and needed workers, and it attracted women as well as men (Ensmenger, 2010b; Koput & Gutek, 2010; Abbate, 2012). Yet, as Koput and Gutek (2010, p. 103) wrote, "Over a relatively short period of time, a field that was once relatively gender integrated has become solidly male dominated." Computing historians and researchers have proposed a number of explanations, including hiring practices in the 1960s and 1970s that favored men, the increasing professionalization of the field, a stronger connection with the technical engineering culture, a male gaming culture that entered computing with the rise of the personal computer, and increasingly stringent requirements for being admitted to an undergraduate computing program due to the increasing popularity of the field.

Ensmenger (2010b) found that companies in the 1960s and 1970s looking for potential computer programmers often used aptitude and personality tests that privileged male-stereotyped characteristics. He argued that the use of personality tests led to a feedback cycle in which companies hired "antisocial, mathematically inclined males," perpetuating the belief that programmers should be antisocial, mathematically inclined males (p. 78).

Ensmenger (2010a) also points to efforts to bring prestige and structure to the field of computing, which involved the creation of professional organizations, networks, and hierarchies that encouraged and facilitated the entry of men. Abbate (2012) argues that this effort to professionalize the field further connected computing with

engineering, specifically engineering's technical and analytical focus and its prestige as a professional field. On university campuses an increasing proportion of computer science programs became located within engineering colleges (Misa, 2010). The percentage of women earning bachelor's degrees in computer science has been shown to be lower at schools where computing programs are located in engineering colleges compared with schools that locate their computing departments in colleges of arts and sciences (Camp, 1997).

But what happened specifically in the 1980s that caused women's representation in computing to drop? One argument points to the rise of the personal computer. IBM launched the personal computer in 1981, and Apple introduced the Macintosh in 1984. Before that, few people's homes or businesses had computers, and girls and boys had similar exposure to computers—generally none. Once computers were in the home, they were rapidly adopted by men and boys as a new kind of toy (Margolis & Fisher, 2002). Haddon (1992), who studied the origins of the home computer market in England, argued that the personal computer linked the computing industry to the electronic "hobbyist" culture and earlier game-playing arenas, such as arcades, that were primarily the domain of men and boys. The gamer culture that has since developed can be particularly inaccessible for women (Parkin, 2014).

Some have suggested that women began earning a declining proportion of computer science bachelor's degrees in the 1980s because of a surge in interest in computing as an academic discipline. This boom overloaded the capacity of academic computer science departments, and schools responded by imposing increasingly stringent requirements for entry and completion of the major. These requirements disproportionately disadvantaged women and people of other underrepresented groups who were generally entering college with less programming experience and less math preparation (Roberts, 1999, 2011).

As in engineering, the proportion of women across computing disciplines varies significantly, with women making up about 39 percent of web developers but only 7 percent of computer network

architects. In no engineering or computing occupation does women's representation match that in the overall full-time labor force (44 percent), and compared with professional occupations overall, where women make up 57 percent of the workforce (U.S. Department of Labor, Bureau of Labor Statistics, 2014a, table 9), women are dramatically underrepresented in computing (and engineering) jobs. Women are best represented among web developers (39 percent), computer systems analysts (36 percent), and database administrators (32 percent). In all other computing (and all engineering) occupations, women account for less than 30 percent of workers, far below parity (see figure 4).

PREPARING K–12 STUDENTS FOR ENGINEERING AND COMPUTING

Math and science courses in elementary, middle, and high school can prepare students for pursuing engineering or computing majors in college and, especially for engineering, are often required. Mathematics can also be helpful for those who enter these fields with an associate degree or certificate or by another means. In elementary and middle school, girls and boys tend to earn similar grades in math and science courses and to have similar scores on standardized math and science exams (Snyder & Dillow, 2013). In high school, girls and boys have earned approximately the same number of math and science credits, and girls have been doing slightly better than boys in these classes, since the 1990s (U.S. Department of Education, National Center for Education Statistics, 2011). Boys are more likely, however, to take the advanced placement exams most closely associated with engineering and computing and tend to outscore girls on these exams and the SAT by a small margin (College Board, 2013a, 2013b).

How relevant are these small gender differences in early science and math achievement to women's underrepresentation in engineering or computing? A recent study by researchers at the University of Texas and the University of Minnesota found that gender differences in achievement in high school, including women's underrepresentation among

those earning the highest standardized math test scores, accounted for very little of the gender difference in the likelihood of choosing an engineering, computing, math, or physical science major in college (Riegle-Crumb et al., 2012). The researchers determined that while some gender differences in STEM achievement existed before college, these differences did not appear to be a strong determinant of who ended up majoring in engineering and computing.

Rather than achievement, interest in STEM fields in high school is more closely associated with the pursuit of an engineering or computing education or career in adulthood (Maltese & Tai, 2011; Benbow, 2012). While achievement in an area often contributes to interest, beginning in young adolescence and increasingly as girls and boys move through middle school and high school, boys tend to express more positive attitudes toward and interest in STEM subjects than girls do (Sandrin & Borror, 2013; Iskander, Gore et al., 2013; Diekman, Weisgram et al., 2015; Else-Quest et al., 2013;

Weisgram & Bigler, 2006; Weisgram & Diekman, 2014).

One nationally representative study found that the key factor predicting STEM career interest at the end of high school was interest at the start of high school (Sadler et al., 2012). While it is certainly possible to decide to pursue a career in engineering or computing well after high school graduation, these findings suggest that early exposure to engineering and computing that sparks an interest in these fields is often a precursor to actually pursuing a career in these fields. For this reason, advocates for improving gender diversity in engineering and computing often focus interventions on increasing interest in the fields among elementary and middle school students (Valla & Williams, 2012). One recent survey found that social encouragement from family, friends, and educators, regardless of their technical expertise, is the factor most likely to encourage girls' interest in computer science (Google, 2014b).

LACK OF COMPUTING EDUCATION IN K–12 SCHOOLS

Just 19 percent of high school graduates reported earning at least one credit in a computing course during high school in 2009, and fewer girls (14 percent) than boys (24 percent) reported taking such courses. These percentages are smaller than in both 1990 and 2000, when 25 percent of high school graduates reported taking computing classes (U.S. Department of Education, National Center for Education Statistics, 2011). According to the National Center for Women and Information Technology (2014a), most students in the United States are not exposed to a rigorous computing education in high school or earlier for several reasons:

1. Only about half of the states allow computing classes to count as an academic subject toward high school graduation (Code.org, 2014). Many states that do allow computing classes to count have only recently adopted this policy. AAUW and other organizations such as the Computer Science Teachers Association and Code.org have worked to encourage states to count high school computing credits as part of the math or science credits required for graduation.

2. Computing courses are sometimes included in vocational course choices and, therefore, may not attract college-bound students.

3. Computing as an elective course competes with other attractive electives, such as music and foreign languages.

4. Computing is often taught by individuals with either little background in the subject or little teaching experience.

Computing classes for middle and high school students introduce girls and boys to the subject at an influential age. These courses are especially useful for sparking girls' interest in computing because girls are less likely than boys to pursue computing on their own outside of a formal learning environment (Margolis & Fisher, 2002).

FIGURE 5. INTENT OF FIRST-YEAR COLLEGE STUDENTS TO MAJOR IN STEM FIELDS, BY GENDER, 2014

Source: AAUW analysis of Eagan et al. (2014).

HIGHER EDUCATION

A gender gap in students' intention to pursue bachelor's degrees in engineering or computing is evident by the time they step foot on college campuses.[7] Young men are much more likely than their female peers to begin college intending to major in engineering and computing (see figure 5). While nearly one out of every five young men who start college intends to major in engineering, only one out of 17 young women starting college has the same intention. Computing is a much smaller academic field, and 6 percent of young men who start college intend to major in computing compared with just 1 percent of young women. This divide by gender holds true across races/ethnicities: Women are far less likely than men within each racial/ethnic category to begin college intending to major in engineering or computing (National Science Foundation, National Center for Science and Engineering Statistics, 2014c).

Of course, not all students who enroll in an engineering or computing major graduate with those degrees. At the bachelor's degree level, the national rate of retention from entry into the major to graduation is approximately 60 percent for engineering and 40 percent for computing (Chen, X., 2013), and some evidence shows that this rate is similar for women and men in engineering (Lord et al., 2013; Ohland et al., 2008). Still, because women make up such a small portion of those who initially major in engineering and computing, understanding why women leave these majors is important.

As figure 6 shows, women's representation among engineering bachelor's degree recipients has increased in a fairly linear fashion, growing from a mere 1 percent in 1970 to 21 percent in 2000. After 2000, participation dipped slightly, to 19 percent in 2013. Women's participation in undergraduate computer science, in contrast, has been declining for decades. Before 1970, women earned between 10 and 15 percent of the fewer than 1,000 bachelor's degrees awarded in computer science each year. Throughout the 1980s it appeared that women might reach parity in computing, with women

earning 37 percent of computing bachelor's degrees in 1984 and 1985. After 1985, however, women's participation in computing reversed course, so that by 2013 the proportion of computing bachelor's degrees awarded to women was half what it had been nearly three decades earlier.[8]
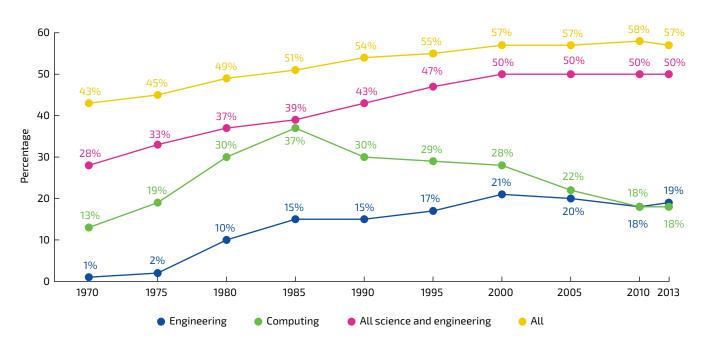
Women's representation among engineering and computing graduates is much smaller than among bachelor's degree recipients overall, where women reached parity with men in 1985 and earned 57 percent of the degrees awarded in 2013. Likewise, in the combined total number of science and engineering bachelor's degrees awarded, including the social sciences and psychology, women reached parity with men in 2000 and continued to earn half of those degrees awarded through 2013 (see figure 6).

Among associate degree earners, women's representation in engineering has hovered around 14 percent since 1990. In computing, however, the representation of women has been declining. Women earned half of the associate degrees awarded in computing in 1990, but by 2013 that number had dropped to 21 percent (see figure A4 in the appendix).

VARIATION IN WOMEN'S REPRESENTATION

The proportion of women earning engineering bachelor's degrees varies substantially among engineering disciplines (see figure 7). Mechanical, civil, electrical, and chemical engineering are the largest engineering fields, accounting for nearly two-thirds of engineering degrees awarded each year. Women accounted for 32 percent of chemical engineering graduates, 21 percent of civil engineering graduates, and only 12 percent of electrical and mechanical engineering graduates in 2013. Because mechanical and electrical engineering are such large engineering disciplines, women's dramatic underrepresentation in these fields is a big factor in women's underrepresentation in engineering overall. Women from underrepresented minority (URM) groups, defined here as engineers who identify as black, American Indian, Alaska Native, or Hispanic, are also severely underrepresented in these disciplines, making up just 2 percent of those awarded bachelor's degrees in mechanical and electrical engineering in 2013 (AAUW analysis of National Science Foundation,
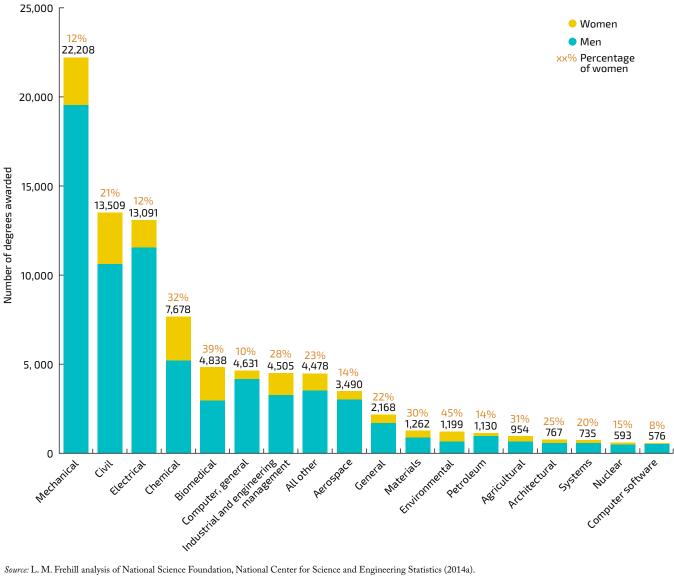
FIGURE 6. BACHELOR'S DEGREES EARNED BY WOMEN, SELECTED FIELDS, 1970–2013

Note: "All science and engineering" includes biological and agricultural sciences; earth, atmospheric, and ocean sciences; mathematics and computer science; physical sciences; psychology; social sciences; and engineering.
Source: L. M. Frehill analysis of data from National Science Foundation, Division of Science Resources Statistics (2013), and National Science Foundation, National Center for Science and Engineering Statistics (2014a).

FIGURE 7. BACHELOR'S DEGREES AWARDED IN ENGINEERING, BY DISCIPLINE AND GENDER, 2013
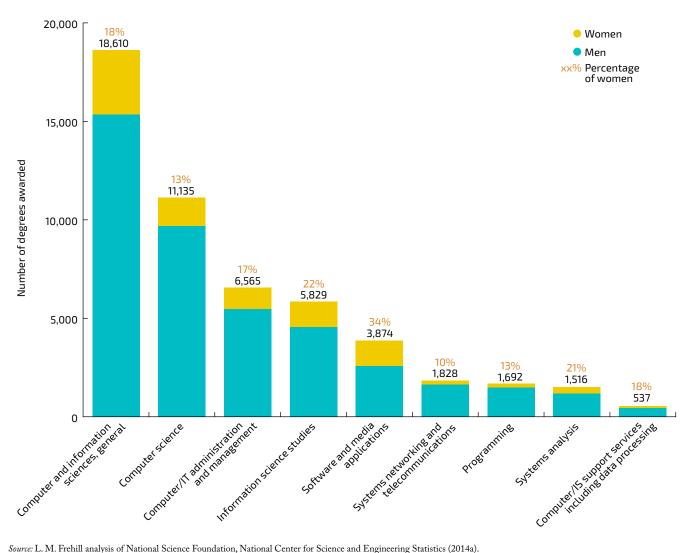
Source: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2014a).

National Center for Science and Engineering Statistics, 2014a, 2014b).

The engineering fields with the largest representation of women, on the other hand, tend to be much smaller fields (see figure 7). Environmental engineering, for example, boasts the highest representation of women, who earned 45 percent of bachelor's degrees in 2013; yet only about 1,200 environmental engineering bachelor's degrees were awarded that year.[9] Environmental engineering was also the field with the highest percentage of URM women, who earned 7 percent of bachelor's degrees awarded in 2013 (AAUW analysis of National Science Foundation, National Center for Science and Engineering Statistics, 2014a, 2014b). The field of bioengineering/biomedical engineering similarly has attracted a relatively high proportion of women (39 percent in 2013) and is somewhat larger, with approximately 4,800 bachelor's degrees awarded in 2013.

FIGURE 8. BACHELOR'S DEGREES AWARDED IN COMPUTING, BY GENDER AND DISCIPLINE, 2013

Source: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2014a).

Percentages aside, the largest numbers of bachelor's degrees awarded to women in 2013 were in civil engineering (2,894), mechanical engineering (2,676), and chemical engineering (2,478). Similarly, the largest numbers of bachelor's degrees earned by URM women were in civil engineering (526), mechanical engineering (415), and chemical engineering (355). At the other end of the spectrum, only 16 URM women were awarded bachelor's degrees in petroleum engineering in 2013, accounting for just 1 percent of the petroleum engineering bachelor's degrees awarded that year

(AAUW analysis of National Science Foundation, National Center for Science and Engineering Statistics, 2014a, 2014b).

The proportion of women earning computing bachelor's degrees also varies by discipline (see figure 8). General computer and information sciences is the largest discipline, making up more than a third of all bachelor's degrees awarded in 2013. Eighteen percent were awarded to women, and 4 percent were awarded to URM women. Women were best represented in software and media applications, where they earned about a third of the

bachelor's degrees awarded in 2013. Information science and systems analysis are the fields with the next highest percentage of women, at 22 and 21 percent. These fields have the best representation of URM women as well, with URM women most highly represented in software and media applications (9 percent) and in information science and systems analysis (7 percent). At the other end of the spectrum, women were least well represented in systems networking and telecommunications, where they were awarded just one in 10 bachelor's degrees in 2013. URM women were least well represented in computer science, where they received only 2 percent of bachelor's degrees in 2013 (AAUW analysis of National Science Foundation, National Center for Science and Engineering Statistics, 2014a, 2014b).

DIVERSITY AMONG U.S. ENGINEERING AND COMPUTING GRADUATES

Engineering and computing have not achieved levels of gender and racial/ethnic diversity on par with those of the general population between the ages 20 and 24. Women of all races/ethnicities except Asian are underrepresented among engineering and computing bachelor's degree recipients compared with their representation in the general population. White women were awarded 13 percent of the engineering and 10 percent of the computing bachelor's degrees in 2013, while making up 28 percent of the general population. The largest discrepancy is among URM women, who were awarded just 3 percent of the engineering and 6 percent of the computing bachelor's degrees in 2013, while making up 18 percent of the general population (see figure 9).

HOW MEN ARE FARING

When it comes to men, the story is different—at least in the number of degrees awarded. Men of all racial/ethnic groups are much better represented among engineering and computing bachelor's degree earners than are women of the same group. In most cases, men are earning engineering and computing degrees in proportion to or better than their representation in the general population (see
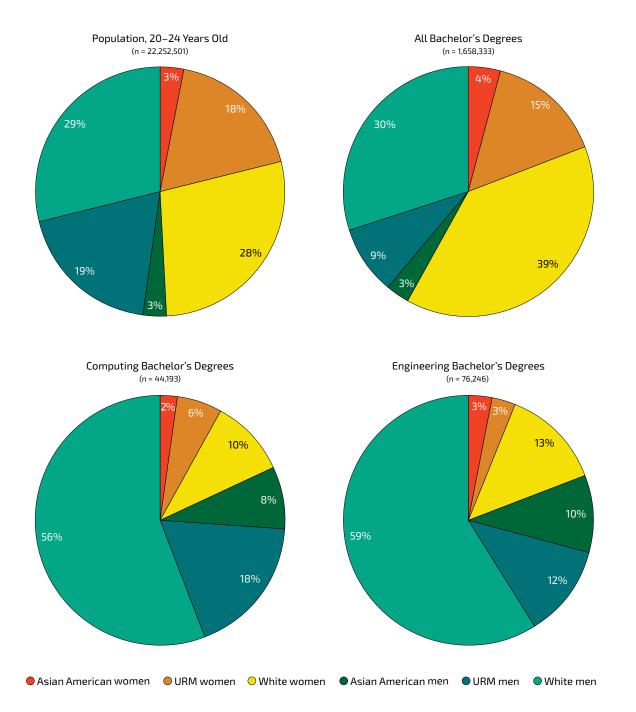
figure 9 and figure A5 in the appendix). This is true for white and Asian American men in both engineering and computing. Black men, too, who represented 8 percent of the 20- to 24-year-olds in the United States, earned 9 percent of computer science bachelor's degrees in 2013.[10] American Indian/Alaska Native men, who represented just 0.5 percent of 20- to 24-year-olds in the United States, earned 0.5 percent of the computer science bachelor's degrees in 2013 (see figure A5 in the appendix).

Together, black, Hispanic, and American Indian/Alaska Native men were awarded 18 percent of computing bachelor's degrees in 2013 and made up 19 percent of the general population of 20- to 24-year-olds. This near parity is especially noteworthy given that men from these racial/ethnic groups are significantly underrepresented among bachelor's degree earners overall, making up just 9 percent of those earning bachelor's degrees in any field in 2013. Any underrepresentation of black, Hispanic, and American Indian/Alaska Native men among engineering and computing bachelor's degree holders is largely symptomatic of the issue of insufficient diversity in higher education overall (Su, 2010). In the engineering and computing workforce, however, black, Hispanic, and American Indian/Alaska Native men are underrepresented. Between 2006 and 2010, black men made up just 4 percent of the engineering and computing workforce. Hispanic men made up 5 percent of the engineering and 4 percent of the computing workforce, and American Indian/Alaska Native men made up 0.2 percent of the engineering and computing workforce.

DIVERSITY OF THOSE WITH ADVANCED DEGREES

Figure 10 underscores the degree to which graduates of engineering and computing programs are not representative of the U.S. population and provides a look at the breakdown at the master's and doctoral levels as well.[11] While white women made up 30 percent of high school graduates in 2012 and URM women made up 18 percent, just 7 percent of doctoral degrees in engineering and computing were awarded to white women, and just 2 percent were awarded to URM women.

FIGURE 9. POPULATION AGES 20–24 AND BACHELOR'S DEGREES AWARDED IN SELECTED FIELDS, BY RACE/ETHNICITY AND GENDER, 2013

Population, 20–24 Years Old (n = 22,252,501)

All Bachelor's Degrees (n = 1,658,333)

Computing Bachelor's Degrees (n = 44,193)

Engineering Bachelor's Degrees (n = 76,246)

Legend: Asian American women · URM women · White women · Asian American men · URM men · White men

Notes: Charts include only U.S. citizens and permanent residents. U.S. citizens and permanent residents of "other/unknown races/ethnicities" (which includes students who report multiple race/ethnicities) and temporary residents are not included. Computing included 5,276 other and 2,365 temporary residents, and engineering included 4,637 other and 6,331 temporary residents who earned bachelor's degrees and, therefore, were not included in these data. Underrepresented minority (URM) includes American Indians and Alaska Natives, blacks, and Hispanics/Latinos.
Sources: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2014b), and U.S Census Bureau (2014d).

FIGURE 10. STUDENT POPULATION FROM HIGH SCHOOL TO DOCTORATE IN ENGINEERING OR COMPUTING, BY RACE/ETHNICITY AND GENDER, 2012

Notes: Students and degree recipients reported as "other/unknown races/ethnicities" were excluded from the totals and percentages reported here. As a result, the following numbers are excluded: first-time, full-time freshmen, 185,677; bachelor's degree, 9,913; master's degree, 4,199; and Ph.D., 479. Underrepresented minority (URM) includes American Indians and Alaska Natives, blacks, and Hispanics/Latinos.
Sources: Prescott & Bransberger (2012); L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2014b).

Part of the reason for the small percentages is that more than half (58 percent) of engineering and computing doctorates were awarded to temporary residents, four of five of whom were men. Looking only at U.S. citizens and permanent residents, 16 percent of engineering and computing doctorates were awarded to white women, and 4 percent were awarded to URM women (AAUW analysis of National Science Foundation, National Center for Science and Engineering Statistics, 2014b), still well below the representation of white and URM women in the overall population. In sum, engineering and computing largely remain men's domains at the college level, and URM women are particularly underrepresented (Ong, 2011).

PEOPLE WITH DISABILITIES

Increasing the number of people with disabilities in engineering and computing is another part of building diversity. About 12 percent of the population has some kind of disability (National Science Foundation, National Center for Science and Engineering Statistics, 2014c). College students with disabilities are somewhat more likely to major in a STEM field than are students without disabilities (Lee, 2011). Students with autism spectrum disorder are especially likely to select a major in a STEM field (Wei et al., 2014). Students with disabilities are about as likely to graduate in engineering or computing as are students without disabilities; however, people with disabilities are

underrepresented in the engineering and comput-
ing workforce relative to the workforce as a whole.
An estimated 6 percent of working computing
professionals and 7 percent of working engineers
report having a disability, compared with 9 percent
of workers overall (National Science Foundation,
National Center for Science and Engineering
Statistics, 2014c).

TRAINING FOR THE ENGINEERING WORKFORCE

Most working engineers (80 percent) have at least
a bachelor's degree, with just over a quarter holding
an advanced degree (23 percent hold a master's
degree, and 5 percent hold a doctorate). Most
engineers with less than a bachelor's degree level
of education have an associate degree (AAUW
analysis of U.S. Census Bureau, 2011b).

The percentage of women among engineering
graduates varies dramatically among institutions.
Many different kinds of institutions have suc-
ceeded in graduating a relatively large proportion
of women in their engineering programs. The few
women's colleges that have engineering programs,
such as Smith College and Sweet Briar College,
graduate 100 percent women. Historically black
colleges and universities (HBCUs), such as Prairie
View A&M University, which awarded 66 percent
of its engineering bachelor's degrees to women in
2012, and top-rated schools, such as Massachusetts
Institute of Technology and California Institute of
Technology, both of which awarded 44 percent of
their bachelor's degrees in engineering to women in
2012, have also succeeded in graduating engineer-
ing classes with a higher than average percentage of
women. At most of the largest engineering schools
in the country, women make up about one of every
five graduates (see figures A6a and A6b in the
appendix).

TRAINING FOR THE COMPUTING WORKFORCE

Computing professionals arrive at their occupa-
tions by more varied means than engineers do.
Computing jobs are available for workers at all lev-
els of educational achievement. A small percentage
(6 percent) of computing professionals hold only a
high school diploma or GED (general educational
development), and 1 percent have not graduated
from high school. About a third (29 percent) of
computing professionals have some college experi-
ence, a certificate (typically requiring one year of
study), or an associate degree (typically requiring
two years of study).[12] Most computing profession-
als (about two-thirds) have a bachelor's degree or
higher; 44 percent hold a bachelor's degree, 18
percent hold a master's degree, and 2 percent hold a
doctorate (AAUW analysis of U.S. Census Bureau,
2011b).

Of computing professionals with bachelor's
degrees or higher, only about half have bachelor's
degrees in computing, engineering, or mathemati-
cal sciences.[13] Nearly a fifth of computing pro-
fessionals with bachelor's degrees were business

EDUCATIONAL ATTAINMENT OF THE ENGINEERING AND COMPUTING WORKFORCE

In this report AAUW follows the protocol of the U.S.
Department of Labor, Bureau of Labor Statistics,
and the U.S. Census Bureau in defining "engineers"
and "computer occupations." Both report workforce
information separately for "engineers" and "draft-
ers, engineering technicians, and mapping tech-
nicians," effectively providing data separately for
engineering jobs that require bachelor's degrees
and those that do not.

In contrast the category of "computer occupations"
combines occupations that require varying levels
of education, including those that require a doc-
torate and those that require an associate degree
or less (U.S. Department of Labor, Bureau of Labor
Statistics, 2009). So, for example, while AAUW does
not include engineering technicians and drafters in
the definition of engineers, computer support per-
sonnel are included in the definition of computing
workers. The result is that the educational back-
grounds of the engineers and computing profes-
sionals that are the subject of this report are some-
what different.

majors, and others majored in the social sciences, the physical or biological sciences, communications, and psychology (AAUW analysis of U.S. Census Bureau, 2014a).[14]

The approximately one-third of computer workers who hold technical bachelor's degrees attended many different kinds of institutions, including public, private nonprofit, and private for-profit institutions. The University of Phoenix, a for-profit institution, was far and away the largest institution in the United States to grant bachelor's degrees in computing in 2012, awarding just over 3,000. As in engineering, the percentage of computing degrees awarded to women ranges widely from less than 10 percent at some institutions to two-thirds of degrees at other institutions, and many different kinds of institutions have succeeded in graduating a large proportion of women in computing programs. For-profit schools, including several Art Institute campuses; HBCUs, such as Johnson C. Smith University;[15] and public and private institutions, such as Northwest Missouri State University, North Carolina Wesleyan College, and Harvey Mudd College, are among the top institutions in women's representation among computing graduates (see figures A6c and A6d in the appendix).

THE ENGINEERING AND COMPUTING WORKFORCE

The great demand for workers in the engineering and computing fields is an important reason to attract more women (Sevo, 2009). Overall, employment in the United States is projected to grow by approximately 15 million jobs (11 percent) between 2012 and 2022. The U.S. Department of Labor, Bureau of Labor Statistics (2014d), predicts that computing occupations will grow at a substantially faster rate of 18 percent. Some of the fastest-growing computing occupations are among those expected to produce the most growth in raw numbers of jobs as well, resulting in 1.2 million computing job openings between 2012 and 2022. Computing occupations that are predicted to grow especially quickly (see figure A7 in the appendix) include the relatively small field of information security analysts (projected to grow 37 percent by

2022); computer systems analysts (25 percent); and the largest computing occupation and largest STEM occupation overall (Landivar, 2013), applications software developers (23 percent). All of these occupations require a bachelor's degree for an entry-level position (U.S. Department of Labor, Bureau of Labor Statistics, 2014e), and most workers in these occupations have a bachelor's degree or higher in computing or engineering fields (AAUW analysis of National Science Board, 2014, appendix table 3-3).

Engineering occupations, on the other hand, are predicted to grow at a slower rate of 9 percent, resulting in slightly more than 500,000 engineering job openings between 2012 and 2022. The engineering occupations predicted to grow at the fastest rates (see figure A8 in the appendix) include the relatively small field of biomedical engineering (predicted to grow by 27 percent by 2022), the similarly small field of petroleum engineering (26 percent), and one of the largest engineering fields, civil engineering (20 percent).
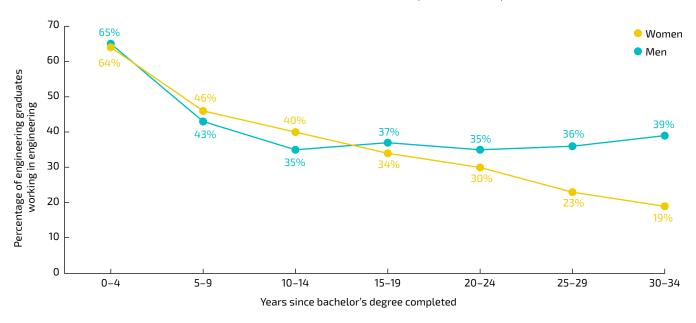
RETENTION IN ENGINEERING

In addition to being less likely than men to go into engineering in the first place, women appear to be less likely than men to stay in the engineering profession (Hunt, 2010; Frehill, 2012). As shown in figure 11, AAUW's analysis of National Science Foundation data finds that while most (about 65 percent) women and men who graduate with bachelor's degrees in engineering initially take engineering jobs, by 10 years into their careers, only about 40 percent of graduates, both women and men, remain in engineering. While men's retention rate levels off at around 40 percent for the next 25 years, the retention rate for women continues to decline. Thirty years into their careers (by the time women and men are in their 50s), women are half as likely as men to report that they are still working as engineers.[16]

RETENTION IN COMPUTING

As in engineering, women appear to be more likely than men to leave the computing workforce (Hewlett, Buck Luce et al., 2008). Among
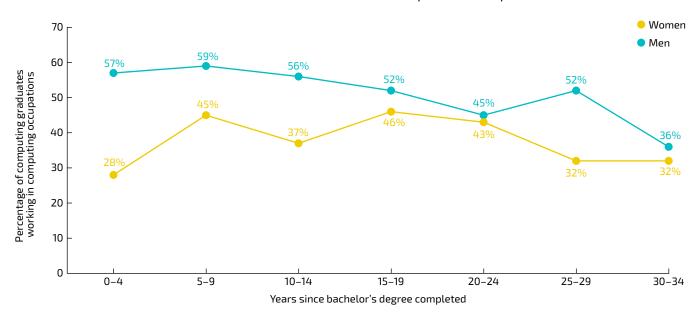
FIGURE 11. RETENTION IN ENGINEERING, BY GENDER, 2010

Notes: Includes only individuals who reported a bachelor's degree in engineering and no additional educational credential as of 2010. Includes women and men who reported earning a bachelor's degree in engineering as well as working in an engineering occupation in either the National Survey of College Graduates or the National Survey of Recent College Graduates administered in October 2010.
Source: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2010a, 2010b).

FIGURE 12. RETENTION IN COMPUTING, BY GENDER, 2010

Notes: The public data used for this analysis combined computing and mathematics occupations and degrees; however, mathematics is typically small compared to computing in both employment and educational data. Includes individuals who reported earning a bachelor's degree in computing or mathematics and no additional educational credential and who were working in a computing or mathematical occupation in either the National Survey of College Graduates or the National Survey of Recent College Graduates administered in October 2010.
Source: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2010a, 2010b).

PATENTING
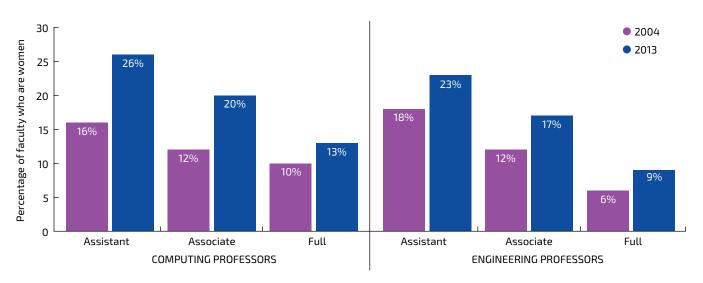
Describing women's participation in engineering and computing overall is important, but it is also important to measure *how* women are participating. Level of participation is more difficult to measure than simple representation, but patenting is one metric of innovation and influence in engineering and computing.

A patent is a set of exclusive rights granted by a government to an inventor to manufacture, use, or sell an invention for a certain number of years. A recent analysis of patenting rates found that only 5.5 percent of commercialized patents are held by women. This disparity was found to be due in large part to women's underrepresentation in engineering, specifically electrical and mechanical engineering, which are the most patent-intensive STEM fields and fields in which women are particularly underrepresented (Hunt et al., 2012).

A recent analysis of patenting in computing found that between 1980 and 2010, only 13 percent of U.S.-invented computing patents had at least one female inventor. Although overall patenting rates for women in computing have been and remain quite low, the trend is positive, with more women being awarded patents for computing inventions in recent years compared with the past. Importantly, this increase happened during a period in which women's participation in computing was declining, which makes the increase particularly noteworthy (National Center for Women and Information Technology, 2012).

Nonetheless, while the trend is positive, the large gender gap in patenting suggests that women are significantly less well represented among those doing leading-edge work in engineering and computing than in these fields overall (Rosser, 2012).

FIGURE 13. FEMALE FACULTY, BY RANK AND DISCIPLINE, 2004 AND 2013

Source: L. M. Frehill analysis of data from American Society for Engineering Education (2005, 2014) and Computing Research Association (2005, 2014).

all workers with bachelor's degrees in computing in 2010, 54 percent of men were working in the computing field, whereas only 43 percent of women were (National Science Board, 2014, appendix table 3-15). Unlike engineering, however, a gender difference in participation appears to start immediately after college graduation. AAUW's analysis of National Science Foundation data (2010a, 2010b) finds that in the first few years after earning computing degrees, 28 percent of women and 57 percent of men report working in a computing job (see figure 12). Men with bachelor's degrees in computing are less and less likely to work in a computing occupation the farther away from graduation they get, while women who graduated longer ago are sometimes *more* likely to be in a computing or math occupation than women who graduated more recently. The trends shown in figure 12 suggest no easy explanation for computing retention rates for men or women. The volatility of the computing labor market and the rapid pace of technological change may be important in understanding the career paths of both women and men with bachelor's degrees in computing.

Glass and colleagues (2013) found that women working in engineering and computing are more likely to leave their occupational fields than are women in other fields. After about 12 years, 50 percent of women who originally worked in STEM, predominantly engineering and computing, had exited and were employed in other fields. In contrast, only about 20 percent of women professionals in other fields, such as management, financial operations, and nursing, exited their professional occupation throughout the course of the study, which spanned almost 30 years. The disparity in retention between STEM and non-STEM professionals was found to be almost entirely due to STEM women switching out of STEM fields but not out of the labor force.

THE ACADEMIC WORKFORCE

As educators of the next generation of engineers and computing professionals, faculty at U.S. colleges and universities represent a critical part of the engineering and computing workforce. College professors are role models, influencing who enters the field and who succeeds in it. Women and people of other underrepresented groups are scarce on engineering and computing faculties at U.S. colleges and universities, with white and Asian men making up the large majority of faculty at all levels and most dominant among full professors (see figures A9 and A10 in the appendix). Women are better represented at the entry level of assistant professor (23 percent in engineering and 26 percent in computing) than at the typically tenured associate level (17 percent in engineering and 20 percent in computing) and the more-senior full level (9 percent in engineering and 13 percent in computing). (Some of these numbers do not match what

METHODOLOGY

This report is based on a review of academic literature, expert advice from an advisory panel, and interviews with leading researchers. The literature review spanned numerous fields, including psychology, computing, organizational behavior, management, sociology, economics, and engineering education, among others. Using multiple databases, including ProQuest Summon, Web of Science, Psycinfo, and JSTOR, AAUW reviewed more than 750 publications, most written within the past 15 years, related to the topic of women in engineering and computing occupations and focusing on empirical research with practical applications.

AAUW identified key, recurrent themes in the literature and, along with a team of expert advisers drawn from academia, industry, associations, and government, selected research findings that have been published or accepted for publication in a peer-reviewed research venue within the last 15 years to feature in the report. These findings, described in chapters 3 through 9, shed light on factors contributing to the underrepresentation of women in engineering and computing. In addition the findings have the potential to increase public understanding and influence policies and practices related to this issue.

is shown in figures A9 and A10 exactly because of rounding corrections.) This trend holds true within racial/ethnic groups as well, with a substantial portion of the few URM women who obtain entry-level faculty positions in engineering and computing not advancing through the ranks (Hess, C., et al., 2013). Black, Hispanic, and American Indian/Alaska Native (URM) women together make up just 1 percent of full professors in engineering and 0.4 percent of full professors in computing (see figures A9 and A10).

The representation of women on engineering and computing faculties has increased over time (see figure 13). Among full professors, for example, women's representation grew from 10 percent to 13 percent in computing and from 6 percent to 9 percent in engineering from 2004 to 2013. At the entry level of assistant professor, the representation of women among college and university faculty has increased in computing (from 16 percent in 2004 to 26 percent in 2013) and in engineering (from 18 percent in 2004 to 23 percent in 2013) during the past decade.[17] The percentages remain low, however, and many engineering and computing students likely still never have a female professor.

SUMMARY

Girls are graduating from high school on nearly equal footing with boys in terms of math and science achievement. Yet young women—across racial/ethnic lines—pursue engineering and computing in much smaller numbers than young men do. By college graduation, women are greatly outnumbered by men in every engineering and computing discipline. Likewise, in the workforce women are dramatically underrepresented in the fields of engineering and computing and are more likely to leave these fields than their male counterparts are. At the faculty level, women remain underrepresented, especially in more-senior positions. The next chapter explores the reasons behind these gender differences.

CHAPTER 1 NOTES

1. In this report STEM refers to the physical, biological, and agricultural sciences; computer and information sciences; engineering and engineering technologies; and mathematics, unless otherwise noted. The social and behavioral sciences, such as psychology and economics, are not included, nor are health workers, such as doctors and nurses.

2. AAUW's analysis of U.S. Department of Labor, Bureau of Labor Statistics (2014e) data finds that "computer and information research scientist" is the only computing or engineering occupation of 31 such occupations to require education beyond a bachelor's degree for an entry-level position. Computer and information research scientists make up less than 1 percent of the engineering and computing workforce.

3. AAUW's analysis of U.S. Department of Labor, Bureau of Labor Statistics (2014e) data finds that nine of 27 science and math occupational categories require education higher than a bachelor's degree for an entry-level position. These categories include animal scientists, physicists, astronomers, biochemists and biophysicists, medical scientists, hydrologists, epidemiologists, mathematicians, and statisticians. Professionals in these occupations make up approximately 28 percent of the scientific and mathematical workforce.

4. Although the U.S. Census Bureau's 2010 *American Community Survey* reported that 4 percent of workers (and 6 percent of computer, engineering, and science workers) "usually" worked from home in 2010, the Census Bureau's 2010 *Survey of Income and Program Participation* (SIPP) reported that 10 percent of workers worked from home "at least one full day a week" in a typical month. Both sources find that more and more workers are working from home over time (Mateyka et al., 2012).

5. In this report, AAUW defines engineering professions to include those that fall under the 17-2000 "engineers" category of the *2010 Standard Occupational Classification* (U.S. Department of Labor, Bureau of Labor Statistics, 2009). Engineering technicians and drafters are not included in this definition. See figure A1 for the full list.

6. In this report, AAUW defines computing occupations to include those that fall under the 15-1100 "computer occupations" category of *2010 Standard Occupational Classification* (U.S. Department of Labor, Bureau of Labor Statistics, 2009). See figure A2 for the full list.

7. Throughout this report, AAUW defines academic computing disciplines as those included in the *2010 Classification of Instructional Programs* (U.S. Department of Education, National Center for Education Statistics, 2010) "computer and information sciences and support services" category (CIP code 11), with the exception of CIP code 11.06, data entry, which the National Science Foundation does not include in the "detailed" field of computer science. Likewise, the academic engineering discipline is defined to include the fields included in CIP code 14, with the exception of CIP code 14.3701, "operations research," which NSF includes in the field of business and management. Engineering also includes three additional disciplines that NSF includes in its category of engineering: engineering/industrial management (CIP code 15.1501), geographic information science (CIP code 45.0702), and materials science (CIP code 40.1001). For a list of academic disciplines included in engineering and computing in this report, see figures A11 and A12 in the appendix.

8. The number of bachelor's degrees in computer science awarded to women has dropped not only in percentages but in actual degrees awarded as well. In 1986 slightly more than 15,000 women earned bachelor's degrees in computer science (National Science Foundation, Division of Science Resource Statistics, 2013), but by 2013 that number had dropped to approximately 9,000 bachelor's degrees (National Science Foundation, National Center for Science and Engineering Statistics, 2014a). On the other hand, men earned more bachelor's degrees (slightly more than 42,000) in computing in 2013 than in past decades. The only year in which men earned more computing bachelor's degrees than 2013 was 2004, when nearly 45,000 men earned computing degrees (National Science Foundation, Division of Science Resources Statistics, 2013).

9. These numbers may underestimate the total number of environmental engineering degrees awarded because some civil and chemical engineering programs also may have an environmental focus. The environmental engineering bar shown in figure 7 includes only those 2013 bachelor's degrees reported to the U.S. Department of Education, National Center for Education Statistics awarded in the primary field of environmental/environmental health engineering.

10. Although engineering is a much bigger field than computing, more black women and men earned degrees in computer science than in engineering in 2013. The reverse, and more expected, scenario is true for Hispanic/Latinos and American Indians/Alaska Natives, who were awarded more degrees in engineering than in computer science (see figure A5 in the appendix).

11. Figures A13 and A14 in the appendix show the percentage of master's and doctoral degrees awarded to women from 1970 to 2013 in all fields, all science and engineering fields, engineering, and computing.

12. Computer user support specialists and web developers are two fast-growing computing occupations that require an associate degree or less for an entry-level position (U.S. Department of Labor, Bureau of Labor Statistics, 2014e).

13. Computing occupations with large numbers of workers who hold bachelor's degrees or higher in computing majors include computer software engineers and applications and systems software developers (AAUW analysis of National Science Board, 2014, appendix table 3-3).

14. Computing occupations with large numbers of workers who hold bachelor's degrees but not computing or engineering degrees are web developers and database administrators (AAUW analysis of National Science Board, 2014, appendix table 3-3).

15. Minority-serving institutions, including historically black colleges and universities, Hispanic-serving institutions, and tribal colleges and universities, have a strong history of graduating relatively high percentages of female STEM majors, including computing majors, who go on to earn doctorates. The persistence of women in computing in these institutions has been attributed, in part, to nurturing environments, faculty who believe in their students, and a collaborative peer culture (Ong, 2011).

16. Gender differences in retention in the engineering workforce may vary based on engineering discipline. Some evidence suggests that attrition rates from the workforce are similar for women and men in civil engineering but that women are less likely than men to stay in mechanical and electrical/computer engineering fields (Frehill, 2010).

17. The faculty data shown in figure 13 and in figures A9 and A10 in the appendix have an important caveat: They represent data only from the institutions that replied to the 2013 American Society for Engineering Education (2005, 2014) and Taulbee surveys (Computing Research Association, 2005, 2014). The ASEE numbers include data from institutions that award approximately 95 percent of engineering bachelor's degrees, so they are a good representation of the field of engineering professors. For computing, the caveat is more important. CRA data include only institutions that confer doctoral degrees, meaning that figures 13 and A10 show data for the faculty at 143 institutions that together award only about one-fourth of computing bachelor's degrees, since many computer science degrees are awarded by institutions that do not offer doctoral degrees, including many for-profit institutions.

CHAPTER 2.
WHY SO FEW?

Study after study finds that women have ability, good grades, and high test scores in STEM subjects, and yet women are turning away, or being pushed away, from engineering and computing fields. A theme that overarches much of the research on this topic is that women often feel as if they don't fit or belong in these fields. Research into this perceived lack of fit provides a complex picture of social and environmental factors influencing and interacting with individual motivations and values that are, in turn, also influenced by the wider culture. This chapter describes the latest research on structural and cultural factors in engineering and computing that may contribute to women's underrepresentation in these fields.

STRUCTURAL AND CULTURAL BARRIERS

As past decades have shown, simply trying to recruit girls and women into existing engineering and computing programs and workplaces has had limited success. Catalyst (2014) found that women in business roles at technical companies, like women in technical roles at these companies, tend to leave at higher rates than their male peers do (53 percent of women compared with 31 percent of men after their first post-MBA job). This finding suggests that the overall workplace culture and environment in technical industries may not be working for women, whether or not they are in technical roles. In both college and workplace environments, institutional structures and practices and more general cultural factors may contribute to the underrepresentation of women in engineering and computing fields.

NARROW FOCUS

One significant impediment, according to some scholars, is an emphasis on logical thinking at the expense of critical thinking in engineering culture (Claris & Riley, 2012). Scholars have pointed to a culture in engineering that discourages thinking beyond the technical parameters of a given problem (Cech, 2014). Engineering students, for example, are rarely asked to reflect on what they do, why they do it, and what the implications might be (Baillie

& Levine, 2013). Specifically, the "culture of disengagement" in many college engineering programs does a poor job of training future engineers in their ethical and social responsibilities and cultivates an understanding of nontechnical concerns, such as the public welfare, as irrelevant to "real" engineering work (Cech, 2014). These elements of engineering culture are not confined to the college environment but persist once engineers enter the workforce, and although they are likely to discourage many women and men from pursuing engineering, they are perhaps especially discouraging for women because women are more likely than men to express a preference for work with a clear social purpose (Konrad et al., 2000).

Engineering and computing programs typically include high course load and workload requirements. Engineering curricula, in particular, are often rigid, making it difficult for students to transfer into engineering if they do not start out in it. One study attests to this difficulty, finding that 90 percent of those studying engineering in their eighth semester in college had identified engineering as their major when they began college (Ohland et al., 2008). Among students with strong mathematical aptitude (including most engineering and computing students), women are more likely than men to also have strong verbal aptitude (Wang et al., 2013). The constrained curriculum in engineering and computing may make it difficult for students to take elective courses in other fields or take advantage of other extracurricular opportunities that can be valuable contributors to the college experience, especially for students with broad interests and aptitudes. For example, one study found that students majoring in engineering and computing were the least likely of all students to take foreign language courses or participate in study abroad programs (Lichtenstein et al., 2010).

ISOLATION

Women in engineering and computing fields often report isolation, a lack of voice, and a lack of support (Ayre et al., 2013; Fouad et al., 2012; Hewlett, Buck Luce et al., 2008; Hewlett, Sherbin et al., 2014; Servon & Visser, 2011). A study of women and men working in technology at 21 high-tech

companies found that women were less likely than men to indicate that their supervisors were receptive to suggestions, less likely to say that their supervisors were available when they needed them, and less likely to agree that "it is safe to speak up most of the time" (Catalyst, 2008). In one study of women in private-sector technical jobs, a third said that they felt extremely isolated at work. In the same study, four of 10 female engineers and computing professionals reported lacking role models, while about half reported lacking mentors (Hewlett, Buck Luce et al., 2008).

STEREOTYPICAL SURROUNDINGS

The physical environment in engineering or computing classrooms and workplaces can make a difference in how comfortable women find the environment. In one study, female students who entered a room containing stereotypical "geek" objects were less likely to identify themselves with computing or feel they belonged with a company or on a team (even an all-female team) than did women who entered a room containing gender-neutral objects (Cheryan et al., 2009).

SOCIAL NETWORKS LESS HELPFUL FOR WOMEN

Social networks appear to be less beneficial for women than for men, perhaps especially in computing. An analysis of social networks among undergraduate management information systems (MIS) students as they searched for jobs found that although social networks improved individuals' job prospects, women's social networks did not provide the job opportunities that men's networks did (Koput & Gutek, 2010). For example, one male student who had a C average, many male contacts, and very few female contacts participated in 16 job interviews, received five job offers, and started his career with a high salary. In contrast, women in the study, who also had many male contacts, generally did not get many job interviews or end up with high salaries, even if they had high grades. According to Koput and Gutek (2010, p. 71), "Women high in aspects of human capital, social capital, or both did not fare as well as might have

been anticipated or as well as seemingly similar men." The same study found that women with strong ties to men were more likely than other women to be seen as legitimate in the technical, male-dominated MIS field. Other research has identified social networks of powerful men, from which women are excluded, as barriers for women in engineering workplaces (Faulkner, 2009a).

WORK-LIFE BALANCE ISSUES

Work-life balance is an important issue for workers, especially women, in engineering and computing. Some researchers argue that rather than work-life balance, the real issue is a "culture of overwork." Organizational cultures of overwork result in dissatisfaction among women and men (Padavic & Ely, 2013). Because culturally women are expected to fulfill the responsibilities associated with home and family and men are expected to be the bread-winners, women may experience negative outcomes as a result of this culture of overwork more frequently than men do. For example, a survey of mid-level scientists and engineers in high-tech companies found that women were more likely than men to suffer poor health and to delay or forgo getting married and having children as a result of work demands (Simard et al., 2008). When employers in male-dominated fields such as engineering and technology expect employees to work long hours (more than 50 hours per week), women with children are much more likely than men or childless women not only to leave their employer but to exit the paid workforce entirely (Cha, 2013). This research suggests that when work responsibilities become incompatible with the demands of family life, women, especially mothers, find themselves in a situation in which they must choose between work and family.

Relatively little research has explored why women leave engineering and computing fields. One study found that half of women who left corporate science, engineering, and technology jobs moved to technical jobs outside the corporate sector, and the rest moved to jobs outside STEM fields altogether (Hewlett, Buck Luce et al., 2008). Preston (2004) identified a lack of mentoring, a mismatch of interests, and difficulty balancing work

and family responsibilities as reasons for leaving. Frehill (2012) found that women were more likely than men to cite a "change in career or professional interests" as the most important reason they left engineering. The first study to comprehensively investigate factors related to women's decisions to leave or stay in engineering careers (Fouad et al., 2012) is described in chapter 9. It identifies factors such as work environment and access to training and development as key to women's decisions to stay in or leave their engineering jobs.

CHALLENGING ACADEMIC WORKPLACES

Women working in academic engineering and computing jobs face challenges similar to those of other women working in engineering and computing. Women in academic STEM environments report lower job satisfaction than their male counterparts do (National Research Council, 2010; Bilimoria et al., 2008), although some evidence suggests that this gender difference in satisfaction has disappeared among engineering and computing faculty in recent years (Ceci et al., 2014). Personal experiences with sexual harassment or gender discrimination are the most likely factors to affect job satisfaction (Settles, Cortina, Malley, et al., 2006), but studies have also connected the general workplace climate—including perceptions of more work-family interference, less support, gender mistreatment, and an overall impression of the workplace as more competitive and hostile—to lower job satisfaction (Settles, Cortina, Malley et al., 2006; Marchetti et al., 2012). In one study of 765 STEM faculty members, women ranked their workplace environment more negatively than men did in six of eight measures, considering it more formal, less exciting, less helpful, less creative, more stressful, and less inclusive. Women in academic science and engineering also reported fewer conversations with colleagues about research, lower access to human and material resources, and lower recognition of accomplishments (Fox, 2010).

Some researchers have suggested that gender discrimination in academia is a thing of the past and that the remaining obstacles to women's full participation in academic STEM fields are work-family balance and pre-college decisions that result in fewer women majoring in fields such as engineering and computing (Ceci et al., 2014). Indeed, as described in chapter 1, women are less likely than men to start college intending to major in engineering or computing, and efforts to encourage girls' interest in STEM subjects may prove useful in increasing the representation of women in these fields. Likewise, some telling statistics point to the difficulties that mothers still face in academic environments. Mason and Goulden (2002) found that among science professors who became parents 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 numbers support the contention that work-family balance is an obstacle to women's full participation in academic STEM workplaces. Rather than showing that gender discrimination no longer exists in academia, however, these numbers may point to environments with policies and structures that make it difficult for women with children to thrive.

While research has found that women who apply for tenure-track positions in math-intensive fields are as likely as their male peers to receive offers, qualified women are less likely than their male peers to apply for these positions (National Research Council, 2010), perhaps because they perceive academic settings as environments that will not support them in achieving their life goals. Research described in chapter 3 demonstrates that, far from being a thing of the past, gender bias in hiring is alive and well in academic environments (Moss-Racusin, Dovidio et al., 2012a).

Asian, black, Hispanic, and American Indian/ Alaska Native women in academic STEM departments face additional challenges. Collecting and aggregating data on specific fields for women of color is difficult because of the low numbers, but women of color in academic science and engineering departments generally report different, and more substantial, stress than do other demographic groups. For example, women and men of color are more likely to report the stress of struggling with personal finances, women of color report more stress than both white women and men of color in lack of personal time and managing household

duties, and women of color report the most stress from discrimination. Additionally, 79 percent of women of color responded affirmatively to the statement "I need to work harder to be perceived as a legitimate scholar," compared with 67 percent of white women, 60 percent of men of color, and 52 percent of white men (National Academy of Sciences, 2013).

STEREOTYPES AND BIASES

Stereotypes and biases are important cultural factors that may influence women's representation in engineering and computing. A stereotype is an association of specific characteristics with a group (Dovidio et al., 2010). Stereotypes can be descriptive (what women and men *are* like) or prescriptive (what women and men *should* be like). Everyone uses stereotypes to process new information quickly, assess differences between individuals and groups, and make predictions. Stereotypes allow us to use fewer cognitive resources than we would if we made individual observations each time we met someone new (Heilman & Eagly, 2008; Heilman, 2012). Indeed, human beings have been described as "cognitive misers" who are reluctant to engage in effortful thought unless absolutely necessary (Fiske & Taylor, 1991). For this reason, stereotypes are very powerful and difficult to override, and they can lead to biased behavior or discrimination when we view members of a group based on their group status rather than as individuals (Heilman, 2012; Dovidio et al., 2010).

Gender stereotypes tend to place greater social value on men and evaluate men's competence as greater than women's (Ridgeway 2001). One specific area in which men are stereotypically deemed more competent than women is mathematics. Parents' and teachers' expectations for children's mathematical achievement are often gender-biased and can influence children's attitudes toward math (Gunderson et al., 2012; Varma, 2010). Parents' and teachers' own feelings about math can rub off on children. In one study, no relationship was found between first and second grade female teachers' math anxiety and their students' math achievement at the beginning of the school year. By the school year's end, however, the more anxious female

teachers were about math, the more likely girls (but not boys) in their class were to endorse the commonly held stereotype that "boys are good at math, and girls are good at reading" and the lower these girls' math achievement was (Beilock et al., 2010).

WARMTH VERSUS COMPETENCE

While men are stereotypically thought of as competent in many domains, women are stereotypically considered to be warm. Competence and warmth are traits that we tend to immediately assign to people we meet, and these traits are often perceived to be in opposition to each other (Holoien & Fiske, 2013). Because competence is valued in engineering and computing, the requirements for being viewed positively as a technical professional and being viewed positively as a woman are often conflicting. As a result, many women in technical roles report difficulty forging strong identities as engineers or computing professionals (Hatmaker, 2013; Faulkner, 2007, 2009a, 2009b; Ayre et al., 2013), and many female engineers describe an increased pressure to prove themselves (Hatmaker, 2013; Smith, L., 2013). When women emphasize their competent characteristics and effectiveness at work, they often experience backlash for violating the gender stereotype that women are warm, and they are seen as less likeable than men who emphasize the same behaviors, especially in male-dominated fields (Phelan et al., 2008; Rudman & Phelan, 2008; Heilman, Wallen et al., 2004). On the other hand, women seen as warm but not competent are less likely to be respected and more likely to be pitied and socially neglected in the workplace (Fiske, 2012; Cuddy et al., 2007).

MICROINEQUITIES

By the time women begin formal engineering or computing training in college, they likely have encountered gender-biased behavior on many occasions. Microinequities have been described as "apparently small events … frequently unrecognized by the perpetrator … which occur wherever people are perceived to be 'different'" (Rowe, 2008, p. 45). Examples include facial expressions, gestures, tone of voice, and subtle actions, such as assigning the role of note taker to a woman rather than a

man. Accumulated over time, these microinequities can affect students' self-concept, which may, in turn, influence their choice of a career (Rowe, 1990; Bandura, 1997).

Camacho and Lord (2011) found that female engineering undergraduates frequently encounter gender-based "microaggressions," small discriminatory behaviors of mostly nonphysical aggression (Pierce, 1970), in the engineering education environment. Such behaviors include encountering surprise that a woman would be interested in engineering, having male students interrupt or speak over them, experiencing difficulty having their ideas heard, being exposed to sexual discussions and joking, hearing suggestions that women are in the department only as a result of affirmative action policies rather than because of their achievements and abilities, and hearing gendered statements by professors during lectures. Other research indicates that microinequities persist long after women enter the engineering workforce (Faulkner, 2009b).

Microinequities illustrate how discrimination in school and the workplace is often subtle and not overt in its intent to harm (Hebl et al., 2002). Nonetheless, microinequities may result in increased stress and feelings of exclusion among women in engineering (Camacho & Lord, 2011).

EXPLICIT AND IMPLICIT BIAS

Biases can be explicit (conscious and self-reported on surveys or in interviews) or implicit (operating automatically, typically outside an individual's conscious awareness). Explicit gender bias has been steadily declining for decades. Whether due to a genuine increase in egalitarian beliefs or to a greater hesitation to express biased attitudes (or some combination of the two), people are less likely today to say that they hold biased beliefs than they were in the past (Banaji & Greenwald, 2013). In contrast, implicit gender biases remain pervasive (Nosek, Banaji et al., 2002b; Lane et al., 2012; Smyth, Greenwald et al., 2015; Dovidio, 2001). Even individuals who consciously reject gender stereotypes often still hold implicit gender biases. In socially sensitive domains involving topics such as race or gender, some evidence indicates that implicit bias is a better predictor of behavior and judgment than

> ## GAMERGATE
>
> Aggression against women is not always subtle. The Gamergate controversy of 2014 dramatically illustrates the virulence of gender bias in the video gaming industry. The controversy began with an ex-boyfriend's postings about the journalistic ethics of his ex-girlfriend, a prominent game developer. These allegations led to an intense flurry of postings in online forums and on social media, which quickly devolved into sexist attacks against the female gamer and against women in the industry. Female gamers were barraged by hostile postings and messages, and some were subjected to threats of rape and death that resulted in the women fleeing their homes. One even received bomb threats as a result of her work as a feminist critic of gaming. Gamergate is a chilling example of the serious online and real-world harassment and aggression that some women face in traditionally male technical realms.

is explicit bias (Greenwald, Poehlman et al., 2009). Implicit and explicit biases are related to each other but understood by psychologists to operate via distinct and different psychological mechanisms (De Houwer et al., 2009; Nosek & Smyth, 2007; Nosek, 2007). Because implicit bias is widespread and the prevalence of explicit bias is declining, this chapter focuses more on implicit bias.

The concept of implicit bias was introduced in 1995, when social psychologists Anthony Greenwald and Mahzarin Banaji built on the psychological concept that our actions are not always under our conscious control. They argued that much of our behavior is driven by stereotypes that operate automatically and, therefore, unconsciously. Researchers theorize that, starting at an early age, we acquire implicit biases simply by living in a society where different types of people fill different roles and jobs (Cvencek, Greenwald et al., 2011; Cvencek & Meltzoff, 2012). Passive exposure to widespread beliefs registers these beliefs in our minds without our even knowing it. For this reason, implicit

attitudes and beliefs may be better described as reflections of the surrounding environment rather than personal attributes (Dasgupta, 2013).

Once in place, implicit biases lead us to seek evidence that supports them and question or disregard evidence that contradicts them (Schmader, 2013). When we encounter another person, we instantly view her or him as a woman or man, and our views of any other characteristics that person may have are shaped by our beliefs about what she or he is and should be like as a woman or a man (Hassan & Hatmaker, 2014; Ridgeway, 2009). For example, a number of qualitative studies conducted in engineering workplaces found that women are often not seen by their co-workers and colleagues as full-fledged members of the engineering profession (Tonso, 2007; McIlwee & Robinson, 1992; Faulkner, 2009b)—they are "highly visible as women yet invisible as engineers" (Faulkner, 2009b, p. 169).

In 1998 Greenwald and his colleagues introduced the Implicit Association Test (IAT), a measure designed to detect the strength of a person's automatic association between two concepts. Today many IATs are freely available online at implicit.harvard.edu. One IAT that is especially relevant to women in engineering and computing is the gender-science IAT, which measures the strength of associations between gender and science. Using a computer, participants quickly sort words in each of two conditions: a gender-stereotypical condition and a counter-stereotypical condition. In the stereotypical condition, subjects use the same keyboard key to categorize items representing male (for example, the word "father") and science (for example, the word "physics") and another key to categorize items representing female (for example, "mother") and liberal arts (for example, "literature"). Next, individuals categorize the same words paired in a counter-stereotypical way, for example, male and liberal arts sorted with one key and female and science items with a different key. Which condition is presented first is randomly varied across participants. A participant's score is based on the difference in the speed and accuracy of sorting between the two conditions.

Both women and men, on average, have a strong tendency on the IAT to more readily associate male with science and female with humanities than the reverse (Nosek, Banaji et al., 2002a, 2002b; Smyth, Greenwald et al., 2015), and implicit associations that pair boys and men with math have been documented in the United States in children as young as age 7 (Cvencek, Meltzoff et al., 2011).

GUIDANCE COUNSELORS

Although the relationship between gender and vocational interests is complicated, evidence suggests that career inventory surveys currently prevalent in high school academic and career counseling may have a gender bias. Studies have found that the RIASEC Inventory, the survey most commonly used by career counselors today, may be better suited to male students than to female students and may lead to different occupation recommendations for girls and boys (Kantamneni & Fouad, 2011; Armstrong et al., 2010).

One study found that a sample of guidance counselors in Utah perceived the values, interests, and qualities of students differently based on gender. Many counselors also showed an "alarming" lack of knowledge about engineering educational and career paths and were unprepared to inform students about engineering opportunities (Iskander, 2013). Other research found that some guidance counselors in the southwest were very much aware that women are underrepresented in STEM occupations and that girls are negatively affected by gender-science stereotypes (Ross, 2012). Understanding more about guidance counselors' gender biases, knowledge of engineering and computing careers, and awareness of the influence of gender biases may help identify ways for them to better help girls make informed educational and career choices.

Most studies that examine the practical impact of implicit biases as measured by the IAT have focused on race and not gender (Banaji & Greenwald, 2013). A few examples of the behaviors found to be predicted by individuals' implicit preference for white people include less comfort and less friendliness when talking with a black interviewer than a white interviewer (McConnell & Leibold, 2001), greater readiness to perceive anger in black faces than white faces (Hugenberg & Bodenhausen, 2003), and greater likelihood to laugh at racial humor and rate it as funny (Lynch, 2010). Green and colleagues (2007) found that physicians with greater implicit racial biases favoring whites recommended optimal treatment for acute cardiac symptoms more often for a white patient than for a black patient. These studies provide evidence that implicit biases are correlated with discriminatory behavior and appear to have real-world implications.

While less research has explored the effects of implicit gender biases as measured with the IAT, recent evidence described in chapter 3 finds that implicit gender-math bias is linked to gender discrimination. Gender bias coupled with racial/ethnic bias presents a particularly challenging environment for women of color in engineering and computing (Ong, Wright et al., 2011). Further study is needed about the connection between implicit biases related to women in science and math as measured with the IAT and actual behaviors toward women in engineering and computing.

BIASED EVALUATIONS

Biased evaluations play an important role in the professional opportunities afforded to women. Even before the formal application process begins, biased evaluations can affect women's chances of getting a position. One study found that professors from many different fields were less likely to respond to an e-mail informally inquiring about research opportunities from a prospective applicant to a doctoral program if it had a woman's name on it (Milkman et al., 2014).

Hiring situations are particularly vulnerable to bias because hiring managers are generally working with limited information under time constraints, and employers typically have little opportunity to reconsider a decision after it has been made (Bendick & Nunes, 2012). Once applicants reach the interview stage, women in typically male fields face additional challenges, such as negative body language from interviewers, that can affect interview performance (Hess, K. P., 2013).

Biased evaluations continue to affect women once they have been hired. Female managers receive lower ratings on performance reviews than male managers do and are held to a higher standard, needing better performance ratings than their male peers to be promoted (Lyness & Heilman, 2006). In male-dominated science and engineering fields women are less likely than men to be seen as experts by their colleagues and to serve in important roles on teams (Joshi, 2014). Managers' discretion over everyday decisions, such as how to execute company human resource policies, can be influenced by gender biases, resulting in diminished opportunities for women and increased opportunities for men (Roth & Sonnert, 2011; Ayre et al., 2013; Bobbitt-Zeher, 2011; Catalyst, 2008; Fouad et al., 2012; Williams, C. L., et al., 2012). For example, women are less likely than men to be granted requests for flexible schedules, and that lack of workplace flexibility can prevent women, especially working mothers, from furthering their careers (Brescoll, Glass et al., 2013).

Castilla and Benard (2010) identified the "paradox of meritocracy," in which managers in organizations explicitly identified as meritocratic favor and reward male employees more generously than equally qualified female employees. This finding may have particular relevance for engineering and computing. More engineers and technical professionals, including organizational leaders, may believe that their workplaces are meritocratic than do professionals in fields that are less data-oriented. One study of scientists and engineers at high-tech companies, however, found that women were less likely than men to see their workplaces as meritocracies, perceiving connections to power and influence as necessary for advancement (Simard et al., 2008).

IN-GROUP FAVORITISM

Research suggests that biased behavior or discrimination today most often results from "in-group" favoritism, or giving preferential treatment to others with whom we identify in some way, as opposed to negative treatment of "out-group" members of groups with whom we don't identify. Laboratory and field studies find that discrimination involving the absence of positive treatment happens in many instances without any accompanying specifically negative treatment and is, in fact, more common than discrimination that involves outright hostility (Greenwald & Pettigrew, 2014). This research suggests that in-group favoritism is an important mechanism by which unequal group outcomes—including unequal outcomes for women—are maintained and is, therefore, a practice that individuals trying to reduce discrimination should minimize.

Still, if more women moved into leadership roles in engineering and technical fields, it is possible that in-group preferences could result in even more women moving into these fields. Kurtulus and Tomaskovic-Devey (2012) found that an increase in the share of female top managers in an organization was associated with subsequent increases in the share of women in mid-level management positions in that organization, particularly female managers within the same racial/ethnic group as that of the top managers.

SEXISM

Sexism can be either hostile or "benevolent." Benevolent sexism is rooted in a belief that women need the help and protection of men (Glick & Fiske, 1996; Fiske, 2012). Women who are seen as warm but not competent are especially likely to be the recipients of benevolent sexist behaviors such as being called "sweetheart" or being offered help with dangerous aspects of a job. While on the surface benevolent sexism may seem positive toward women, its effects are quite the opposite.

In one study, participants looked at a job interview transcript in which a male interviewer showing hostile sexism (such as a belief that women are incompetent), benevolent sexism

EVEN MEN ARE AFFECTED BY GENDER BIASES AGAINST WOMEN

Gender biases can create obstacles not only for women in technical workplaces but also for the men who work with them. In one study of equally performing teams working on a male-typed task, teams with a higher percentage of women rated both their female and male peers' work more negatively overall and expressed less desire to work together in the future (West et al., 2012). Another study found that in a typically male field, people rated their male colleagues as less masculine and less deserving of workplace success if they had female supervisors (Brescoll, Uhlmann et al., 2012). This research sheds light on the magnitude of the problem of gender bias in predominantly male fields and perhaps points to one mechanism by which it is maintained. If men's work is devalued when men work with women, men might take steps to avoid working with women, exacerbating the challenges facing women in male-dominated fields. While diversity has demonstrated benefits, there are real challenges to achieving it.

(such as a belief that women should be protected), or no sexism interviewed a female candidate for a stereotypically male job. Researchers found that the more participants reported liking the sexist interviewer, the less competent and deserving of the job the participants found the candidate (Good, J. J., & Rudman, 2010). Importantly, observers more frequently liked the benevolent sexist than the hostile sexist interviewer, and observers need not have held sexist beliefs themselves to like the sexist interviewer.

When a leader in an organization is sexist, women can face particularly challenging circumstances. Good and Rudman explain:

> The more a sexist boss is liked by co-workers and upper level management, the less competent female employees may seem as a result of his sexist treatment. Because benevolent sexism is often not viewed as sexist

… and in some cases is viewed as positive, chivalrous behavior … it is plausible that benevolent sexists are often viewed more favorably than hostile sexists, as was the case in the present study. As a result, women may be especially vulnerable when targeted for benevolent sexism because the perpetrator is often viewed positively, even though his treatment can undermine female recipients.

Benevolent sexism has also been shown to result in women receiving fewer challenging assignments, which can limit career development and advancement (King et al., 2012). Whether sexist behavior is more prevalent in engineering or computing workplaces than elsewhere is not clear. Still, evidence shows that women experience more sex discrimination in workplaces where they make up less than one-fourth of the workers (Stainback et al., 2011), and research described in chapter 4 finds that men in engineering and computing fields tend to have higher explicit and implicit gender-science biases than do men in other fields (Smyth, Greenwald et al., 2015).

SEXUAL HARASSMENT

Sexual harassment, defined broadly as unwelcome conduct of a sexual nature, can include behaviors such as direct and unwanted sexual advances and physical contact or a hostile work environment that includes sexual and sex-based taunting, comments, or denigration (Berdahl, 2007). Sexual harassment is widespread in engineering and technology (Servon & Visser, 2011; Faulkner, 2009a). One recent study of college-educated women in the private science, engineering, and technology sector found that 63 percent of women in engineering and 51 percent of women in technology had experienced sexual harassment (Hewlett, Sherbin et al., 2014). Organizational climate is a major factor in the prevalence of sexual harassment in the workplace (O'Leary-Kelly et al., 2009). Studies suggest that male workers in male-dominated fields may harass their female co-workers as a way to protect their territory when they sense that women are encroaching on male space (Berdahl, 2007; Chamberlain et al., 2008; McLaughlin et al., 2012).

Because of its pervasiveness, sexual harassment can seem "normal," and women may hesitate to report it, opting instead to employ coping mechanisms such as tuning it out or thinking of it as a necessary evil. Denissen (2010) documented how women in the building trades prioritized maintaining good relationships with their co-workers above reporting sexual harassment, attempting to ignore the persistent harassing behavior because of possible repercussions. In a study of technology workplaces, Hunter (2006) found similar challenges for women, where female employees chose not to report sexual harassment and tried to downplay their femininity to "fit in."

The consequences of sexual harassment are tangible and troubling. Personal or observed experiences with sexual harassment or gender discrimination are associated with alienation and low job satisfaction (Settles, Cortina, Buchanan et al., 2013; Settles, Cortina, Malley et al., 2006). Women who are targets of workplace incivility such as sexual harassment are more likely to consider quitting their jobs and dropping out of their career fields (Cortina, Magley et al., 2001). Sexual harassment can affect mental and physical well-being through increased stress, anxiety, and depression and lowered self-esteem (Bowling & Beehr, 2006). These effects extend beyond the employees targeted by harassers. Female and male employees who witness gender-based hostility at work also express greater organizational withdrawal and lower well-being (Miner-Rubino & Cortina, 2007).

Not all women are equally vulnerable to sexual harassment. Women of color are more likely to experience sexual harassment as well as racial/ethnic-based harassment (Berdahl & Moore, 2006; Cortina, Kabat-Farr et al., 2013). Additionally, women in positions of authority are more likely to report harassing behaviors than are women in non-supervisory positions, which supports the idea that sexual harassment may be connected to dominance and control (McLaughlin et al., 2012; Stainback et al., 2011; Chamberlain et al., 2008). The negative effects of workplace harassment are mitigated in workplaces where women believe that they have a strong organizational voice (Settles, Cortina, Stewart et al., 2007).

HOW STRUCTURAL AND CULTURAL BARRIERS AFFECT WOMEN

The factors described above have tangible effects on women in engineering and computing. From influencing girls' and women's preferences to their sense of belonging in these fields, cultural and structural elements, including stereotypes, biases, microinequities, and sexism, shape girls' and women's experiences in engineering and computing.

STEREOTYPES INFORM PREFERENCES

Gender biases affect not only how we view and treat others but also how we view ourselves and the choices we make about our own futures. From early childhood, cultural stereotypes guide our choices and behavior, steering us toward certain careers that seem to be the best fit for our interests and abilities and away from others. Studies suggest that girls who associate mathematics with boys and men are less likely to perceive themselves as being interested in or skilled at mathematics and spend less time studying or engaging with mathematics concepts. As early as first grade, children have already developed a sense of gender identity, and most have developed implicit biases associating boys with math as well (Cvencek, Meltzoff et al., 2011).

As described in chapter 4, individuals' implicit biases are related to their college majors, with women in science and engineering exhibiting particularly weak, and men in those fields exhibiting particularly strong, science-male implicit biases (Smyth, Greenwald et al., 2015; Nosek & Smyth, 2011; Lane et al., 2012; Smeding, 2012). Although the causal direction is not known, researchers suspect that implicit biases likely influence the choices that women and men make, while at the same time the environments in which women and men are immersed shape their implicit biases.

Jacquelynne Eccles, a leading researcher in the field of occupational choice, has spent the past 35 years developing a model and collecting evidence about career choice (Eccles [Parsons] et al., 1983; Eccles, 1994, 2007). She found that women are less likely than men to enter occupations such as engineering and computing because they have less confidence in their math and physical science abilities and because they place less subjective value on these fields than they place on other occupational niches (Eccles, 2011b).

Many researchers have found a perceived difference in the value that women and men place on doing work that contributes to society, with women, on average, more likely than men to prefer work with a clear social purpose (Jozefowicz et al., 1993; Margolis, Fisher, & Miller, 2002; Lubinski & Benbow, 2006; Eccles, 2007). A meta-analysis of job-attribute preferences found that the largest gender differences in desired job characteristics are related to communal goals, that is, helping other people and working with people, with women expressing a greater preference for both (Konrad et al., 2000). As described in chapter 6, engineering and computing careers are perceived by most people as inhibiting communal goals, and individuals who highly endorse communal goals are less likely to express interest in these fields (Diekman, Brown et al., 2010).

If women perceive engineering and computing as fields that will not allow them to meet highly valued goals, it is not surprising that they might choose other career paths, even other STEM career paths (Benbow, 2012). Eccles and her colleagues found that the desire at age 20 to have a job that helps people is a very strong predictor of both women and men completing a major in the biological rather than the physical sciences or math and working in biological or medical occupations rather than physical science or engineering occupations at age 25 (Eccles, 2009, 2011a, as reported in Kimmell et al., 2012). In the same vein, Harrison and Klotz (2010) found that the percentage of women in sustainability leader positions in design and construction companies, a position that explicitly connects engineers' contributions to problems such as energy and water resource depletion, climate change, and social inequity, is much higher (39 percent) than the percentage of women in general management positions (8 percent) in those same companies.

Eccles (2011b) points out that women (and men) likely do not consider the full range of

options when choosing a career. Many options may never be considered because women are unaware of their existence. For example, Google (2014b) identified exposure to computing as a leading factor in women's choice to pursue computing. Even when girls and women are aware of career options, they may not seriously consider those options because women have inaccurate information regarding either the option itself or their ability to achieve in that field. For example, Teague (2002) found that the issues that deter many women from pursuing computing occupations are not supported by the actual experiences of the women working there. Women may not seriously consider other careers because these options do not fit well with their ideas of what is appropriate work for women, further reducing women's perceptions of the field of viable options.

Focusing on girls' and women's choices might seem to "blame the victim"—women—for their underrepresentation in engineering and computing. According to sociologist Maria Charles (2011, p. 25), however, acknowledging gender differences in educational and career choices doesn't blame women for women's underrepresentation in engineering and computing unless preferences and choices are understood purely as a reflection of individuals' intrinsic qualities, separate from the social environment in which preferences emerge:

> The argument that women's preferences and choices are partly responsible for sex segregation doesn't require that preferences are innate. Career aspirations are influenced by beliefs about ourselves (what am I good at and what will I enjoy doing?), beliefs about others (what will they think of me and how will they respond to my choices?), and beliefs about the purpose of educational and occupational activities (how do I decide what field to pursue?). And these beliefs are part of our cultural heritage. Sex segregation is an especially resilient form of inequality because people so ardently believe in, enact, and celebrate cultural stereotypes about gender difference.

Recent analyses of international differences in the composition of engineering and computing fields make clear that the surrounding culture makes a difference (Frehill & Cohoon, 2015; Charles, 2011). While in the United States approximately one-fifth of computer science degrees are awarded to women, in Malaysia women earn about half of computer science degrees. Similarly, engineering is the most strongly and consistently male-typed field of study worldwide, but the gender composition of engineering varies widely across countries. In the United States fewer than one-fifth of engineering degrees are awarded to women, but in Indonesia women earn just under half of engineering degrees. Women make up about a third of recent engineering graduates in a diverse group of countries, including Mongolia, Greece, Serbia, Panama, Denmark, Bulgaria, and Malaysia (Charles, 2011).

In the United States and other industrialized countries, individuals and especially girls are encouraged to choose careers based on self-expression and self-realization, whereas in developing countries personal economic security and national development are often much more central concerns to young people and their parents. Perhaps ironically, this allows women in countries such as the United States more opportunity to conform to gender stereotypes in their career choices (Charles & Bradley, 2009; England, 2010).

STEREOTYPE THREAT

In addition to affecting preferences, stereotypes affect women through a phenomenon known as stereotype threat. Stereotype threat describes a threat—sometimes referred to as an anxiety—that people experience when they fear being judged in terms of a group-based stereotype (Steele, 1997; Steele & Aronson, 1995). One need not believe the stereotype nor be worried that it is true of oneself to experience stereotype threat and its negative effects. To be susceptible, individuals must only be aware of the stereotype, identify with the group that is stereotyped, and care about succeeding in the domain in which the stereotype applies

(Steele, 1997). For this last reason, people who care the most about succeeding in a domain may experience the highest levels of stereotype threat. Robust gender-math stereotypes in U.S. culture make stereotype threat an important phenomenon in understanding women's underrepresentation in engineering and computing.

Stereotype threat has many negative effects, including physiological stress responses such as a faster heart rate, increased cortisol levels, and increased skin conductance related to increased monitoring of one's performance and efforts to regulate unwanted negative thoughts and feelings. These extra processes are understood to "hijack cognitive resources" (Schmader & Croft, 2011, p. 792)—specifically working memory capacity—needed for successful performance (Schmader, 2010; Schmader, Forbes et al., 2009; Schmader, Johns et al., 2008; Schmader & Johns, 2003). Stereotype threat has been shown to result in decreased math performance among women (Koch et al., 2014; Spencer et al., 1999; Nguyen & Ryan, 2008; Walton & Spencer, 2009; Good, C., Aronson et al., 2008), decreased interest and motivation in STEM fields among women (Davies et al., 2002), and decreased sense of belonging (Walton & Cohen, 2007). It ultimately may result in disidentification with the stereotyped domain (Steele, Spencer et al., 2002; Steele, 1997). Stereotype threat can be particularly harmful to women of color because they have to contend with the threat of confirming stereotypes based on both race and gender (Settles, 2004).

Stereotype threat is triggered by cues from the environment that alert an individual to the possibility of confirming a negative stereotype about a group to which she or he belongs. Cues are often quite subtle. For example, being a member of a minority group, as women in engineering and computing often are, in and of itself can trigger a sense of threat. In one study female STEM majors who viewed a video of a scientific conference with noticeably more men than women in attendance exhibited higher indications of stereotype threat and reported a lower sense of belonging and less desire to participate in the conference compared

with women who viewed a similar video with a gender-balanced group of attendees (Murphy et al., 2007). In another experiment, subtle sexist behavior by men triggered stereotype threat in female engineering majors resulting in their underperformance on a math, but not a verbal, test (Logel et al., 2009).

Another study found that when watching a video in which a woman was subjected to dominant behavior, including command statements like "you need to..." combined with gesturing and a relaxed posture by a man in a math context, female participants showed reduced math performance and reported greater worry about confirming the negative stereotype that women are not as good as men at math. When women watched a video in which the man and woman were equal in dominance or the woman was dominant over the man, however, female participants did not experience stereotype threat (Van Loo & Rydell, 2014). This last finding demonstrates the potentially far-reaching benefits of encouraging equality and female leadership in the classroom and workplace, because seeing women in leadership roles can actually protect other women from the harmful effects of stereotype threat.

Until recently, research on stereotype threat focused primarily on the effect of stereotype threat on academic performance in the learning environment. Researchers are just beginning to explore the effects of stereotype threat in the workplace, focusing less on performance measures and more on measures of psychological disengagement, such as the degree to which women and men might say they feel disconnected from their work or mentally exhausted at the end of the day. A study described in chapter 5 found that the more female science faculty members discussed research with male colleagues, the more disengaged women felt from their work. The more women socialized with their male colleagues, on the other hand, the more engaged women felt with their work (Holleran et al., 2011). The researchers hypothesize that research conversations with male colleagues may trigger stereotype threat among female scientists, whereas social conversations may increase feelings of belonging and, therefore, reduce experiences of stereotype threat.

Because the effect of stereotype threat in the learning environment has been so clearly and repeatedly demonstrated, it is evident that stereotypes can affect stereotyped individuals in important ways. Understanding how stereotype threat affects women in the workplace, especially in fields such as engineering and computing, is an important area for future research.

SENSE OF BELONGING

Perhaps because of all these factors taken together, women often report feeling that they don't belong in engineering and computing fields (Ayre et al., 2013; Faulkner, 2009b). Research described in chapter 8 shows that even among first-year engineering students, women are less likely to perceive engineering as the right career for them (Cech, Rubineau et al., 2011).

A sense of belonging in a particular setting or broader field is associated with a variety of positive outcomes for individuals (Walton, Cohen et al., 2012; Walton & Cohen, 2007). For example, a brief intervention aimed at increasing first-year college students' sense of social belonging was found to positively affect participants' GPA and self-reported health and well-being (Walton & Cohen, 2011). Even more relevant, women participants in a social-belonging intervention who learned that adversities and worries about belonging were common for all engineering students raised their engineering GPAs, improved their academic attitudes, and viewed their daily adversities as more manageable (Walton, Logel et al., 2014). In another study, women showed improved scores on math tests if they wrote a brief essay about social belonging beforehand (Shnabel et al., 2013). Finally, a series of lab studies found that sense of belonging in math is a good predictor of whether women will continue to take math courses (Good, C., Rattan et al., 2012). Sense of belonging can have important effects even when individuals are unconscious of it. In some of the above studies, participants indicated no awareness of the intervention's impact (Walton & Cohen, 2011).

WHERE DO WE GO FROM HERE?

The chapters that follow examine specific research findings on pivotal issues affecting the representation of women in computing and engineering. The results suggest that with small and large changes in education and the workplace, progress can be made for the existing generation of women in these fields as well as future generations.

GENDER BIAS AND EVALUATIONS

When I hear the idea that women are "choosing" not to study science, technology, engineering, and math, I think that might be true, but there might be good reasons they're choosing not to study these subjects, and one of those reasons could be discrimination.
—Ernesto Reuben

Despite our best intentions, most of us evaluate and treat women differently than we do men. Evidence shows that bias against women, particularly in stereotypically male domains, is widespread (Banaji & Greenwald, 2013; Heilman, Wallen et al., 2004). This chapter highlights two studies that demonstrate the prevalence and real-world impact of gender bias in hiring decisions. The first study examines the impact of gender bias on evaluations by science faculty, and the second study explores the effect of implicit gender bias (bias that operates automatically, typically outside an individual's conscious awareness) on evaluations in the population more broadly. Both studies make clear that gender bias affects people's evaluations of one another and, specifically, hiring decisions.

A STUDY OF GENDER BIASES AMONG SCIENTISTS

Scientists by definition strive to be objective. If anyone were immune to the effects of gender bias, a scientist would be a likely candidate. Academic scientists are an especially important group given their influence on the students who will become the next generation of scientists, engineers, and computing professionals.

Corinne Moss-Racusin, an assistant professor at Skidmore College, and her former colleagues at Yale University, John Dovidio, Victoria Brescoll, Mark Graham, and Jo Handelsman, examined whether faculty members in biology, chemistry, and physics departments at three public and three private large research universities across the country make gender-biased judgments. Keeping the true purpose of the study hidden, the researchers contacted faculty members asking for help in developing appropriate mentoring programs for undergraduate science students. As part of the study, each scientist who agreed to participate was asked to provide feedback on an application for a student science-laboratory manager position. Half of the science professors reviewed an application from a student named "Jennifer," while the other half reviewed an identical application from a student named "John." Moss-Racusin told AAUW:

We pre-tested the names and had them rated on trait dimensions, like how intelligent they sounded, how recognizable, how warm, how likeable, etc. We chose the names that were rated as equivalent, so any differences between the two conditions should be attributable solely to the gender of the student and not to any superficial differences between the names.

The applicants' credentials were purposely presented to describe someone who could quite possibly be successful as a lab manager but was not an obvious star—a "qualified but not irrefutably excellent applicant" (Moss-Racusin, Dovidio et al., 2012b, p. 2). This approach was chosen to replicate the situation for most aspiring scientists, including the type of students most affected by faculty judgments and mentoring. The science faculty members (33 women and 94 men)[1] assessed the applicant on competence, hirability, and likeability and told the researchers the salary and mentoring that they would offer the student, with the understanding that their feedback would be shared with the student they had rated (Moss-Racusin, Dovidio et al., 2012b).

PERVASIVE GENDER DISCRIMINATION AMONG SCIENCE FACULTY

The results were unequivocal. Scientists, both women and men, viewed the female applicant as less competent and less hirable than the identical male applicant and were less willing to mentor the female candidate than the male candidate (see figure 14). Faculty members also indicated that they would offer less money to the woman than the man. Asked to choose a starting salary ranging from $15,000 per year to $50,000 per year, scientists indicated that they would offer an average of slightly more than $26,500 to the female applicant and an average of slightly more than $30,000 to the male applicant.

Although scientists often reported liking the female student more than the male student, liking her more did not translate into positive perceptions of her competence or into material outcomes such as a job offer, good salary, or career mentoring.

FIGURE 14. FACULTY RATINGS OF LAB MANAGER APPLICANT, BY GENDER OF APPLICANT

Source: Moss-Racusin, Dovidio et al. (2012a).

The researchers also looked into the underlying factors that might influence this behavior and found that once they controlled for the perceived competence of the applicant, scientists' preference for hiring men disappeared. This finding indicates that scientists were less likely to hire a woman than an identical man *because they viewed the woman as less competent*, not because of some other potential reason (such as a perception that a woman would be less committed to the job or more likely to leave the position).

This study provides unique experimental evidence that science faculty members discriminate against female undergraduates. Female and male scientists were equally likely to discriminate against female applicants, and scientific field, age, and tenure status had no effect on the results. Faculty in all scientific fields discriminated against women, women were as likely as men to discriminate, and younger faculty were as likely as older faculty to discriminate.

SUBTLE GENDER BIAS LINKED TO DISCRIMINATION

After providing feedback on the male or female applicant, the scientists completed the Modern Sexism Scale, a commonly used and well-validated scale that measures modern views toward women and gender (Swim et al., 1995). This scale is designed to detect explicit gender bias focusing on subtle, contemporary manifestations of bias rather than more old-fashioned, overtly hostile attitudes toward women. For example, participants rated their agreement with statements such as "On average, people in our society treat husbands and wives equally" and "Discrimination against women is no longer a problem in the United States."

The researchers found that faculty members with subtle gender biases made more negative evaluations of female applicants. That is, the more gender bias the scientists expressed on the Modern Sexism Scale, the less competent and hirable they perceived the female applicant to be and the less

mentoring they were willing to offer her. Moss-Racusin explains:

> We are not talking about faculty members refusing to meet with a female student under any circumstances or telling a female student something egregious like "You don't belong here, and I would never train you." Their outcomes or behaviors are just slight downgrades of what they would offer the identical male student—they're tweaks. We are not talking about a $30,000 differential in salary; we are talking about $4,000 per year. … Yet, these subtle downgrades accumulate over time and may come to powerfully shape choices and careers.

HOW BIAS AFFECTS WOMEN IN ENGINEERING AND COMPUTING

According to Moss-Racusin, the findings of this experiment are relevant to the engineering and computing fields because the biased evaluations found here are driven by stereotypes that women are not well suited to science. Gender stereotypes may be even stronger in the engineering and computing fields, where women are even less well represented than in the scientific fields surveyed in this study.

The differences uncovered in this study could translate into large, real-world disadvantages for women in engineering and computing. Because confidence develops, in part, from feedback from our environment (Bandura, 1982), teacher and faculty assessments of students' competence contribute to students' career choices. This study suggests that girls and young women are less likely than their male peers to receive good evaluations of their competence, rewards, and mentoring from their teachers and professors throughout their STEM education, even when their performance is the same as boys' and men's.

Biases continue to affect women once they move into the workplace. From hiring decisions to project assignments to promotions, the findings from this study reveal that female engineers and computing professionals are likely to be evaluated as less competent, less hirable, and less valuable than identically qualified male counterparts.

Moss-Racusin and her colleagues' study exposes the lack of a level playing field in academic science. One might think that science professors, by virtue of their rigorous training in producing objective outcomes, would not be influenced by gender biases, but this study demonstrates that this is simply not true. Ironically, a belief in one's objectivity may increase biased behavior (Uhlmann & Cohen, 2007). Moss-Racusin told AAUW, "We are all—even those of us who are extremely focused on being egalitarian—exposed to these pervasive stereotypes throughout our surrounding culture, and we're all fairly affected by them." Understanding that bias is widespread is an important first step toward reducing biased behavior.

The biases uncovered in Moss-Racusin and her colleagues' study are likely a combination of explicit biases and implicit biases. The study found an association between stated subtle gender bias and lower assessment of women's competence, suggesting an important effect of explicit bias. At the same time, gender bias emerged as a general effect in the whole sample, including the scientists who did not explicitly express even subtle gender biases, suggesting an important effect of implicit bias operating mostly beneath the level of consciousness.[2]

IMPLICIT GENDER BIASES AND DISCRIMINATION IN HIRING

Some years ago Ernesto Reuben, an economist at Columbia Business School, noticed a number of articles on gender differences in personal characteristics such as risk-taking, willingness to negotiate, and enjoyment of competition. These articles proposed that women's preferences related to factors such as these explained women's underrepresentation in certain positions and fields. Reuben told AAUW, "After reading these articles, I thought they were missing something. I thought that we need to be thinking not only about how women are different from men but about how perceptions cloud judgment and how this can filter back into women's incentives to even try for certain types of jobs."

Reuben wondered if something was going on in the hiring environment that might help explain

women's underrepresentation in certain positions and fields. To explore this question, he and his colleagues, Paola Sapienza from the Kellogg School of Management at Northwestern University and Luigi Zingales from the Booth School of Business at the University of Chicago, conducted a study on the practical effects of implicit gender biases on hiring practices (Reuben et al., 2014a, 2014b).

A HIRING EXPERIMENT

In a laboratory experiment focused on hiring, just under 200 undergraduate students—in groups of around 14 students each—performed an arithmetic task on a computer, summing as many sets of four two-digit numbers as possible during a four-minute period, and then took part in a hiring exercise. Participants were told that they would be paid a small amount according to the number of correct answers they provided and additional money if they were chosen to be hired. Payment was offered as a way to motivate participants to think hard about the questions and to want to be hired, as would most often be the case in an actual hiring scenario. The researchers chose the arithmetic task because research shows that it is performed equally well by women and men while at the same time belonging to an area (mathematics) about which there remains a pervasive stereotype that men perform better.

Following the arithmetic task, participants were told the number of problems they had solved correctly. The participants also were told that they would perform the same task a second time and were asked to estimate how many questions they would answer correctly the second time. They also were told that their earnings, which were again based on the number of correct answers they provided, would not be affected by the accuracy of their estimate.

Before the second task began two participants were chosen randomly to be "job candidates." They walked to the front of the room carrying "Candidate A" and "Candidate B" signs, while the remaining participants acted as "employers," tasked with hiring one of the two candidates to perform the second arithmetic task. If employers chose correctly—that is, actually chose the candidate who performed better than the other candidate on the second arithmetic task—they received increased compensation for the study.[3] After the employers made their hiring decision, the experiment was repeated a number of times with other randomly chosen job candidates. Employers chose candidates from pairs representing any combination of women and men including same-sex pairs to avoid making gender overly obvious as a factor in employers' decisions; however, the researchers analyzed data only from the instances in which the two candidates in the pair were of different genders.

PHASE 1: HIRING DECISIONS BASED ON THE CANDIDATES' APPEARANCE ONLY
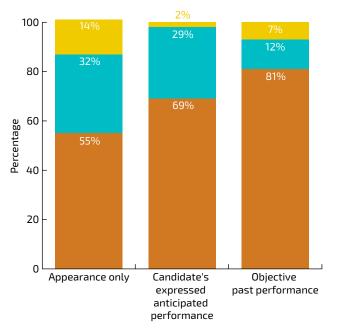
The evaluation portion of the study included three phases. In phase 1, employers were asked to choose between the two candidates based only on the applicants' appearance. As might be expected, when basing a hiring decision purely on appearance, employers frequently made bad hiring decisions, selecting the higher-performing candidate only about half (55 percent) of the time (see figure 15).

Not surprisingly, the bad hiring decisions were not gender neutral. Employers were more than twice as likely to choose the man as the woman when they made a bad hiring decision, choosing the lower-performing man 32 percent of the time and the lower-performing woman 14 percent of the time. Both female and male employers expected women to perform worse than men.

PHASE 2: HIRING DECISIONS BASED ON THE CANDIDATES' PREDICTIONS OF FUTURE PERFORMANCE

In phase 2, employers were shown the candidates' estimates of their performance on the second arithmetic task. This phase simulated a real-life interview situation in which employers ask—and often have to take a candidate's word for—how candidates would expect to perform in a given job, a scenario especially common in situations where job skills are less quantifiable and more subjective. With this limited additional information, the employers in the study did a better job, choosing the top performer 69 percent of the time (see figure 15). Yet in this scenario, when employers

FIGURE 15. PROBABILITY OF SELECTING THE BEST CANDIDATE FOR A MATHEMATICAL TASK

Notes: The percentage of times that a lower-performing man was chosen in each condition was calculated from information provided in figure 1 in the source. The authors multiplied the percentage of times the lower-performing candidate was chosen by the percentage of times the lower-performing chosen candidate was a man.
Source: Reuben et al. (2014a).

knew the candidates' estimated future performance, employers still chose a lower-performing man (over a higher-performing woman) 29 percent of the time—nearly as often as when employers made their decision based solely on appearance. In contrast, employers chose a lower-performing woman only 2 percent of the time. In other words, employers made fewer mistakes overall when they knew candidates' estimates of their future performance, but when employers did make a bad hiring decision, they nearly always erred in favor of the lower-performing man and almost never in favor of the lower-performing woman.

PHASE 3: HIRING DECISIONS BASED ON OBJECTIVE PAST PERFORMANCE

In phase 3, employers were told the actual performance of each candidate on the first task. In this case, employers did an even better job, choosing the top performer 81 percent of the time (see figure 15). When employers hired the lower-performing candidate, they were still nearly twice as likely to hire the lower-performing man over the higher-performing woman than the reverse, but the gender discrepancy was not as great as when employers based their decisions on candidates' appearance or candidates' future anticipated performance.

IMPLICIT BIASES ASSOCIATED WITH DISCRIMINATORY BEHAVIOR

The researchers also asked all participants to complete a math/science-gender Implicit Association Test (Greenwald, McGhee et al., 1998). The test results were clear: Implicit gender biases were related to discriminatory hiring practices. The study found a strong correlation between implicit math/science-male bias and bad hiring decisions favoring men.

Employers with stronger math/science-male biases were more likely than others to choose a man rather than a woman in each phase of the study. The study found that employers, especially those with stronger math/science-male implicit biases, are likely to rely on their own stereotypes and biases when hiring employees, even when objective past performance information is available. Frequently, these biases will lead employers to hire the less capable candidate.

IMPLICATIONS FOR WOMEN IN ENGINEERING AND COMPUTING

This study presents a discouraging scenario for women in typically male fields such as engineering and computing. No matter what type of information employers had about applicants, employers' bad hiring decisions usually favored a low-performing male candidate over a high-performing female candidate.

In both the first and second phases of the study, nearly one in three times the higher-performing woman did not get hired. The odds of higher-performing men getting hired were much better than higher-performing women getting hired in every scenario, especially when employers based their decisions on candidates' predictions of their future performance.

One might think that this study overestimates the effect of biases on hiring because employers undoubtedly have experience with hiring that should give them an edge in accurately evaluating candidates over the student employers in the experiment. Real-world employers also have much more at stake and, therefore, should be more inclined to seek information about past performance (such as references). While true, at the same time, this study may underestimate the effect of biases on hiring, since past performance is likely to be even more ambiguous in reality than in this experiment, and stereotypes thrive in cases where qualifications are ambiguous. Reuben told AAUW that he believes the findings from this study are quite relevant to real-world situations:

> These implicit associations that we are measuring or capturing—these are not from the lab. They were not created in the lab. We are just putting study participants in a context where they have to make choices, and they do so based on their biases. I don't see why the biased decisions we see in the lab wouldn't translate to real decisions outside.

THE ADVANTAGE OF OBJECTIVE INFORMATION

This study provides clues about reducing the effect of gender bias on hiring. The more objective information employers had to go on, the better and less-biased decisions they made. Specifically, when employers had information about applicants' past math performance, they chose the top-performing candidate 81 percent of the time. In contrast, employers chose the top performer only 55 percent and 69 percent in phases one and two of the study, when they had less-objective performance

information on which to base their decisions. The researchers found that self-reported information doesn't help as much as objective information because "men tend to be more self-promoting than women in these reports but employers … do not fully appreciate the extent of this difference" (Reuben et al., 2014a, p. 4408).

While objective information helps, it doesn't fully overcome the problem of gender-biased hiring. Even when participant employers had objective information on the past performance of candidates, they chose to hire the lower performer one in every five times, and when they did, they were twice as likely to hire the lower-performing man as the lower-performing woman. This gender gap in hiring decisions is due to a systematic underestimation of the performance of women compared with men (Reuben et al., 2014b). While it can be difficult to learn objective information about a job applicant's past performance that is relevant for the job she or he is seeking, the findings from this study suggest that the more employers can base their hiring decisions on objective information, the better—and less-biased—decisions they will make.

WHAT CAN WE DO?

Chapter 10 includes recommendations, based on the large body of gender-bias literature, for counteracting the harmful effects of gender bias. From these two studies, several recommendations are clear.

A first step toward addressing biases in hiring is acknowledging the reality that we are all influenced by gender biases, whether or not we consciously endorse them. Reuben told AAUW that, for the most part, "we are not trying to convince people that discrimination is bad anymore. Now we're just trying to make people aware that they might be discriminating." Requiring researchers who receive federal funds to participate in training on how to counteract the harmful effects of bias could help increase awareness. One practical way to do this is to incorporate bias training into the responsible conduct of research (RCR) training already required for individuals, including many academic

scientists, who work on federally funded research projects. Institutions should consider requiring bias training for all administrators as well.

Second, Reuben and his colleagues found that employers made better and less-biased hiring decisions when they were provided with objective information about past performance. Employers should base hiring decisions on objective past performance information as much as possible.

Third, more research is needed to establish the effectiveness of interventions aimed at reducing both implicit and explicit bias, particularly research in applied settings including workplaces that employ engineers and computing professionals. Moss-Racusin and her colleagues recently published recommendations for the design and evaluation of bias-reduction interventions to ensure that they are evidence based and scientifically validated (Moss-Racusin, van der Toorn et al., 2014). She told AAUW:

> I hope that in 10 years we will have some theory-driven, solid, validated programs for prejudice reduction and boosting diversity in STEM. I hope that we will be able to show that if we administer interventions under these circumstances to these folks, we are most likely to see improvement. I hope that we will have a deep tool kit, that we will know, "for this kind of audience this would be best; for that kind of audience that would be best." I don't think we are there yet, but we are moving there.

CHAPTER 3 NOTES

1. The demographic breakdown of the study's sample is consistent with the demographic breakdown of the population of science professors in the United States overall. Because of this, the results of this study can be generalized, with some confidence, to the broader population of science professors.

2. Although in their study Moss-Racusin and her colleagues did not directly assess the science faculty members' implicit gender biases (for example, by administering an Implicit Association Test) for feasibility reasons, she told AAUW, "It would be very interesting to see if implicit gender bias is linked to effects in the same way that the modern sexism scale is." Determining the relative impact of explicit biases compared with implicit biases on evaluations is an important question for future research.

3. One advantage of this experimental design is that it narrows the factors influencing employers' decisions to perceptions of competence alone. Extraneous factors such as employers' concerns that women will drop out of the labor force or not be as committed to their jobs shouldn't have influenced the student employers' decisions because they were tasked only with hiring the candidate best able to conduct a four-minute math task within the time frame of the session.

GENDER BIAS AND SELF-CONCEPTS

There is a huge difference between the gender-science associations in the minds of male and female scientists … and we have much to learn about how this gap may affect learning and work environments.
—Frederick Smyth

Implicit biases are associated not only with how we evaluate and treat others but also with attitudes and outcomes about our own future (Smyth, Greenwald et al., 2015; Nosek, Banaji et al., 2002a). Researchers hypothesize that the influence goes in both directions: Implicit biases shape outcomes and actions (such as majoring in engineering or computing), and experiences (such as majoring in engineering or computing) shape implicit biases (Nosek & Smyth, 2011). Women and men are exposed to the same stereotypes about women in math and science in U.S. culture and, on average, acquire the same implicit or unconscious "science/math=male" biases by age 7 or 8 (Cvencek, Meltzoff et al., 2011).

Three long-time researchers of implicit bias, professors Brian Nosek and Frederick Smyth at the University of Virginia and professor Anthony Greenwald at the University of Washington, examined the relationship between gender-science implicit biases and engineering and computing outcomes, specifically college major, for women and men. The study's sample included more than 175,000 participants who visited the publicly available Project Implicit website (implicit.harvard.edu)[1] between May 2004 and January 2012. The median participant age was 25, 70 percent were women, more than three-quarters were white, and all had at least some college education.

ASSOCIATING SCIENCE WITH MALE

At the Project Implicit website, participants indicated their current or past college major, answered questions about their explicit gender-science associations, and completed the gender-science Implicit Association Test (IAT), which tested how rapidly participants associated science with male and science with female. A score of zero indicates that the participant was equally fast categorizing science with male and science with female. Positive values indicate a stronger association (or faster categorization) of science with male than with female,[2] and negative values indicate a stronger association of science with female than with male (Smyth, Greenwald et al., 2015).

IMPLICIT SCIENCE-MALE BIAS

Overall, women and men both exhibited a similar strong association of science with male. When the researchers broke down the data by college major, however, striking results emerged. Men who majored in scientific fields such as engineering or computing had strong implicit science-male biases, while women who majored in those fields had weak science-male implicit biases.[3] In the least scientific fields, such as the visual and performing arts and humanities, this situation was reversed: Women held much stronger science-male implicit biases than men did (see figure 16). Smyth told AAUW, "This big difference in implicit bias between fields is compelling evidence that these implicit associations are not a one-size-fits-all. Implicit bias is not something that is intractable, that cannot move."
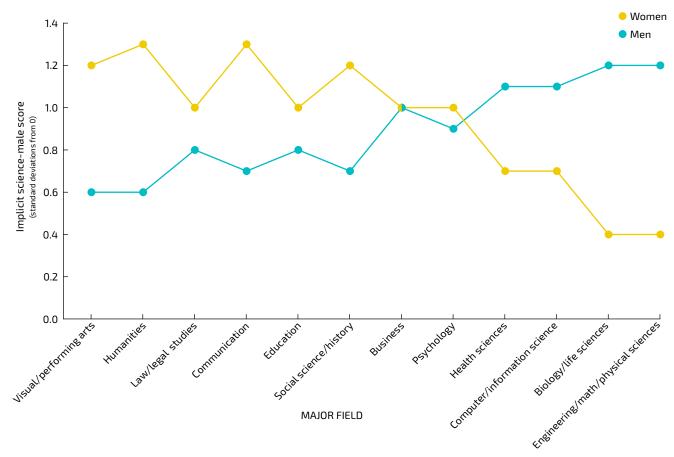
In the most scientific fields (including engineering and computing), men held much stronger science-male implicit biases than women did. "Those gender differences are in the realm of the biggest cognitive gender differences that we ever see," said Smyth. Men in science and women in the humanities (those in gender-traditional fields) had the strongest biases while the weakest science-male biases were found among women and men in gender-nontraditional fields.

Notably, female engineers and computer scientists did not show a reversal in typical implicit biases; that is, they did not more strongly associate science with female than with male. Smyth told AAUW:

> I see it working like this: A man in science gets up every morning, looks in the mirror, and if he's feeling good about his scientific achievement lately, the connection between maleness and science is reinforced. This process need have nothing to do with thinking disparagingly about women in science. Unconsciously, routinely, this provides steady fuel to associations between maleness and "scienceness" for him. For women, the same thing happens, their science and female associations are routinely stoked, but they still are in this culture where there are so many men and still a great deal of stereotyping, so the averages for the women don't

FIGURE 16. AVERAGE SCIENCE-MALE IMPLICIT ASSOCIATION TEST SCORE, BY GENDER AND COLLEGE MAJOR

Notes: Majors are ordered from left to right by ratings of science content. A score of 0 indicates no science-male implicit bias. Lower numbers on the y axis represent lower science-male implicit bias scores.
Source: Smyth, Greenwald et al. (2015). Adapted with permission from Frederick L. Smyth.

move into the science-is-female portion of the chart. They're still solidly in the science-is-male portion.

Yet even though women in engineering and computing associated science with male more readily than science with female, they had weaker implicit science-male biases than women in nonscientific fields had. Supporting this finding, another study showed that women with weaker math-male implicit biases reported more participation in math, more self-ascribed mathematical skill, and higher scores on the SAT and ACT math tests compared with women who had stronger math-male implicit

biases (Nosek & Smyth, 2011). Study after study has found that women in engineering and computing tend to have weak implicit associations between science/math and male (Nosek & Smyth, 2011; Smyth, Greenwald et al., 2015; Smyth, Guilford et al., 2011).

These findings cannot explain which came first—implicit bias or college major choice. Do weak implicit science-male biases lead women to major in engineering or computing, or when women major in engineering or computing, do their science-male biases weaken? This research doesn't answer these questions, but researchers suspect that both happen. Implicit biases probably

IMPLICIT BIAS IS A GOOD PREDICTOR OF COLLEGE MAJOR

Implicit science-male bias has been found to be a stronger predictor of majoring in a STEM field than has explicit bias (Nosek & Smyth, 2011; Nosek, Banaji et al., 2002a) or an individual's score on the math SAT, an indicator often used to identify potential for achievement in these areas. The correlation is in opposite directions for women and men. For women, weaker science-male bias is associated with majoring in STEM fields, whereas for men, stronger science-male bias is associated with majoring in these fields. Importantly, the correlation between level of implicit bias and majoring in a STEM field is as powerful for individuals who test highest on standardized math tests as for those who test lowest.

Smyth and his colleagues were not surprised to find that implicit biases more accurately predicted majoring in a STEM field than explicit biases did because the biases we report are subject to our own limited abilities to see ourselves clearly and motivations to present ourselves in a favorable light. Implicit biases, in contrast, are more difficult to mask.

influence the choices that women make, while at the same time, the environments in which women are immersed shape their implicit biases (Nosek & Smyth, 2011). Regardless of the causal direction, these studies illuminate a strong relationship between implicit biases and the pursuit and attainment of science, engineering, and computing degrees—positive for men and negative for women.

EXPLICIT SCIENCE-MALE BIAS

This study also found that men who had majored in engineering, computing, math, or a physical science reported the highest levels of explicit science-male bias as well. On a questionnaire, on average, men who majored in scientific fields such as engineering and computing reported stronger conscious

science-male associations than other women and men did, including women in engineering and computing (see figure 17). One possible explanation for this is that some of the explicit associations people report are based on dominant patterns in their environment. For example, as shown in figure 17, women in health sciences and biology have lower explicit science-male biases than other women do, probably because male-to-female ratios are much lower in health and biological sciences than in other scientific fields. In engineering and computing, on the other hand, male-to-female ratios are much higher than in other fields, and men in these fields report higher science-male biases than other men do.
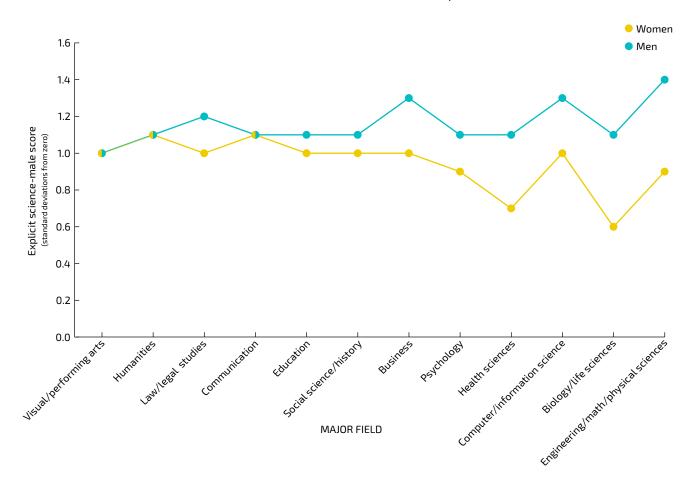
HOW GENDER BIASES AFFECT ENGINEERING AND COMPUTING ENVIRONMENTS

In a sense these findings are not particularly surprising. It is logical that men who major in engineering, computing, and science associate themselves with science and so more readily associate science with men more generally. By the same token, it is logical that women who major in engineering, computing, and science associate themselves with these fields and so are less likely to readily associate science with men. Yet even though these findings are not particularly surprising, they beg an important question: What is the impact on women's representation in engineering and computing of classrooms and workplaces made up primarily of men with strong math-male and science-male implicit biases? According to Smyth, we still have a lot to learn about that.

While ample evidence shows that implicit bias influences perceptions of women in science and math, little research specifically links IAT scores with discriminatory behavior in the area of women in engineering and computing. Still, research described in chapter 3 provides some evidence that implicit math/science-male biases as measured by the IAT are associated with discriminatory behavior toward women (Reuben et al., 2014a).

The research of Smyth and his colleagues found that men who majored in engineering

FIGURE 17. AVERAGE SCIENCE-MALE EXPLICIT ASSOCIATION SCORE, BY GENDER AND COLLEGE MAJOR

Notes: Majors are ordered from left to right by ratings of science content. A score of 0 indicates no science-male explicit bias. Lower numbers on the y axis represent lower science-male explicit bias scores.
Source: Smyth, Greenwald et al. (2015). Adapted with permission from Frederick L. Smyth.

and computing had some of the highest levels of science-male implicit biases of anyone majoring in any field and the highest levels of explicit science-male biases of all (Smyth, Greenwald et al., 2015). Smyth told AAUW, "Should we be very afraid? I don't think so, any more than we should already be working hard to create inviting, welcoming environments and continuing to learn as much as we can about what facilitates a sense of belonging among people who don't feel as well represented in a particular domain."

REDUCING DISCRIMINATORY EFFECTS OF IMPLICIT BIASES

Reducing possible discriminatory effects of implicit biases requires organizations to institute policies and practices that make hiring and promotion criteria explicit, because without clearly defined criteria, implicit bias can easily creep into decision making. According to Smyth:

Our best advice for counteracting the effects of implicit bias is for organizations to do sustained work to create welcoming,

equality-focused environments. Educating people about implicit bias, giving them a sense of the literature and some of these fascinating studies in itself accomplishes little. Following the advice of Tony Greenwald and Mahzarin Banaji in their book *Blindspot* [Banaji & Greenwald, 2013], we recommend that organizations put into place "no-brainers" that minimize subjective aspects of decision making about people, because we are always at risk of being influenced by biases that we don't know we have.

Putting in place "no-brainers" means removing opportunities for bias to influence our decisions. For example, as much as possible, organizations should remove information about an individual's age, race, or gender from decision-making contexts.

Smyth notes that it takes concerted effort to create and maintain environments that are welcoming:

> If you look around and see portraits on the wall in the engineering conference room that are 19 men and one woman, that sends a message that this is a male bastion. Organizations can think creatively about honoring their legacy of male leaders with a contemporary reality that includes women. It's tricky, and we need to be always thinking creatively because there isn't any clear, slam-dunk method that's yet been developed for changing implicit biases.

CHANGING IMPLICIT BIASES

The idea of changing implicit biases indeed seems to be a formidable task. How can you change something you're not even aware that you have? Yet women in engineering and computing have weaker science-male implicit biases than women in nonscientific fields do. Therefore, reducing math-male and science-male implicit biases, especially among girls, seems like an important avenue to explore to make engineering and computing careers true options for girls and women. Fortunately, because implicit attitudes are linked to the environment, researchers theorize that "such biases should shift when people are immersed in different types of situations where

they encounter admired and counter stereotypical individuals who do not fit their prescribed role in society" (Dasgupta, 2013, p. 241).

One recent experiment provides support for the notion that implicit biases are indeed malleable. Nilanjana Dasgupta, a psychology professor at the University of Massachusetts, Amherst, and her colleagues found that college women who had a female as opposed to a male instructor for a calculus course had significantly more positive implicit attitudes toward math and stronger implicit self-identification with math after the course than before the course (Stout, Dasgupta et al., 2011).[4] Women's explicit beliefs about math did not change even though their implicit associations did. Dasgupta (2013, p. 264) explained:

> In talking to participants at the end of the study, it was eminently clear that these women were unaware that the people they came in contact with in class … had any effect on their own academic self-concept and career goals. Like most people, participants described their academic interests as driven mostly by their intrinsic interest and motivation. They were unaware of the profound effects their local environments were having on their intellectual self-concept and career trajectories.

Importantly, while women had more positive implicit attitudes toward math and stronger implicit self-identification with math after taking a calculus course taught by a woman, women's math-male implicit biases did not change. Nevertheless, according to Smyth, the changes in attitudes and self-identification are theoretically important precursors to changes in math-male implicit biases:

> Changes in implicit attitudes toward math and self-identification with math are related to changes in implicit gender biases toward math. If we make substantial changes in implicit self-concept about a domain [in this case, mathematics], then we ought to see a corresponding change in the stereotype.

The message from Dasgupta's study is that female role models, specifically teachers, can change girls' and women's attitudes and identification

with math and science. Researchers suggest that these changes will ultimately lead to changes in implicit biases. Other research by Dasgupta and her colleagues clarifies that relatability is a necessary element for role models to be effective. Female experts portrayed as "superstars" who are unique and exceptional have little impact—and sometimes have a deflating effect—on young women's views of themselves. Likewise, role models with whom young women do not identify have little effect on women's self-concepts even if they are in frequent contact. Dasgupta's research suggests that changing implicit self-concepts (and eventually implicit biases) requires both frequent exposure to female role models as well as feeling a connection with these role models (Asgari et al., 2010; Dasgupta, 2013).

WHAT CAN WE DO?

The effect on the engineering and computing workplace and education environments of so many men with strong science-male implicit biases is unknown and is an area ripe for future research. Most women in engineering and computing, in contrast to their male colleagues, tend to have relatively weak science-male implicit biases. Because of this, it makes sense to consider ways to reduce girls' and women's science-male implicit biases as a potential way to increase the chances that girls and women will develop an interest in these fields.

While research has yet to identify a clear-cut method for reducing implicit biases, female role models with whom women can identify may help. Female role models have been shown to strengthen young women's math attitudes and self-concepts—precursors to reducing gender-math and gender-science implicit biases—and increase girls' and women's abilities to truly consider engineering and computing fields as viable career options. In addition, organizations should create welcoming environments for women. This includes actively developing female leaders and training managers to run productive, inclusive teams. Organizations should also make hiring and promotion criteria explicit and examine these criteria for implicit biases. Finally, organizations should make the first round of hiring, awards, and promotion discussions gender-, disability-, and race-blind when possible.

CHAPTER 4 NOTES

1. Project Implicit is a popular website at which visitors can participate in studies and learn about implicit social cognition related to a variety of topics. Thousands of individuals visit the website each week. While participants in this study were not randomly chosen, Smyth told AAUW that he's conducted similar, smaller studies with representative samples of participants and has consistently found patterns identical to that shown here, strengthening the credibility of this pattern.
2. A science-male IAT score could just as accurately be called a liberal arts-female score since both stereotypes are combined in IAT methodology.
3. Nosek & Smyth (2011) found similar results using the gender-math IAT.
4. Participants' implicit attitude toward math was assessed by measuring how quickly participants categorized words related to math, such as "algebra" or "equation," with positive versus negative words, such as "joy" or "filth." Participants' implicit self-identification with math was assessed by measuring how quickly participants paired the same math words with first-person pronouns, such as "me" or "myself," compared with third-person pronouns, such as "they" or "them" (Stout, Dasgupta et al., 2011).

CHAPTER 5.

STEREOTYPE THREAT IN THE WORKPLACE

After women run the gauntlet of standardized testing and make it into graduate programs or even careers in STEM, they still find themselves in contexts where the concern that they might be judged through the lens of a stereotype can rear its head.
—Toni Schmader

Women presented with the stereotype that men are better at math perform worse on difficult math tests than women who are told that there are no gender differences in math performance (Spencer et al., 1999). This lowered performance is a result of a phenomenon called "stereotype threat," or a fear of confirming a negative stereotype about your group (Steele, 1997). Hundreds of studies have verified the influence of stereotype threat in many domains, including academic performance among black students (Steele & Aronson, 1995; Taylor & Walton, 2011), memory in older adults (Hess, T. M., et al., 2003), girls' chess performance (Rothgerber & Wolsiefer, 2014), and women's athletic performance (Hively & El-Alayli, 2014). In every case even subtle reminders of negative stereotypes can have an impact on performance, sometimes in dramatic ways. For example, according to a meta-analysis by Walton and Spencer (2009), stereotype threat results in an underestimation of the intellectual ability of black and Latino students by approximately 40 points on the SAT math and reading tests.

Stereotype threat is thought to undermine performance in part by reducing working memory capacity as individuals use some of their finite cognitive resources to suppress negative emotions or knowledge of a stereotype to focus on a task (Croizet et al., 2004; Schmader & Johns, 2003). Stereotype threat has been shown to increase stress and anxiety (Blascovich et al., 2001; Bosson et al., 2004; Inzlicht & Ben-Zeev, 2003) and is theorized to ultimately lead to disidentification and disengagement from domains in which a person feels stereotyped (Steele, 1997).

A study by University of Waterloo psychology professor Christine Logel and her colleagues (2009) explored whether interpersonal interactions outside the classroom can create stereotype threat conditions for women in a male-stereotyped field. The researchers found that interacting with subtly sexist male peers caused women who were majoring in math, science, or engineering to experience stereotype threat. Men holding sexist attitudes revealed their sexism through subtle but consistent behaviors, including behaving in more dominant and flirtatious ways. After interactions with these men, women subsequently performed worse on an engineering or math test (but not an English test) than did women who interacted with nonsexist men.[1]

HOW STEREOTYPE THREAT AFFECTS WOMEN IN THE WORKPLACE

Researchers have only recently begun to examine how stereotype threat operates in the workplace (Kalokerinos et al., 2014). Most research to date on stereotype threat has focused on academic performance (Walton & Spencer, 2009). By virtue of its relationship with stress, anxiety, and disengagement, however, stereotype threat could also lead to a wide variety of negative experiences for stereotyped individuals at work. Engineering and computing workplaces, in which women potentially face an almost constant threat of confirming the stereotype that men are better suited for science and math, are prime work environments in which to explore stereotype threat.

Toni Schmader, a psychologist at the University of British Columbia, and her colleagues Shannon Holleran, Jessica Whitehead, and Matthias Mehl are among the first researchers to study stereotype threat in the workplace. Moving beyond strict issues of performance, these researchers conducted an experiment that explored whether experiences of stereotype threat might relate to disidentification or disengagement in the workplace. In an interview with AAUW, Schmader explained how they shifted their focus from the classroom to the professional field:

As we tried to understand the lower representation of women in science and technology fields more generally, it became a practical but also a theoretically interesting question as to why the effects of stereotype threat would be limited to the earlier stages of the pipeline, when people are getting their education and their credentials. There are reasons why you might think that people would have good coping strategies for dealing with stereotype threat by the time they get to a professional environment. But we

suspected that there were still ways in which stereotype threat would be experienced in workplace environments, and so we set out to test that.

Moving from the laboratory to the workplace meant that Schmader and her colleagues needed a new way to identify when female scientists experienced stereotype threat in the workplace and how to measure changes in performance. The researchers hypothesized that stereotype threat could come into play for female science and engineering faculty when they talked about their research with male colleagues. Schmader told AAUW why they tested stereotype threat within conversations:

> Science faculty members don't take standardized tests on a regular basis. So where do we feel like our ideas are tested? They're obviously tested in reviews of articles submitted to journals, but they can also be tested in conversational contexts, and that's what led us to look at conversations themselves as potential triggers of stereotype threat.

To capture whether conversations could trigger stereotype threat, 37 faculty members from STEM departments at a large public university carried portable recording devices for four days. The devices recorded 50 seconds of conversation every 9 minutes from 6 a.m. to 11 p.m. The research team transcribed the resulting conversations that took place between colleagues during the work day, coding the gender of the speakers and whether the conversation concerned research or social matters. Two researchers also independently rated each conversational snippet for the speaker's level of competence, likeability, and contribution to the conversation. Researchers combined conversation data with a questionnaire on job engagement (Holleran et al., 2011).

RESEARCH CONVERSATIONS AND STEREOTYPE THREAT
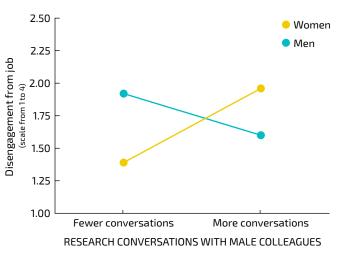
Schmader and her colleagues found that the more women discussed research with male colleagues, the less engaged they reported feeling with their work.

Men, on the other hand, showed the expected relationship of being more engaged with their work when they had more conversations about research with their male colleagues (see figure 18).[2] In addition, researchers coded the female scientists, on average, as sounding less competent than their male peers during research conversations with other male colleagues. The researchers found no gender differences in perceived competence during any other situations.

The relationship between social conversations and engagement also differed by gender. In contrast to research conversations, social conversations with male colleagues were related to more engagement for female scientists (see figure 19). Social conversations between two male colleagues or two female colleagues, on the other hand, were related to less engagement, which is what one might expect since more time socializing at work means less time working.

While researchers cannot draw definitive conclusions from their correlational data, Schmader and her colleagues hypothesize that research conversations with men may cue stereotype threat for female scientists. Social conversations with male colleagues, on the other hand, do not appear to activate a negative stereotype of women in STEM and may actually lessen the threat women feel in male-dominated environments by increasing a feeling of belonging (Holleran et al., 2011). Far from the last word on the subject, these findings point to additional questions about how stereotype threat operates and affects women in typically male work settings.

Other research supports the potential for stereotype threat and negative work outcomes when women compare themselves to men in the workplace. Courtney von Hippel, a senior lecturer in psychology at the University of Queensland in Australia, and her colleagues conducted studies of stereotype threat in the workplace that found that women who compared themselves to men in the same organization experienced stereotype threat (von Hippel, Issa et al., 2011). Experiences of stereotype threat, in turn, were associated with a separation of a "female" identity and a "work" identity (von Hippel, Walsh et al., 2011), decreased

FIGURE 18. RESEARCH CONVERSATIONS WITH MALE COLLEAGUES AND LEVEL OF JOB DISENGAGEMENT, BY GENDER
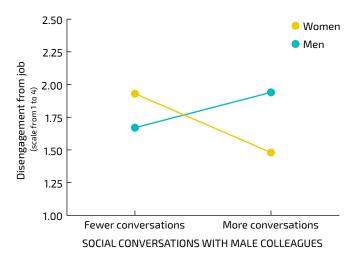
Notes: On average, study participants' conversations with their male colleagues were about research 47 percent of the time. The "fewer" value represents 19 percent, in other words, study participants who talked about research 19 percent of the time when they spoke with their male colleagues. The "more" value represents 77 percent, in other words, women and men who talked about research 77 percent of the time they conversed with their male colleagues. Nineteen percent is one standard deviation lower than the average value, and 77 percent is one standard deviation higher than the average value (AAUW communication with Toni Schmader).
Source: Holleran et al. (2011).

FIGURE 19. SOCIAL CONVERSATIONS WITH MALE COLLEAGUES AND LEVEL OF JOB DISENGAGEMENT, BY GENDER

Notes: On average, study participants' conversations with their male colleagues were about social topics 23 percent of the time. The "fewer" value represents 5.5 percent, in other words, study participants who talked about social topics 5.5 percent of the time when they spoke with their male colleagues. The "more" value of social conversations with male colleagues represents 40.5 percent, in other words, study participants who talked about social topics 40.5 percent of the time when they conversed with their male colleagues. Five and one-half percent is one standard deviation lower than the average value, and 40.5 percent is one standard deviation higher than the average value (AAUW communication with Toni Schmader).
Source: Holleran et al. (2011).

perceived likelihood of achieving career goals, reduced job satisfaction, and greater intentions to quit (von Hippel, Issa et al., 2011).

LIMITATIONS AND UPCOMING RESEARCH

Understanding the implications of stereotype threat in the workplace is important. Stereotype threat may be a key to why many women leave engineering and computing jobs, since disengagement is theorized to be a hallmark response to stereotype threat over time (Aronson et al., 2002; Steele, 1997). To gain a better understanding of how stereotype threat affects women in typically male work environments, Schmader and her colleagues are now exploring stereotype threat among professional engineers. This research will add to their earlier findings by specifically measuring professional engineers' concern about being evaluated based on their gender. Preliminary findings suggest

that conversations with male colleagues that cue feelings of inauthenticity or a lack of acceptance are associated with an increase in gender awareness, which in turn correlates with higher levels of mental exhaustion and lower job commitment (Hall et al., in press). Understanding more about how stereotype threat operates in the workplace is an important area for future investigation as researchers continue to explore the factors behind the underrepresentation of women in engineering and computing.

WHAT CAN WE DO?

Schmader's ongoing research is finding that gender-inclusive policies are associated with fewer experiences of stereotype threat as well as greater organizational commitment and life satisfaction among female professional engineers (Hall et al., in press). Examples of gender-inclusive policies

include efforts to reduce sexual harassment at work, policies that reduce work-family conflict, and use of gender-inclusive language. Employers should be careful about the language used in job postings because language can make a difference in who applies for positions. Job postings and descriptions should be gender neutral and use words that include feminine strengths and skill sets. Job advertisements, mission statements, and internal communications should explicitly convey that an organization values diversity and gender inclusiveness. Finally, increasing the number of women in the workplace at all levels of management can reduce the prevalence of stereotype threat. Research suggests that stereotypes are activated for women more frequently when men significantly outnumber women (Inzlicht & Ben-Zeev, 2000; Murphy et al., 2007).

CHAPTER 5 NOTES

1. Logel and her colleagues inferred that women experienced stereotype threat in this experiment because women reported suppressing concerns about gender stereotypes. Suppressing these concerns is an established mechanism of stereotype threat that can lead to lowered performance and other outcomes.
2. Schmader and her colleagues found no significant relationship between engagement and research conversations with female colleagues, although conclusions were tempered by the low number of conversations between female colleagues in the study.

CHAPTER 6.

MAKING THE WORLD A BETTER PLACE

Communal goals are highly valued generally by society. While we have good reason to suspect that bringing in the communal aspect of engineering and computing might be especially effective at attracting and retaining girls and women, we have also never shown that it dissuades men or boys. To me that speaks to the potential power of this approach as a lever to bring more people into these fields.
—Amanda Diekman

Some researchers argue that the underrepresentation of women in engineering and computing may be explained in part by the perception that these fields lack an emphasis on communal goals. In other words, because engineering and computing occupations seem less likely than other professional fields to involve collaboration or a direct benefit to others, they may be less appealing to many women—and to many men as well.

Two studies led by Miami University psychology professor Amanda Diekman and her colleagues Elizabeth Brown, Amanda Johnston, Emily Clark, and Mia Steinberg addressed the potential impact of gender differences in "communal" and "agentic" values on the representation of women in STEM fields such as engineering and computing. Psychologists use these two terms to describe contrasting fundamental orientations of human experience: Communal motivations describe an orientation to others and are associated with maintenance of positive relationships; agentic motivations are associated with self-advancement in social hierarchies, making one's own free choices, and acting independently (Trapnell & Paulhus, 2012). This chapter considers the degree to which these concepts help us understand women's underrepresentation in engineering and computing.

The motivation to help others is widely valued. In much of the world, including the United States, the majority of people—both women and men—endorse communal values, such as working for the well-being of others, caring for the disadvantaged, and responding to the needs of others as their most important guiding principles (Schwartz & Bardi, 2001, as summarized in Grant, 2013). Individuals whose jobs allow them closer contact with the beneficiaries of their work report greater motivation and exhibit greater persistence in their jobs (Grant, 2007; Grant et al., 2007), and people generally tend to positively evaluate those who are described as communally oriented (Diekman, 2007; Prentice & Carranza, 2002).

WOMEN AND COMMUNAL VALUES

The idea that women are more motivated than men to pursue work that helps people is a stereotype. The purpose of highlighting this research is not to perpetuate the stereotype but to explore the possible ramifications of this small gender difference for women's representation in engineering and computing. Of course, not all women are motivated to the same extent by the same goals (Quesenberry & Trauth, 2012), and certainly many men prioritize communal values more highly than many women do. Nonetheless, on average, women are more likely than men to say that they prefer work with a clear social purpose (Eccles, 2007; Lubinski & Benbow, 2006; Pöhlmann, 2001; Konrad et al., 2000; Margolis, Fisher, & Miller, 2002). Even girls and young women are more likely than boys and young men to say that they want "helping others" to be an important aspect of their future jobs (Jones et al., 2000; Weisgram, Bigler et al., 2010).

WORKING WITH AND HELPING PEOPLE

Diekman and her colleagues included two motivations within their definition of communal goal orientation: collaboration and helping (Diekman, Weisgram et al., 2015; Diekman & Steinberg, 2013). Although these concepts are separate and distinct, much of the evidence so far suggests that individuals' endorsements of these components of communal goals tend to align with each other (Diekman, Weisgram et al., 2015). Diekman and her colleagues are beginning to conduct research that teases apart these two motivations to gain a more fine-grained understanding of the influence of each element on various outcomes, but the latest research on this topic combines the two motivations (Diekman & Steinberg, 2013).

HOW TRADITIONAL GENDER ROLES AFFECT VALUES

Values are not altogether freely chosen. Social forces may teach girls and women to value helping others. Research shows that women are expected to be nurturing and other-oriented and, unlike men, are penalized when they don't behave in altruistic ways (Chen, J. J., 2008; Heilman & Chen, 2005; Heilman, 2001; Heilman & Okimoto, 2007; Rudman & Glick, 2001; Rudman, Moss-Racusin et al., 2012). For men, who have traditionally occupied provider and leadership roles, self-oriented behavior, such as earning money and gaining power, are especially valued (Eagly & Wood, 2012; Eagly, 1987).
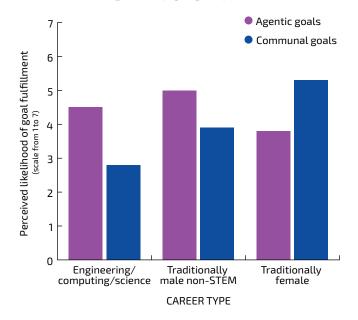
WOMEN'S AND MEN'S PRIORITIES

As women have advanced in educational achievements and labor force participation, they have become more similar to men in their motivation for self-advancement. By some measures, women are even more achievement-oriented than men are today. For example, in a recent survey of young adults ages 18 to 34, women were more likely than men to say that being successful in a high-paying career or profession is very important or one of the most important things in their lives, representing a gender reversal compared with responses to a similar survey conducted in the late 1990s (Patten & Parker, 2012). This example demonstrates the effect that cultural factors have on individuals' goals, since any biological factors related to motivation for self-advancement could not have changed much in the overall population in the past two decades. While women and men have converged in how much they value self-advancement, during the same period, gender differences in the value placed on working with and helping others have remained relatively stable and moderate in size (Eagly & Diekman, 2003; Twenge, 1997).

PERCEPTIONS OF ENGINEERING AND COMPUTING

Engineering and computing occupations are generally perceived as unengaged with societal and community concerns and involving little contact with

FIGURE 20. PERCEIVED COMMUNAL AND AGENTIC GOAL FULFILLMENT, BY TYPE OF CAREER
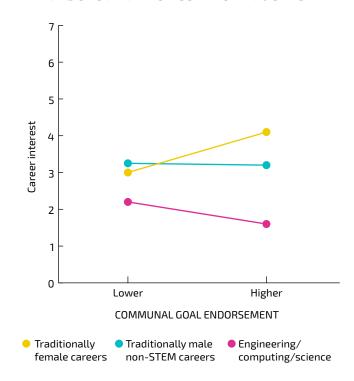
Source: Diekman, Brown et al. (2010).

other people (National Academy of Engineering, 2008). In two studies Diekman and her colleagues looked at how perceptions of these fields might affect women and men differently. In the first study the researchers asked 360 undergraduate students to rate a combination of STEM, non-STEM traditionally male careers, and traditionally female careers[1] by how much they would allow individuals to fulfill communal and agentic goals. Students were asked to estimate how well a career fulfilled agentic goals as well as how well it fulfilled communal goals.[2] The findings were clear: Participants rated engineering, computing, and science careers as less likely to fulfill communal goals than traditionally female careers or traditionally male non-STEM careers (see figure 20).

CAREER INTERESTS

Participants then rated the goals according to how important each goal was to them personally on a scale ranging from 1 (not at all important) to 7 (extremely important) and rated their career

FIGURE 21. CAREER INTEREST AS A FUNCTION OF ENDORSEMENT OF COMMUNAL GOALS

● Traditionally female careers ● Traditionally male non-STEM careers ● Engineering/computing/science

Note: Scale from 1 (not at all) to 7 (extremely interested).
Source: Diekman, Brown et al. (2010).

interest in each of a number of STEM, traditionally male non-STEM, and traditionally female careers. Diekman and her colleagues found that the more individuals endorsed communal goals, the more interest they expressed in traditionally female careers and the less interest they expressed in engineering and computing careers. The trend shown in figure 21 is consistent with previous research indicating that individuals who pursue engineering and science careers on average place an unusually low value on having a job that directly benefits other people or society (Eccles, 2007).

PAST ACHIEVEMENT AND CONFIDENCE

In the next part of the study, Diekman and her colleagues assessed the participants' belief in their ability to succeed (self-efficacy) in engineering and computing careers and estimated participants' experience in STEM subjects, using enrollment in STEM classes. The researchers found that even

among students with strong past STEM achievement and belief in their mechanical, computational, and scientific abilities, those who were more motivated to work with and help people were less likely to express interest in engineering and computing fields. Communal goal endorsement predicted a lack of interest in engineering and computing. Finally, like other studies, this study (Diekman, Brown et al., 2010) found that women, on average, placed greater importance than men did on working with and helping people, and a follow-up study (Diekman, Clark et al., 2011) confirmed this finding (see figure 22).[3]

WHY RELATIVE ASSESSMENT MATTERS

Researchers theorize that an individual's relative, rather than absolute, assessment of her or his abilities and values is the critical factor in selecting a career path (Eccles, 2011b; Evans & Diekman, 2009). Both women and men value communal goals, but unlike men, women, on average, rank these goals higher than self-advancement goals. Even though the gender differences in both the desire for self-advancement and the desire to help others are small to moderate, they matter when it comes to career choices. If individuals tend to choose the career that best suits their abilities and best matches their values, it follows that women, on average, would be more likely to enter into what are perceived as helping professions and less likely to pursue engineering and computing careers.

Diekman is quick to point out that gender differences in motivation to work with people and to help people do not fully explain women's underrepresentation in engineering and computing fields. When she and her colleagues controlled

FIGURE 22. AVERAGE GOAL ENDORSEMENT, BY GENDER

	Women	Men
Communal goals	5.6	5.0
Agentic goals	5.1	5.3

Note: Scale from 1 (not at all important) to 7 (very important).
Source: Diekman, Clark et al. (2011).

for communal goal orientation, the gender difference in interest in a STEM career narrowed, but it did not disappear. In an interview with AAUW, Diekman said, "One of my fears is that this research will be interpreted as suggesting that gender differences in communal goals are the only thing that matters." Without diminishing the importance of other factors such as workplace culture, gender bias, and stereotypes, Diekman's research suggests that understanding individuals' motivation to work with and help people is an important part of the puzzle of why women are less likely than men to pursue careers in engineering and computing.

THE IMAGE OF ENGINEERING AND COMPUTING

If the opportunities for achieving communal goals in engineering and computing careers were better communicated to the public, might more girls and women aspire to these careers? Some indicators suggest that this might be true. For example, certain engineering disciplines with a clearer social purpose, such as biomedical engineering and environmental engineering, have had more success attracting a higher percentage of women than have other disciplines, such as mechanical or electrical engineering (Yoder, 2013).

Diekman, Clark, and their colleagues (2011) conducted a second study to test this hypothesis more broadly. In this study 241 students from an introductory psychology course were asked to read about a day in the life of an entry-level scientist. Participants were randomly assigned to read about either a scientist whose tasks involved working with and helping others or a scientist who completed the same tasks without working with and helping others. Some gender differences emerged in participants' responses. Women who read about the scientist who worked with and helped others were more likely than other women to express a positive attitude toward a science career. In contrast, among men no significant difference in positivity toward a science career was found whether it was framed as a collaborative or an independent career.

Thus, framing a science career as involving more collaboration and helping others resulted in women being more positive about that career without turning men away. Other research has found that, overall, students are more positive toward a science career when they perceive it to be a career through which they can help people (Weisgram & Diekman, 2014; Weisgram & Bigler, 2006).

THE REALITY OF ENGINEERING AND COMPUTING CAREERS

Diekman's second study suggests that showcasing communal aspects of engineering and computing can change public perceptions. Engineering and computing professionals have helped people and society in myriad ways, including improving sanitation, fighting diseases, helping people with disabilities, developing modes of transportation and infrastructure, connecting people around the world, tracking the spread of diseases, and developing sustainable forms of energy. In addition, many engineers and computing professionals work in teams.

Yet, it is still important to consider whether most engineering and computing jobs involve working with and helping people. What if the stereotype that these are solitary jobs that don't provide opportunities for making a social contribution is mostly accurate? If that's true, then recruiting communally oriented women and men into engineering and computing through marketing campaigns touting the collaborative, helpful aspects of these fields will result in an exodus from the field later. The reality, of course, is more important than public perception.

Some evidence suggests that engineering careers, in particular, fall short in providing opportunities for fulfilling communal goals. One study of working engineers found that women who expressed an interest in social dimensions of work were more likely than others to want to leave their engineering jobs (Fouad et al., 2012). Fletcher (1999) found that female engineers frequently helped others, mentored others, and went the extra mile in the interest of getting the job done, but this work was frequently not recognized by others in the

engineering firm as "real" work. Rather, other-oriented behaviors were viewed as outside the scope of engineering work and misinterpreted as natural expressions of femininity. Most difficult for the female engineers, communal behaviors were both expected of female engineers and devalued by the engineering culture.

Ironically, Diekman's research suggests that other-oriented activities (which are often viewed as separate from and less valuable than the real work of engineering or computing) may be crucial for creating and maintaining long-term engagement in engineering or computing work, especially for individuals who are strongly motivated by communal goals (Diekman, Weisgram et al., 2015).

WHAT CAN WE DO?

Working with people and helping others are valued goals for most people (Schwartz & Bardi, 2001), especially women (Diekman, Clark et al., 2011). The more that engineering and computing educators and employers can incorporate communal goals into their environment, the more open the doors of these fields will be to people, many of whom are women, who strongly value working with and helping others.

Employers, engineering and computing professionals, STEM teachers, parents, and anyone seeking to motivate young people to consider engineering and computing careers can take some relatively simple steps to put this research into practice. Talk about the ways that engineers and computing professionals solve problems for society. Showcase how professionals' everyday work aligns with the societally beneficial outcomes that are the ultimate goals of engineering and technology. Individual engineers and computing professionals can work through professional associations to mentor students and new co-workers. Employers can encourage and value efforts and activities that fulfill communal goals while at the same time providing value for their organization. One possibility is to formally recognize the necessary nontechnical work (such as working well with others and mentoring) as much as the necessary technical work in producing a product. Another possibility is to put in place paid social service days where employees volunteer in their community.

CHAPTER 6 NOTES

1. STEM careers rated by participants included mechanical engineer, aerospace engineer, computer scientist, and environmental scientist. Traditionally male non-STEM careers included lawyer, physician, architect, and dentist. Traditionally female careers included preschool or kindergarten teacher, registered nurse, social worker, human resources manager, and education administrator.

2. Some of the agentic goals that Diekman and her colleagues included were power, recognition, achievement, individualism, success, demonstrating skill or competence, and competition with others. Some of the communal goals they included were helping others, serving humanitarian needs, serving the community, working with people, and connecting with others.

3. In Diekman's 2010 and 2011 studies, women endorsed communal goals more strongly than agentic goals and more strongly than men did. Unlike the 2011 study, however, the 2010 study found no statistically significant difference between men's endorsement of communal goals and men's endorsement of agentic goals: Men rated them equally important.

CHAPTER 7.

COLLEGE ENVIRONMENT AND CURRICULUM

People often say it's about the students at Harvey Mudd. I don't think it's just about the students. I think it's about the unified efforts of the faculty and the president. If a school wants to graduate more women with computer science degrees, it can't necessarily make its whole student body look like Harvey Mudd students, but it certainly can make its faculty work together.
—Christine Alvarado

Because many technical jobs require an engineering or computer science degree, it is important to understand the effect of the engineering and computing college environment on women's underrepresentation in those jobs. Many beginning college students have little or no engineering or computing experience, and the students who do have experience overwhelmingly tend to be men. Yet a number of colleges and universities have succeeded in graduating higher than typical percentages of women from their engineering and computing programs.

Harvey Mudd College (HMC), a science- and engineering-focused liberal arts college with just under 800 students in Claremont, California, is widely recognized for dramatically increasing the percentage (and number) of women majoring in its computer science program from a historical average of 12 percent to approximately 40 percent over the past five years (Alvarado & Judson, 2014) (see figure 23). This percentage is well above the national average of 18 percent.

Historically HMC, like almost all colleges and universities, had little success attracting women to computer science. In fact, until recently women at HMC were less well represented in computer science than in any other field of study (Alvarado & Dodds, 2010); administrators and HMC professors decided to focus on increasing the representation of women in the computer science program in 2006. Christine Alvarado, then a computer science professor at HMC (now a faculty member in computer science at the University of California, San Diego), and her colleagues Ran Libeskind-Hadas, Zach Dodds, and Geoff Kuenning based their efforts on a perception that, for the most part, students without prior computer science experience do not really understand what computer science is.

Alvarado and her colleagues believed that this lack of understanding was an important reason few women expressed interest in computer science. The professors hypothesized that just by making clear to students what computer science is, they could increase the number of female computer science majors and dramatically improve the computer science experience for all their students. To achieve this goal, HMC implemented three major changes focused on first-year students, well in advance of

when most students declare a major at the school (Alvarado, Dodds et al., 2012):

1. HMC revised the introductory computer science course that presents the breadth of the computer science field in addition to the basics of programming.
2. HMC provided research opportunities for women immediately after their first year of college to expose them to real computer science problems as early as possible.
3. HMC gave first-year students opportunities to attend the annual Grace Hopper Celebration of Women in Computing conference hosted by the Anita Borg Institute for Women and Technology.
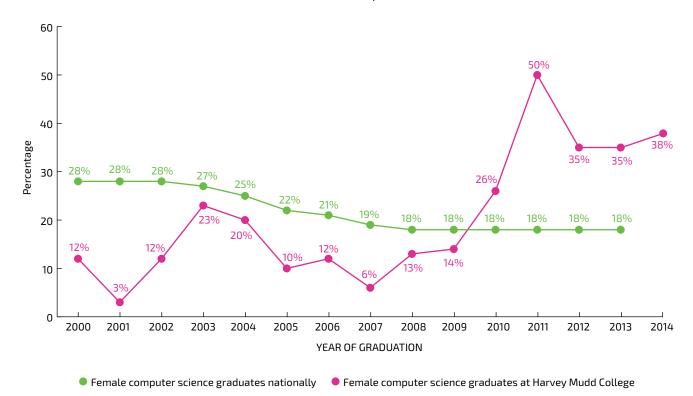
COMPUTER SCIENCE FOR EVERYONE

All first-year students at HMC are required to take and pass an introductory computer science class. Until 2005, everyone took the same Java-based course, in which students were allowed to work ahead to accommodate different levels of experience. Professors identified several problems during the course's 10-year run. The class was too easy for some and too difficult for others (Alvarado, Dodds et al., 2012). Additionally, students "were coming out kind of feeling the same way they did when they came in," said Alvarado in an interview with AAUW. She and her colleagues worried that the students weren't developing an understanding of what computer science was—or how "cool" it was. The students "weren't seeing what we're seeing about this field," she said. The professors determined that students were missing the true nature of computer science and its major contributions to other fields and society.

These problems disproportionately affected women because women, on average, come to HMC with less computer science experience than men do (Alvarado & Judson, 2014). For this reason, women were apt to find the introductory computer science class more difficult than their male colleagues did and were less likely to have a positive view of computer science heading into the course. In addition, as described in chapter 6, women generally are

FIGURE 23. FEMALE COMPUTER SCIENCE GRADUATES NATIONALLY AND AT HARVEY MUDD COLLEGE, BY GRADUATION YEAR, 2000–2014

● Female computer science graduates nationally ● Female computer science graduates at Harvey Mudd College

more likely than men to express a preference for work with a clear social purpose (Diekman, Clark et al., 2011; Lubinski & Benbow, 2006; Eccles, 2007). Alvarado and her colleagues hypothesized that by highlighting the broad applications and social relevance of computer science they could improve the experience for all students and raise the number of women in the major.

In 2006 HMC replaced its introductory computer science course with a course nicknamed "CS for Scientists and Engineers," which emphasizes the breadth of the field first and uses Python, a more flexible and forgiving programming language, rather than Java (Alvarado, Dodds et al., 2012). HMC professors hoped to boost students' enjoyment and increase the number of students who chose to continue in computer science by emphasizing its diverse practical applications. In addition,

the professors hoped to create an enriching environment for students of all experience levels while still cultivating the programming and computational thinking skills required for success in future computer science courses (Dodds et al., 2008).

EMPHASIZING PRACTICAL APPLICATIONS AND BUILDING CONFIDENCE

The revised introductory class covers the necessary introductory programming skills while emphasizing practical computer science applications as demonstrations of the importance of computer science to other fields and to society. Alvarado told AAUW that an overemphasis on programming in an introductory computer science course can obscure the true nature of computer science:

What we try to emphasize at Harvey Mudd is that computer science is not primarily about programming. You are not learning to program for the sake of programming. You are learning to solve problems using programming as a tool … so you have to learn how to use the tool effectively. We try to emphasize the actual end goal and the higher level concepts and then tie them back in and say, "Here's how you use programming to do that."

From the beginning of the course, students are exposed to the different ways in which computer scientists think about solving problems. Students are immediately assigned interesting programs to write. The first assignment uses a language called Picobot that controls a robot in a web simulation. Picobot is so easy to pick up that all students can write their own solutions to actual problems after the first class. At the same time it is a challenge for everyone because none of the students have worked with the language before (Alvarado, Dodds et al., 2012). Using a language that is new for everyone also helps lessen the students' perception that some students already know everything about computer programming while others know nothing. This perception can be a demotivating factor for some students, especially women, in computing (Margolis & Fisher, 2002).

Alvarado emphasized that the new course aimed to encourage those with less experience. She told AAUW, "I think a huge part of what discourages people with no experience from pursuing computer science in college is that they get into these classes, and they feel behind from the very second they sit in their seat." She would like to see a shift away from the attitude that only those who can be immediately identified as good programmers should be encouraged to go on in computer science. Instead, she says, "If you give students the right introduction, the time that they need to blossom, and the environment where they feel comfortable, they're definitely capable of doing the work, and they're interested in doing it."

To achieve this environment HMC developed two tracks for its revised introductory course. Students without computer science experience are placed in the standard section (the Gold section) and those with prior computer science background are placed in the enrichment section (the Black section). The two sections cover the same material at the same time, but the Black section explores more challenging applications of the same fundamental concepts (Alvarado, Dodds et al., 2012):

Topic and application distinctions are carefully chosen so that the additional material is enriching and motivating but that students in Gold are at neither a real nor a perceived disadvantage in CS2 [the computer science course that follows the introductory course] and subsequent classes. The goal of the Black/Gold split is to give the inexperienced students a comfortable and safe environment in which to develop a passion for CS without interactions that might suggest— incorrectly—that they are too "far behind" other students to succeed in the field. In fact, the Black/Gold split has a less touted, but equally important, benefit: In the Black section we help debunk some of the misconceptions that *experienced* students bring to CS, for example, that mastery of syntactic constructs is central to the field—or that CS is merely programming.

"I have taught the Gold section for a couple of years," Alvarado told AAUW, "and the first day of class I have asked students to raise their hands if they are nervous about the class. Probably about 80 percent of the students raise their hands. Just looking around and realizing they are surrounded by a bunch of people who don't know what they are doing either seems to make students feel better." She continued:

It is fun to teach the students who have grown up knowing that they want to do computer science—that's great—but it is even more exciting to teach the type of students who have never really seen themselves as computer scientists and never really thought they could do it or have no experience with it and discover it. That's how I got interested in women in computing—because there tend to be a lot more women in [the latter] category.

HMC faculty carefully structured the revised course to cover all the material required in an introductory computer science course in six fairly independent modules, each representing a different way computer scientists think about problems. This format allows students who might feel overwhelmed by a given topic to set aside the struggles of that module before long and engage in a different set of challenges as the course develops. At the end of the semester, professors build on the practical knowledge students have gained with a team project that incorporates programming skills and encourages creativity (Alvarado, Dodds et al., 2012).

To assist the learning process, HMC introduced optional weekly labs, staffed by faculty, for the introductory course. As an incentive to participate, students who attend the weekly two-hour lab receive full credit for one of the three or four weekly homework problems, regardless of whether they finish the problem or not. Inexperienced students benefit from a lightened workload, and more contact with faculty encourages students to get help early with difficult concepts (Alvarado & Dodds, 2010).

RESULTS OF THE REDESIGN

The results have been overwhelmingly positive. In 2007, one year after the revised course was initially offered, Alvarado and her colleagues compared the later performance of students who had taken the original introductory computer science course with those who had taken the revised course. At that time, some of the students taking CS2 had taken the revised course in 2006, and others had taken the original introductory course. Although CS2 involves significant Java programming, which was taught in the original introductory course but not in the revised course, and does not use Python, the programming language used in the new introductory course, midterm exam scores for students who had taken the revised course averaged 84 percent compared with 80 percent for students who had taken the original course. Likewise, students who had taken the revised course averaged 85 percent on the CS2 final exam compared with an average of 80 percent for students who had taken the original course (Dodds et al., 2008). Equally important, a survey found that 75 percent of students who took the revised course felt that it changed their perception of computer science, whereas only 47 percent of students who took the original course felt that way (Alvarado & Dodds, 2010).

PROMOTING EARLY RESEARCH EXPERIENCES

The second major change that Harvey Mudd College introduced was the opportunity for women to participate in computer science research within a year of starting college. The goal of this change was to instill in young women the confidence that they can do real-world computer science. While physical sciences often provide first- or second-year students with the opportunity to participate in lab research in a supporting role, until 2006 computer science research opportunities at HMC were mostly available to students who had completed several computer science courses. Beginning in 2006, HMC began to offer research experiences to women the summer after their first year of college, before most had declared a major. Despite having completed only one or two introductory computer science courses, these students make concrete progress on real research problems each year (Alvarado & Dodds, 2010).

Accumulating evidence suggests that research experiences have a notable effect on encouraging women to pursue computer science. Among the women who participated in computer science research between 2007 and 2011, 66 percent chose to major in computer science, compared with less than 20 percent of HMC students overall (Alvarado, Dodds et al., 2012). Evidence shows that these research experiences have a bigger influence on women than on men. Looking only at students who participated in summer computer science research after their first year, the survey found that 67 percent of female students compared with 25 percent of male students listed research experience as an influence in choosing a computer science major (Alvarado & Dodds, 2010). While the numbers of students participating in these research opportunities are still fairly small, the results suggest that the opportunity to conduct computer

science research early in women's college careers can provide important encouragement for them to pursue computer science.

THE GRACE HOPPER CELEBRATION OF WOMEN IN COMPUTING

The third major change that Harvey Mudd instituted was providing first-year students with the opportunity to attend—for free—the Grace Hopper Celebration of Women in Computing (GHC), a conference held each fall since 1994. Named after Rear Admiral Grace Hopper, an early computing pioneer who created the first compiler in 1952, GHC has grown into a gathering of thousands that provides support and community for women in the field of computing and includes many students. Results from the *2013 Evaluation and Impact Report* (Anita Borg Institute, 2014b) indicate that students feel less isolated, more committed to computing, and more inspired after attending the conference. In 2013, 85 percent of the students who responded to the survey agreed that attending GHC increased their commitment to a technology career.

HMC began taking first-year female students to GHC in 2006. A primary objective is to recruit and retain first-year women into computing by combating some of the factors that have been shown to prevent women from pursuing computing careers, including a lack of confidence, a perception of the culture as geeky or hostile, a misunderstanding of the field, and a lack of mentors and support networks. At GHC, students see a computing culture that is different from the stereotypical culture they might expect. They are exposed to real-world computing applications, interact with computing professionals, learn first-hand about exciting computing-related companies, and increase their network of friends and colleagues. Twelve students from HMC attended the conference in 2006, and the number has grown every year to 52 students in 2014. The computer science department recruits students by e-mail during the summer before their freshman year and takes students regardless of

whether they have expressed an interest in computer science.

Results indicate that attending GHC at a critical juncture in a student's decision process (three to 18 months before declaring a major) can dramatically affect a student's major and likely career path (Alvarado & Judson, 2014). Starting in 2007 and more formally in 2009, HMC has conducted an annual survey of conference attendees to try to understand the effect the trip has on students. Survey results from 2009 and 2010 indicate that the conference is effective in addressing the barriers that keep women from choosing to study computer science. Eighty-eight percent of students responded that attending GHC gave them a better understanding of computer science, 85 percent said GHC changed their perception of the computer science culture, 72 percent indicated that GHC increased their desire to take another computer science class, and 62 percent said that GHC increased their desire to major in computer science.

The conference has an effect on students with some computer science background as well as those without. Nearly four out of five students (78 percent) who were already considering majoring in computer science agreed that attending GHC increased their desire to major in computer science. Among GHC attendees who were not considering majoring in computer science before the conference, a majority (64 percent) indicated that attending the conference increased their desire to take another computer science course, and 43 percent said that attending GHC increased their desire to major in computer science (Alvarado & Judson, 2014).

By examining enrollment patterns, Alvarado and her colleagues found that students who attended GHC were indeed much more likely to take another computer science course (52 percent) and major in computer science (37 percent) than were female students who did not attend (31 percent and 10 percent, respectively). Certainly some of this effect is due to self-selection, since those more interested in computer science probably more often applied to go to the conference. Yet looking only at those who came to HMC with no intention to major in computer science, 25 percent of those

FIGURE 24. FACTORS CONTRIBUTING TO HARVEY MUDD COLLEGE STUDENTS' CHOICE TO MAJOR IN COMPUTER SCIENCE, BY GENDER

Taking the revised introductory computer science course	Women	85%
	Men	81%
Participating in early research opportunities	Women	67%
	Men	25%
Attending the Grace Hopper Celebration	Women	47%

Note: Percentages indicate survey respondents who participated in the practice who reported that it contributed to their choice of a computer science major.
Source: Alvarado, Dodds et al. (2012).

who attended GHC went on to major in computer science whereas only 10 percent of those who did not attend GHC went on to major in computer science. This point bears repeating: One of four women who came to Harvey Mudd not considering a computer science major and who attended GHC ended up majoring in computer science.

An HMC survey found that all three changes the school instituted to increase the number of women computer science majors did in fact do so, particularly the revisions made to the introductory course (see figure 24).

BEYOND HARVEY MUDD

Harvey Mudd's success story is important and encouraging for other colleges and universities struggling to diversify their computer science departments, but how transferable are the changes? Some school administrators might believe that this success was possible only because of HMC's small size and science and engineering focus. Scalability and logistics are major concerns for larger and more diverse colleges and universities looking to make similar changes.

Now at the University of California, San Diego, Alvarado has first-hand experience attempting to institute similar changes at a larger, more diverse institution. She identified the much higher student-to-faculty ratio at UCSD as one of the big challenges: "It's more difficult to track students, it's more difficult to schedule students, it's more

difficult to get messaging out to students, it's more difficult to coordinate across these huge sections and across multiple offerings of the same course—the logistics are difficult." Nevertheless, a small but growing body of evidence suggests that the changes are transferable with some modifications to fit specific departments.

INSTITUTIONAL COMMITMENT

To begin with, Alvarado emphasizes the need for an institution-wide commitment to addressing women's underrepresentation:

The most important thing we had going for us at Harvey Mudd was that we had wide support throughout the department and throughout the college. We had our president, Maria Klawe, pushing for this, and she was essential in making this work. She got in and started talking it up to people, and she found us money and personal connections. She provided support at a very high level and made people pay attention. I think we can talk about the individual things we did at Harvey Mudd, and those are important, but until [increasing the representation of women in computing] is made a priority at a school in a very broad way, these initiatives may not be successful.

EXPANDING ON THE HMC MODEL

Harvey Mudd's documented progress has recently prompted several companies, including Facebook, Intel, Google, and Microsoft, to give more than $1 million to 15 colleges and universities to institute similar changes. As part of the Building Recruiting and Inclusion for Diversity initiative led by the Anita Borg Institute for Women and Technology and HMC, researchers will gather data on participating institutions' progress in increasing women's representation in computing to better understand what kinds of changes work in which contexts (Anita Borg Institute, 2014a).

REVISING THE INTRODUCTORY COMPUTER SCIENCE COURSE

Variations of Harvey Mudd's revised introductory computer science course have now been taught at a number of other colleges and universities, yielding insights into how well it can be adapted to other environments. Bucknell University adopted the Gold approach in fall 2011, with high levels of satisfaction reported among faculty and students despite an increased workload and many students reporting that the course influenced their decision to major in computer science (Alvarado, Dodds et al., 2012). At the University of California, Riverside, the introductory course was not divided into sections according to the background of the students. Professors found that this negatively affected the experience for some students. From this result Alvarado and her colleagues determined that maintaining the separation of students with different backgrounds in computer science is an integral part of the success of Harvey Mudd's approach, perhaps particularly at large, diverse institutions.

If a full redesign is impossible, Alvarado and her colleagues suggest that small changes to existing courses can make a big difference. For example, teaching computer science in a contextualized way that gives students an opportunity to see its applications is increasingly common at colleges and universities across the country. Alvarado points to Georgia Tech, where professors developed a course to teach computer science concepts by manipulating digital media, such as pictures and sounds, as a good example of a contextualized computing curriculum with more standard introductory content. While science-heavy applications that work at HMC may not work everywhere, almost all disciplines include computation in some form. Computer science professors can construct meaningful and relevant assignments from any number of fields (Alvarado, Dodds et al., 2012).

EARLY RESEARCH EXPERIENCES

Research opportunities are the part of the program that Alvarado is finding the easiest to transfer to UCSD: "We have a very active set of research projects here at UCSD, and it's relatively easy just to plug into the research that is going on already." Guiding undergraduate research projects for students with little computer science experience may seem daunting for faculty. Yet Alvarado and her colleagues suggest that with the right structures in place, it is quite doable. At Harvey Mudd, incorporating several elements has led to significant satisfaction among both students and faculty (Alvarado, Dodds et al., 2012):

- Open-ended projects with sufficient scaffolding. Each project should include a well-defined sequence of tasks to accomplish, along with a substantial creative component.
- Teamwork. Students benefit from working together. Faculty advisers must ensure that mentor-partner relationships are natural and complementary and that teams work well together.
- Lots of communication. Daily communication—ideally twice a day—with faculty advisers is critical. Insist that participants maintain a careful daily log of their activities and questions to make meetings with faculty more efficient.

ATTENDING THE GRACE HOPPER CELEBRATION

How feasible is it for other schools to send their female computing students to Grace Hopper? According to Alvarado, the first question people often ask is about funding. HMC has been pleasantly surprised at its ability to raise internal and external funding to send all students who have applied to GHC because of a high interest from potential employers, alumni, and philanthropists. Demonstrated results should assist in further fundraising for HMC and other schools (Alvarado & Judson, 2014).

Even if colleges and universities can raise funds to send students to GHC, size limitations of GHC could also be an issue. While GHC continues to grow, it also sells out every year. One answer to this problem is more celebrations. Regional conferences, hosted by a partnership of the Anita Borg Institute for Women and Technology, the Association for Computing Machinery Women's Council, and the National Center for Women and Information

Technology, are springing up around the United States and around the world. Alvarado has focused on the regional Grace Hopper Celebrations for the students at UCSD because the conferences are easier (and less expensive) to reach and are often free for students. Alvarado said:

> Regional celebrations can be better because they are not as big and intimidating. Eight thousand people attended the most recent national Grace Hopper Celebration, and first-year students can feel kind of lost. Regional celebrations are much more intimate—around 200 people—and for the most part mainly students attend.

WHAT CAN WE DO?

Since 2006, when it first implemented the practices summarized above, Harvey Mudd College has seen a dramatic and lasting increase in the number and percentage of women who choose to major in computer science. Clearly the turning point in women's representation occurred with the class of 2010 (see figure 23), the first class that experienced the new practices (Alvarado, Dodds et al., 2012).

HMC hasn't solved all the problems, however. When students who had considered majoring in computer science but decided against it were asked to list important factors in their decision, 28 percent of women and 31 percent of men listed "I didn't feel like I fit in as a CS major/I didn't feel comfortable with the culture" as an important factor. In addition Alvarado and her colleagues found that more women (26 percent) than men (14 percent) chose a different major in part because they thought that computer science was too hard (Alvarado & Dodds, 2010).

Still, HMC's experiment is encouraging, not least because the school has also seen a significant increase in the number of men majoring in computer science in the past few years. From data HMC has collected, it appears that as many men as women enjoy and are motivated by the revised introductory course. When HMC asked the graduating classes from 2009 to 2012, "What is the SINGLE most important experience that led you to choose a CS major?" the revised course was the most cited experience for women (34 percent) and tied for the most cited experience for men (29 percent) with "experiences before college" (Alvarado, Dodds et al., 2012).

Recommendations that stem from Harvey Mudd's success include exposing a broad range of people to computing and moving away from the idea that certain people (often with strong programming skills) are cut out for computer science while others are not. High schools, middle schools, and elementary schools should offer courses in computer science. The more experiences students have with computer science before they get to college, the more opportunities will be open to them.

Colleges and universities should require all undergraduate students to take at least one computer science course, no matter what their major, and should engage students in hands-on research early in their college education. College and university computer science departments should highlight as early as possible the different facets that make up computer science and show the impact that computer science has on society.

Departments should split classes by experience, providing students with less experience in computer science with the time and environment they need to build their skills and interest. Even without changing an introductory computer science course, it may be possible to develop at very little cost multiple sections to accommodate students with different experience levels.

Computer science departments should take students to the Grace Hopper Celebration of Women in Computing or similar conferences to give them a sense of identity with people in the field and share their excitement for it. Taking even a few students can change their mindset and have an important effect on a school's program. Schools should take a mix of students interested in computing and those not considering computer science as a major.

CHAPTER 8.

PERSISTENCE AND SENSE OF FIT

Women, after a few weeks or months or years in engineering, might begin to see themselves as less capable professionals than men because they are interacting in a space that tends to be masculine and tends to devalue what are seen as feminine traits or feminine contributions to the field.
—*Erin Cech*

"Being an engineer" includes more than knowledge and skills in mathematics and science. Prospective engineers must be able to deal with ambiguous, messy problems, and they need to share a commitment to the values of the profession and be comfortable with its norms. Erin Cech, an assistant professor of sociology at Rice University, and her colleagues Brian Rubineau, Susan Silbey, and Carroll Seron noticed that not much research addressed "not only the confidence a person has in his/her ability to do things like take a math test or take a science test but also the confidence to imagine oneself going out and applying for a job in engineering and being an engineer." They coined the term "professional role confidence" to describe how comfortable professionals or prospective professionals are in their ability to fit into and fulfill all the aspects of their roles. Cech and her colleagues measured the influence of this sense of fit on the persistence of women and men in engineering programs in colleges and universities.

EXPERTISE AND CAREER-FIT CONFIDENCE AMONG UNDERGRADUATES

In engineering, a field in which the educational and professional environments are closely linked, professional role confidence starts to develop as women and men begin their engineering education. Undergraduate engineering students are engineers-in-training, adding direct experiences with the profession to their previous understanding of the field. As they train for their careers, engineering students consider whether they will be successful, happy professionals in their chosen field. Whether or not they see themselves as successful and fulfilled and whether they feel that engineering is a good fit for their skills and interests will affect whether they continue working toward a degree and whether they pursue an engineering career.

Cech and her colleagues (2011) further refined the concept of professional role confidence by dividing it into two discrete concepts: expertise confidence (the confidence that one possesses the requisite skills and knowledge to be a professional in a chosen field) and career-fit confidence (confidence that the field is consistent with one's interests, values, and identity). Expertise confidence answers the question, "Do I have the capabilities to be successful in this role?" Career-fit confidence answers the question, "Is this the right career for me long term?"

To understand gender differences in professional role confidence and the impact of professional role confidence on retention in engineering, Cech and her colleagues interviewed 288 engineering students in the second semester of their first year and again in their fourth year of college. The students studied at four universities: a land-grant college typical of the public institutions that educate 80 percent of U.S. engineers, a highly ranked private engineering school, and two small, innovative programs developed to challenge the engineering education offered at conventional engineering schools.

During their first semester, students at all four schools were required to take a course intended to introduce them to the engineering profession. As described by Cech (2014, p. 49), students quickly develop a sense of the culture and norms once they enter their training program:

> Through classes, internships, design projects, and friendships, students are transformed from laypersons into engineers; they are expected to adopt the profession's epistemologies, values, and norms; identify with particular symbols; and learn to project a confident, capable image of expertise.

Cech and her colleagues assessed first-year engineering students' expertise confidence by asking them to rate their confidence on the following three indicators as a result of their engineering courses:

- Developing useful skills
- Advancing to the next level in engineering
- Believing that I have the ability to be successful in my career

The researchers assessed career-fit confidence by asking students in their first year of engineering school to rate their confidence in the following four indicators as a result of their engineering courses:

MEASURING PROFESSIONAL ROLE CONFIDENCE EARLY

Assessing students' professional role confidence during their first year of engineering school may seem early. How confident can young people feel about their engineering expertise and about how well an engineering career is likely to fit them less than a year into their training? In an interview with AAUW, Cech explained why it makes sense to assess professional role confidence so soon:

> Students come in with a fairly vague understanding of what this occupational field is. They often get information about the field from websites or friends or relatives who are engineers. It's not until they start taking classes in the major and start meeting other members of their major that they start their professional socialization as engineers. And the socialization process is quite intense. The undergraduate experience is not only about learning how to do the homework assignments but learning what it means to be an engineer. So even though we take this measure in the spring semester of the freshman year, they've already encountered a rather intense socialization process where they're trying to figure out—talking with their classmates, talking with professors—what it means to be part of this profession and whether it is the right fit for them.

- Believing that engineering is the right profession for me
- Selecting the right field of engineering for me
- Finding a satisfying job
- Feeling a commitment to engineering

For their persistence measures, Cech and her colleagues assessed two kinds of persistence: behavioral persistence (students' actual completion of an engineering major between the first and fourth years) and intentional persistence (students' belief in the fourth year that they will be an engineer in five years).

STAYING WITH THE PROGRAM

Cech and her colleagues (2011) found that men expressed more behavioral and intentional persistence than women did. That is, men were more likely than women to persist from the first to the fourth year and actually earn an engineering degree, and in their senior year men were more likely than women to report that they intended to be an engineer in five years.

In addition, men expressed significantly more professional role confidence, both expertise confidence and career-fit confidence, than women did, even after controlling for students' actual performance. Consistent with the researchers' hypothesis, students with greater confidence in their expertise and career fit were more likely to persist in engineering. Most important, when women and men had the same expertise confidence and career-fit confidence, women were no less likely to persist than men—either in completing an engineering degree (behavioral persistence) or in intending to work as an engineer in the future (intentional persistence). In other words, women and men with similar views on whether engineering was a good fit for their skills, interests, and values were equally likely to continue in engineering in school and intend to continue in engineering in the workforce. The study also assessed the influence of family plans and self-assessment of mathematical ability but did not find evidence that either of these measures lowered women's persistence in engineering during engineering school.

Looking at the different measures of persistence, Cech and her colleagues found that expertise confidence predicted behavioral persistence and that career-fit confidence predicted intentional persistence. In other words, students who believed that their skills and expertise fit the engineering field were more likely to persist in the major and earn an engineering degree. On the other hand, students who felt that their interests and values fit the

culture of engineering were more likely to intend to be an engineer five years after graduation.

The finding that expertise confidence has little impact on plans for a future career in engineering while career-fit confidence is strongly and positively related to future career plans is particularly important. The degree to which students expect to fit in with the engineering culture and norms is a strong indication of their intention to pursue an engineering career, much more so than students' confidence in their engineering skills.

A GENDERED SENSE OF FIT

Naturally, engineering students expect that the skills taught in engineering courses will be the skills they will use in the field. But Cech argues that engineering degree programs largely ignore a variety of areas of expertise that are necessary to be successful as a professional engineer:

> The classes that students take are overwhelmingly math- and science-based, with perhaps one class on technical writing and one class on engineering ethics. But if you talk to engineers who are in the field, they will tell you they are required to have a whole fleet of other kinds of skills to be successful. They need to be good communicators, they need to be good managers, they need to be organized, and they need to understand the complexities of the relationship between the technical things they're working on and other social processes.

A narrow math and science emphasis disproportionately disadvantages women because it emphasizes male-stereotyped skills while devaluing skills that are gender neutral or female-stereotyped, such as writing, communication, and managerial skills. Cech recommends displaying the need for these other competencies by providing opportunities for undergraduates to do actual engineering and design work as soon as possible. Working on engineering problems in the field, Cech says, differs from solving homework problems, and she would like to see undergraduates "have exposure to what the profession of engineering actually is, rather than what they imagine the engineering profession

to be." Engineering students may be developing a sense that the engineering profession is not the right fit for them based on mistaken or incomplete perceptions of what the work is actually like.

As described in chapter 6, a second reason that the undergraduate engineering experience may be turning women away from engineering is a lack of emphasis on the social impact of engineering work. Cech (2014) found that students' interest in public welfare concerns declined over the course of the undergraduate engineering program. She told AAUW:

> The professional socialization that [students are] getting in these engineering programs is generally not emphasizing things like public welfare issues and social consciousness. This relates to the broader issue of how we represent the engineering profession at its fullest level of complexity, not characterizing it as only math and science equations but articulating the variety of things it has to offer. Portraying engineering in this more complex way would allow a broader spectrum of students to believe that engineering is the right field for them, to have greater career-fit confidence and greater expertise confidence. More students would likely see engineering as something that they could be good at. There are very deeply rooted needs for consideration of social justice and public welfare concerns in the kind of work that engineers do, and separating these kinds of questions from the standard curriculum is problematic.

FITTING IN AT WORK

Cech's study specifically measures the professional role confidence of undergraduates. Yet from all appearances, the issue of women leaving the engineering workforce is more significant than the issue of women leaving college engineering programs. Cech told AAUW:

> There is nothing to suggest that these processes end after people walk across the stage and have their degree. We don't leave our professional training and go into the workforce and never again worry about how we're

doing and whether or not we have the right expertise or whether the profession is the right fit. These are questions that continually come up for young professionals and perhaps professionals throughout their career.

Cech and her colleagues are following up with the students who participated in the study to see how professional role confidence in college relates to persistence in the engineering workforce.

Research on the influence of professional role confidence in the engineering field is in its early stages. The research to date demonstrates that professional role confidence is significantly associated with engineering persistence and that women tend to have less professional confidence than men have. Development of an identity as an engineer has been shown to be a characteristic of women who persist in engineering careers (Buse et al., 2013). These findings point to increasing women's sense of fit with the professional role as a potential key to closing gender gaps in engineering. When asked what can be done to increase professional role confidence among women in engineering, Cech acknowledged that it is difficult: "It requires changing the culture of the field, the culture of the profession." Increasing the number of women who are comfortable being an engineer likely will require sustained effort from engineering schools and workplaces to make clear the reasons why women belong in engineering.

WHAT CAN WE DO?

A number of recommendations stem from this research. College and university engineering departments should emphasize the wide variety of expertise necessary to be successful as an engineer. A narrow focus on math and science obscures the other areas of expertise—writing, communicating, organizing, and managing—that engineers need to be successful. Including engineering design activities in the field early in undergraduate coursework allows students to see the differences between textbook problems and the creativity and critical thinking necessary for actual engineering problem solving. Recognizing that these areas of expertise are critical to the engineering role also shifts the image of who is a good fit for engineering and stops the devaluing of competencies and contributions that are female stereotyped.

Enable early contact between students and professionals. Meaningful contact with engineers in the field provides students with role models and mentors and also helps students understand the breadth of skills that they will need to be successful. Individuals with low professional role confidence could benefit from interaction with professionals with whom they can identify.

Provide girls with opportunities to tinker. More boys than girls arrive at college with experience tinkering or programming. Giving girls opportunities to develop confidence in their design abilities well before they finish high school could help them develop expertise confidence and comfort with being an engineer, which could then increase their persistence in the field. Increasing the number of girls who enter college with experience in design could also help shift the perception that women are not naturally a good fit for engineering work.

Finally, spread the word that engineering skills and competencies are learned, not innate (Dweck, 2007). A conception that some people's brains are hardwired to do engineering work (and that men are better at math and science than women are) contributes to low professional role confidence by perpetuating a stereotype that some people are natural engineers while others are a poor fit for engineering. In engineering classrooms, reinforcing the idea that successful engineers are those willing to practice to develop their skills and persist through difficulties can help reduce false assumptions about engineering competence.

CHAPTER 9.

A WORKPLACE FOR EVERYONE

A lot of the studies have focused on fixing women—fixing their confidence, fixing their interests. We did not find that any of those factors influenced women engineers' persistence decisions at all, which is why we are saying we really need to be focusing on the environment.
—Nadya Fouad

Many researchers have looked at why women choose to enter STEM careers such as engineering and computing and the factors involved in preparing women for these careers, but retention of women in these fields has received much less attention. Recruiting women will be truly successful only if women who start in engineering and computing stay in these fields. Despite evidence that women are more likely than men to leave engineering and technical jobs (Hunt, 2010; Society of Women Engineers, 2006; Hewlett, Buck Luce et al., 2008), few researchers have studied why, and under what conditions, women choose to leave.

A SURVEY OF WOMEN ENGINEERS

In 2009, distinguished professor of educational psychology Nadya Fouad and business school professor Romila Singh at the University of Wisconsin, Milwaukee, along with colleagues Mary Fitzpatrick and Jane Liu, launched a survey funded by the National Science Foundation to uncover the factors that lead women to stay in engineering. Drawing from the population of women who had graduated with an undergraduate degree in engineering at any time in the past (Fouad et al., 2012), the survey compared women currently working as engineers with women who had left the field. Participants included women who earned engineering degrees as far back as 1947 and as recently as 2010.

The researchers were determined to reach as representative a sample as possible, so they contacted engineering deans at the top 50 universities that graduate women in engineering. To understand issues particular to women of color in engineering, the researchers also contacted the top 20 universities that graduate Latino, black, and Asian engineers. Thirty universities agreed to participate, including universities in every region of the United States: private institutions such as Cornell and Stanford; public universities such as Penn State and the University of Florida; and technical schools such as MIT and Georgia Tech.

In addition to the women at the 30 official partner universities, women from another 200 universities completed the survey (at NSFpower.org) after hearing about it from others (Singh et al., 2013). In the end, the researchers received more than 5,500 responses.

The survey was designed to assess factors that could influence engineers' likelihood of leaving the field, such as vocational interests, job and career satisfaction, work-family conflict, training and development opportunities, a variety of workplace support mechanisms and initiatives, undermining behavior in the work environment, and survey takers' commitment to their employer and the engineering profession. The survey also included questions that allowed the researchers to assess respondents' self-efficacy (their belief or confidence in their ability to complete tasks or reach goals) and positive outcome expectations (their belief or confidence that a given behavior will lead to a particular outcome).

Fouad, Singh, and their colleagues published a report in 2012 based on the more than 5,500 survey responses from women with engineering degrees.[1] More than half of the respondents were currently working as engineers, about a quarter had previously worked as engineers but had left the field, and the rest had earned engineering degrees but never worked as engineers.

THOSE WHO STAYED VERSUS THOSE WHO LEFT

To understand any possible differences between women who had left and women who had stayed in engineering, the researchers compared the survey responses of women currently working in engineering with the responses of women who had left within the previous five years.[2] By a surprising number of measures, the two groups of women were similar: They had similar undergraduate majors, were equally likely to be married and have children, were of similar racial/ethnic backgrounds, and were of similar age.

The two groups of women were also psychologically similar, being equally interested in engineering and equally confident in their engineering abilities. Both groups were equally confident in their ability to navigate the political environment in their workplace and their ability to manage multiple work-life

role demands and had similar expectations in these arenas.

What was not the same for the two groups of engineers was the workplace environment. Compared with those who stayed in engineering, those who left were

- Less likely to report opportunities for training and development that would have helped them advance
- Less likely to report support from a supervisor or co-worker
- More likely to report undermining behaviors from supervisors
- Less likely to report support for balancing work and nonwork roles

Indeed, the survey clearly showed that women are not leaving because of something they are lacking. As Fouad told AAUW, "A lot of the studies have focused on fixing women—fixing their confidence, fixing their interests. We did not find that any of those factors influenced women engineers' persistence decisions at all, which is why we are saying we really need to be focusing on the environment."

WORKPLACE BARRIERS

Comparing persisters with nonpersisters is useful for understanding which factors contribute to women leaving engineering. To better understand the differences between women who are solidly committed to their engineering jobs and those who may leave, the researchers analyzed how current engineers' job satisfaction and intention to leave their organizations related to a number of other factors. They found two workplace factors that lowered job satisfaction: excessive and ill-defined work goals and various kinds of incivility, including explicit insults directed at women.

Excessive workloads included being expected to work more than 50 hours per week and take work home at night and on weekends, as well as too much responsibility without commensurate resources such as budget, staff, and time. Ill-defined responsibilities included a lack of clearly defined goals, objectives, and responsibilities and contradictory and conflicting work requests and

requirements. Engineers burdened with excessive and ill-defined work goals were the least satisfied with their jobs and the most inclined to leave their organizations. Overwork and lack of clarity about assignments were related not only to a weaker commitment to their specific employer but to the engineering profession as a whole.
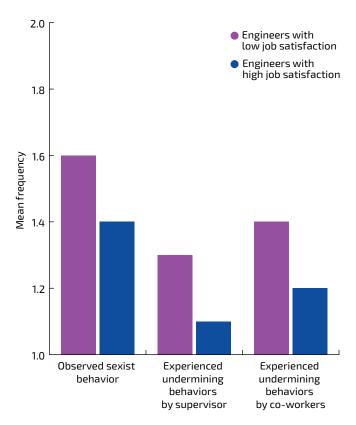
INCIVILITY AT WORK

The second factor that lowered women engineers' job satisfaction, incivility at work, included being treated in a condescending, patronizing, or discourteous manner by supervisors, senior managers, and co-workers. The researchers asked participants to estimate on a scale of 1 (never) to 6 (every day) how frequently in the past month they had experienced specific undermining behaviors (from supervisors and co-workers separately), such as having their ideas belittled; being insulted, talked down to, not defended, or given the silent treatment; and generally having their efforts to be successful on the job undercut. In addition, participants were asked how often in the past year they had observed any supervisor, senior manager, or colleague exhibit sexist behaviors such as ignoring or interrupting a female employee, speaking in a condescending or patronizing manner to a female employee, making offensive or embarrassing public comments about the physical appearance of a female employee, or making sexually suggestive comments to a female employee.

Figure 25 shows that, on average, engineers who reported less satisfaction with their jobs also reported observing more sexist behavior at work in the last year and experiencing more undermining behaviors by both co-workers and supervisors in the last month. While the differences are not huge, they are statistically significant, and, of course, no one should have to endure these types of behaviors in the workplace or elsewhere, so the answer to all three of these questions should be never.

Female engineers who reported that supervisors more frequently belittled, patronized, or systematically undermined them were the least satisfied with their jobs and were less satisfied than those receiving uncivil treatment from co-workers. Women in such undermining environments were also less

FIGURE 25. FEMALE ENGINEERS' EXPERIENCE OF INCIVILITY AT WORK, BY LEVEL OF JOB SATISFACTION

Note: Scale from 1 (never) to 6 (every day). Participants estimated the frequency with which they experienced undermining behaviors in the past month and the frequency with which they observed sexist behavior in the past year.
Source: Fouad et al. (2012). AAUW communication with Romila Singh.

committed to the organization as a whole, more likely to intend to leave their job, and more likely to experience high levels of work-family conflict.

These findings are particularly revealing because, although some research has identified the engineering work culture as unfriendly to women, this study is the first to identify specific kinds of undermining behaviors that may contribute to an uncomfortable work climate for women and affect their inclination to leave the field of engineering.

WHY WOMEN STAY IN ENGINEERING

According to Fouad, Singh, and their colleagues, current engineers who were the most satisfied with their jobs and committed to the field of engineering overall were the most likely to experience support in the workplace. Engineers who were satisfied with their jobs felt that their contributions were valued and recognized and that their organization cared about their well-being, opinions, and general satisfaction at work. They also received more tangible development opportunities, such as challenging assignments that helped them advance their skills and formal training opportunities. They worked for organizations that provided clear, transparent paths for advancement and were more likely than engineers with low job satisfaction to report that their organization provided supportive work-life policies.

SELF-EFFICACY AND POSITIVE OUTCOME EXPECTATIONS

Delving a bit deeper, Singh, Fouad, and their colleagues Mary Fitzpatrick, Jane Liu, Kevin Cappaert, and Catia Figuereido conducted a follow-up analysis (Singh et al., 2013) of two factors that they suspected might be especially important for understanding current female engineers' intentions to stay or leave: engineering task self-efficacy (the strength of a person's belief in her ability to complete tasks and reach goals related to her engineering job) and engineering task outcome expectations (the strength of a person's belief that a certain action or behavior related to her engineering work will result in a positive outcome).

To estimate current engineers' levels of engineering task self-efficacy, the researchers looked at the extent of study participants' confidence on a scale of 1 (not at all confident) to 5 (very confident) in performing a variety of common engineering tasks, such as "design a new product or project to meet specified requirements" and "troubleshoot a failure of a technical component or system." To estimate current engineers' levels of outcome expectations, the researchers analyzed participant ratings of their level of agreement, from 1 (strongly disagree) to 5 (strongly agree), with statements such as

"If I perform my job tasks well, then I will earn the respect of my co-workers," "If I achieve in my job, I expect I'll receive good raises," and "When I am successful at my work tasks, then my manager(s) will be impressed."

Analysis of the survey responses showed that engineering task self-efficacy and positive outcome expectations were related both to higher job satisfaction and higher organizational commitment, which in turn were related to engineers' greater intention to stay in their jobs.

WHAT ABOUT MEN?

Some have asked whether women and men respond differently when it comes to workplace environment—including self-efficacy and positive outcome expectations—and intentions to stay or leave engineering. Singh and Fouad responded by launching a similar study for men (at NSFgears. org). Preliminary results suggest that the same things that affect women's tendency to leave organizations—lack of opportunities for advancement, lack of opportunities for training and development, and excessive workloads—also affect men. Says Fouad, "We're arguing that changing the environment is good for everybody, men and women."

A BETTER FUTURE FOR WOMEN (AND MEN) IN ENGINEERING?

Singh and Fouad believe that creating supportive work environments is possible. Singh told AAUW:

A lot of the recommended changes that come out of our study have been put in place by organizations often cited in lists of great places to work. The recommendations that follow from our findings are not necessarily novel or foreign. It's just that some engineering firms may have been slow to acknowledge the need for them. … What we really need are systemic changes, an overhaul of the entire system.

While not necessarily easy to change, reducing excessive work demands and clarifying work goals seem like possible changes for leaders of engineering organizations to make. But is an uncivil and undermining work environment changeable? Singh thinks so:

There's a lot of research on incivility and undermining behaviors in organizations. Organizations that have taken a very intentional and purposeful approach to combating that have succeeded. These are all learned behaviors that, if they're not dealt with and negative consequences don't follow, employees come to understand that they can get away with. The prevalence of incivility and undermining behaviors in an organization really stems from the organizational culture: whether the top leadership and whether the leadership at every level is tolerant or intolerant of these kinds of behaviors.

WHAT CAN ORGANIZATIONS DO?
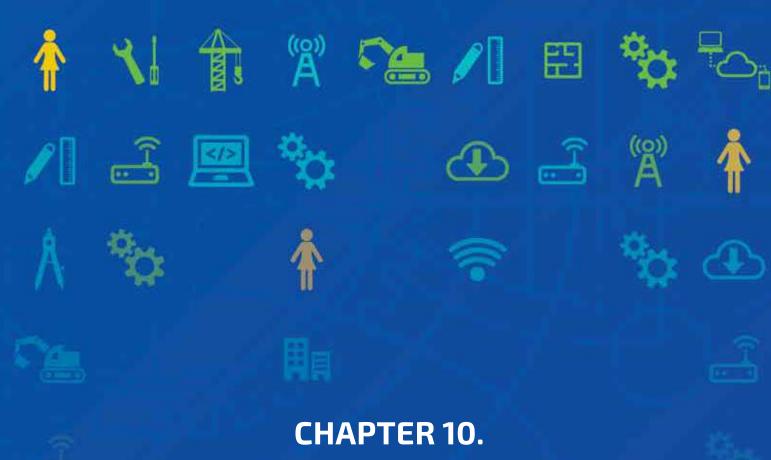
Self-efficacy and positive outcome expectations might at first glance appear to be individually developed and determined, but both characteristics are influenced to a great degree by an individual's environment. "[Self-efficacy is] not something that is fixed," explains Singh. "It's really malleable. It is context sensitive and can change in response to certain elements in the work environment." So while some components of an individual's engineering task self-efficacy and positive outcome expectations are specific to an individual's psychological makeup, both characteristics are decidedly affected by an individual's workplace environment. For example, a person at one company might be given the resources and authority to troubleshoot a failure and be rewarded if she solves the problem. That person is likely to have high self-efficacy and positive outcome expectations. At another company the same person might not be provided with the resources and authority to investigate the failure and will not be rewarded if she solves the problem. In the second case the person will likely have little confidence in her ability to succeed and will likely develop negative outcome expectations.

Organizations can improve employees' self-efficacy and outcome expectations through a number of actions and policies. Organizations can

ensure that employee roles and responsibilities are clearly defined, employees are provided with the resources they need to fulfill those responsibilities, and employees receive training and development. Organizations can acknowledge and reward employee contributions and ensure that employees do not have excessive workloads. Through these efforts, organizations can improve self-efficacy and positive outcome expectations among all employees and in the process retain their female engineers.

CHAPTER 9 NOTES

1. *Stemming the Tide* (Fouad et al., 2012) was written for and funded by the National Science Foundation. Unlike the follow-up article (Singh et al., 2013), the 2012 report was not peer-reviewed. Despite that fact, the findings from the 2012 report are included here because of the importance of understanding factors that relate to the retention of women in engineering to the overall issue of women's underrepresentation in engineering and computing. Fouad, Singh, and their colleagues' study (2012) is the first to comprehensively investigate factors related to women's decisions to leave or stay in engineering.

2. The researchers compared responses from current engineers with those of engineers who had left the field in the previous five years (rather than with those of women who had left at any point in their careers) to provide similar time frames for comparison as well as to ensure that recollections were recent enough to be accurate.

CHAPTER 10.

WHAT CAN WE DO?

Underrepresentation of women in engineering and computing is a deeply rooted and complex social problem. But recent research and real-world initiatives have shown that there are ways to reduce gender bias, increase the perceived and actual social relevance of engineering and computing, and ultimately increase women's sense of belonging in these fields. Employers, educators, policy makers, and individuals can all take steps to improve women's representation in engineering and computing.

REDUCE THE INFLUENCE OF GENDER BIAS

Reducing bias against women in engineering and computing fields is a society-wide endeavor. The best long-term strategy for accomplishing this goal is to change cultural stereotypes that lead to gender biases—for example, that men are better than women at math, science, and the other skills that engineers and computing professionals need. Ironically, one way to change the operative stereotypes is for a critical mass of women to succeed in engineering and computing occupations (Eagly & Diekman, 2012), which brings us back to square one.

CHANGE IMPLICIT BIASES

Implicit gender biases are more prevalent today than explicit gender biases are. While evidence is sparse on how to change implicit biases in the long term (Lai et al., 2013), positive role models appear to make a difference (Young, D. M., et al., 2013; Manke & Cohen, 2011; Asgari et al., 2010; Drury et al., 2011). A natural experiment in India, where a law reserved village council leadership positions for women in randomly selected villages, illustrates this finding. Researchers found that men in villages that were required to have female council leaders held weaker implicit biases associating leadership with men than did men living in villages without a gender quota (Beaman et al., 2009).

Because implicit associations between math and gender have been shown to be in place by age 7 or 8 (Cvencek, Meltzoff et al., 2011), our best chance to influence implicit biases may be to expose girls and boys to positive female role models

in engineering and computing early in life (Baron et al., 2014). Changing the formation of implicit biases among children may be an effective approach for reducing discrimination in the long term, but other tactics are needed to minimize the negative effects of gender bias in the workplace today. While everyone has a role to play, employers occupy positions of particular influence in this project.

CHANGE ORGANIZATIONAL PRACTICES

Research points to a number of organizational practices that can help reduce the influence of gender bias. For example, making job qualifications clear and applying them evenly to all candidates, basing decisions on objective past performance, being aware of one's own potential biases, and allowing sufficient time to make in-depth and individualized evaluations can reduce the influence of gender biases on hiring decisions (Uhlmann & Cohen, 2005; Isaac et al., 2009; Reuben et al., 2014a; Bendick & Nunes, 2012). Implementing the following practices can also help reduce gender bias related to both hiring and retaining women in engineering and computing.

REMOVE GENDER INFORMATION FROM CANDIDATE EVALUATIONS

One approach to reducing the influence of biases in evaluations of others is to remove information about an individual's age, race, and gender from decision-making contexts. A classic example of this approach relates to the hiring of professional musicians. In 1970 fewer than 10 percent of instrumentalists in major U.S. symphony orchestras were women. Orchestra applicants typically competed for positions by performing before an audition committee. Because of concerns that selections might be biased in favor of the students of certain renowned teachers, several major U.S. orchestras in the 1970s experimented with a new procedure that involved placing a screen between the auditioning musicians and the committee, so that judges could hear but not see the applicants. In the 20 years following the adoption of blind auditions, the proportion of women hired by major symphony orchestras doubled—from approximately 20 percent to approximately 40 percent (Goldin & Rouse, 2000).

Removing gender information from the application process allowed for a fairer hiring process. Of course, hiding individuals' characteristics is not always feasible, but in certain situations, such as when an organization is evaluating résumés of job applicants, limiting gender information available to reviewers may help reduce gender discrimination.

HOLD MANAGERS ACCOUNTABLE

Accountability can encourage managers and recruiters to rely less on gut instincts, which may be based on unconscious biases, and exert more effort to gather relevant information and process the information more carefully. When individuals know that they will be held accountable for their actions and decisions, they tend to act in ways that prepare them to justify their judgments. Stereotypes are an easy and efficient way to make decisions for the many professionals who are under time pressure or working on many tasks simultaneously, so when evaluators are not held accountable for their judgments, they are likely to rely on stereotype-based expectations (Heilman, 2012).

EMPHASIZE THAT GENDER DIVERSITY IS A GOAL

Research has found that a multicultural approach, a vision of diversity that celebrates social and cultural differences (Gutiérrez & Unzueta, 2010), is more effective in reducing bias than a colorblind approach that ignores different group identities in favor of emphasizing an overarching organizational identity (Plaut et al., 2009; Stevens et al., 2008). A multicultural approach is also more effective at creating environments in which minority groups are likely to be engaged in their work and committed to organizational success (Purdie-Vaughns et al., 2008; Plaut et al., 2009).

While the terms "multicultural" and "colorblind" pertain specifically to racial, ethnic, and cultural diversity, the message is relevant for gender diversity as well. A colorblind approach with respect to gender is akin to an organizational culture in which issues of gender are rarely mentioned. Even if the organization emphasizes the general importance of diversity, the importance of gender diversity, in particular, can be obscured because diversity is understood to mean a number of different things (Bell

& Hartmann, 2007; Unzueta et al., 2012). When organizational leaders talk about the importance of diversity, they should be clear that one desired result is recruiting and retaining more women.

INTRODUCE EFFECTIVE DIVERSITY INITIATIVES

Diversity does not automatically lead to better outcomes. A study of 700 private companies found that strategies in which responsibility and accountability for diversity were clear, as when they were assigned to a diversity committee or to a full-time diversity staff, were the most effective. Mentoring and networking interventions were moderately effective as a means to reduce the social isolation of people from nondominant groups. Diversity training or diversity evaluations that aimed to reduce managerial bias were the least effective (Kalev et al., 2006).

Nonetheless, some diversity training programs have been shown to reduce gender bias in the workplace as well as in higher education settings, including in STEM-specific settings (Moss-Racusin, van der Toorn et al., 2014; Carnes, Devine, Isaac et al., 2012; Carnes, Devine, Manwell et al., 2014; Devine et al., 2012). One study (Catalyst, 2012) examined the effect of diversity and inclusion education at a global engineering company and found that a diversity training program had a transformative effect on those attending the program, shifting both their mindset and behavior, as well as having a positive effect on the workplace climate. Before attending the program, participants were noncommittal about whether white men enjoyed privileged status in U.S. society. Four months after the program, however, participants reported an increased awareness of white male privilege. They said that they were more likely to think critically about social groups, take personal responsibility for being inclusive, consider other points of view, and listen empathetically. Co-workers noted some of these changes as well. Training was especially successful for participants who were not previously concerned about being prejudiced, a group of people particularly unlikely to recognize and account for their own biases without external intervention. Critical success factors in this training program included senior leader participation, a compelling

rationale that was clearly and persuasively communicated beforehand, ample opportunities for practice, and an absence of blaming participants for inequality.

This study is notable because significant shifts in beliefs are rarely found in attitudinal research. People's beliefs about inequality are particularly resistant to change (Hafer & Bègue, 2005, in Catalyst, 2012). In addition, most of the participants were white men, a group of people who have an important role in creating inclusive work environments because they hold a majority of senior leadership positions in organizations, especially in engineering and technical organizations. Research finds that people tend to value and approve of diversity-championing efforts when they are performed by white men but disapprove of the same efforts when performed by women and other underrepresented groups (Hekman & Foo, 2014). The success of this effort points to the possibility that diversity training can help organizations achieve cultural change despite the finding by Kalev and colleagues (2006) that diversity training is often ineffective. Clearly, diversity training programs are not created equal, nor is the larger context in the organization unimportant.

IMPLEMENT AFFIRMATIVE ACTION POLICIES

Affirmative action refers to "positive steps taken to increase the representation of women and people of other underrepresented groups in areas of employment, education, and culture from which they have been historically excluded" (Fullinwider, 2014). Affirmative action programs vary in their prescriptiveness for employers. At one end of the spectrum, opportunity-focused affirmative action programs seek to expand recruitment of underrepresented groups or eliminate discrimination from the hiring and promotion process, while at the other end, quotas prescribe strong preferential treatment from employers (Harrison, D. A., et al., 2006).

Examples of affirmative action policies include placing job opening announcements where more women and people of other underrepresented groups will be likely to see them and conducting outreach programs designed to attract women and people of other underrepresented groups.

Federal agencies require that government contractors develop affirmative action programs in which they establish goals to reduce or overcome any instances in which their workforce has fewer women or people of other underrepresented groups in a job than would reasonably be expected by their availability (U.S. Department of Labor, Office of Federal Contract Compliance Programs, 2002).

Affirmative action policies are tools that recruiters and managers can use to counteract their gender biases so that they don't, intentionally or unintentionally, keep women and people of other underrepresented groups out of engineering and computing jobs (Crosby, Iyer, & Sincharoen, 2006; Walton, Spencer et al., 2013). Affirmative action policies are the only means of correcting discriminatory injustices in the United States that do not rely on the aggrieved parties coming forward on their own behalf (Crosby, Iyer, & Sincharoen, 2006). This is especially important since many employees who are at a disadvantage on the basis of demographic characteristics, such as gender or race, may not consciously recognize problems related to discrimination against their own group (Crosby, Iyer, Clayton et al., 2003).

Some critics of affirmative action policies suggest that such policies lower the quality of the selected individual or group; however, research on affirmative action policies related to gender shows that this is not true. Balafoutas and Sutter (2012) conducted a laboratory experiment where a variety of affirmative action policies were applied to a series of competitions. The presence of affirmative action policies, such as requiring a woman to be among the winners and giving applicants "points" just because they were women, resulted in no significant differences in the overall performance of the winner pool as compared to scenarios in which affirmative action policies were not used. The researchers found that the presence of affirmative action policies encouraged more highly qualified women to enter the competition and did not discourage men from competing, which means that although affirmative action policies resulted in more women being among the winners, women were rarely selected over more-qualified men. Affirmative action policies in this study encouraged

women to throw their hats into the ring, raising the competence of the applicant pool overall.

Along the same lines, an examination of the effects of political representation quotas in Sweden found that gender quotas (reserving a certain percentage of positions for women) increased the competence of the candidates overall and the group of male candidates in particular, by reducing the number of less-qualified men running for political office (Besley et al., 2013). These studies suggest that affirmative action policies help level the playing field for applicants without reducing the talent that employers can attract. Such policies are most successful in workplaces where executives support them and where affirmative action goals and policies are clearly and persuasively communicated to staff.

CHANGE INDIVIDUAL BEHAVIORS

For individual women in engineering and computing, navigating around systemic biases can be difficult if not impossible. Yet research points to certain survival skills for women in traditionally masculine environments that may be useful, although these strategies are not a substitute for addressing fundamental issues of inequality.

Research shows that when women in hiring situations include clear evidence of competency but avoid appearing self-promoting in interviews, they are viewed more positively. In addition, if women use only their first and middle initials instead of their first name (if it's clearly a woman's name) in their initial application, they may decrease the chance that gender bias will influence prospective employers' evaluations of their application (see Isaac et al., 2009, for an overview of this literature and original sources). Research also shows that when women present their contributions as motivated by the interests of the group rather than themselves, they tend to be perceived more positively (Lucas & Baxter, 2012; Ridgeway, 1982; Shackelford et al., 1996).

Specific to counteracting the negative effects of stereotype threat, approaching interviews as challenges in which the goal is to build skills rather than perform well has resulted in women feeling less threatened and performing better (Stout & Dasgupta, 2013). Self-affirmations and reappraising negative thoughts—for example, thinking about stressful situations in ways that allow one to feel calm—have also been shown to protect women from the negative effects of stereotype threat (Legault et al., 2012; Martens et al., 2006; Schmader, Forbes et al., 2009).

Finally, just knowing about stereotype threat has been shown to lessen its effects. Simply understanding that stereotypes are an external source of stress can protect women from the harmful effects of stereotype threat (Johns et al., 2005; Dar-Nimrod & Heine, 2006).

MAKE ENGINEERING AND COMPUTING MORE SOCIALLY RELEVANT

Strategically incorporating activities that reflect communal values into engineering and computing curricula and work—and, correspondingly, strategically communicating the societal benefits of engineering and computing to the public—is a way to increase women's representation in these fields. As Amanda Diekman told AAUW:

> People do not think STEM fields, in particular engineering and computing, provide opportunities for working with others and helping others, so anything that can be done to incorporate that kind of activity, to highlight that and draw attention to it, will increase people's interest and engagement in the domain and their ability to see themselves as part of that field.

Evidence suggests that highlighting the communal aspects of STEM careers increases girls' interest in these careers (Colvin et al., 2013; Tyler-Wood et al., 2012).

INCORPORATE COMMUNAL VALUES INTO COLLEGE CURRICULA AND CULTURE

Evidence suggests that incorporating communal values into engineering and computing curricula is especially beneficial for women. Vaz and colleagues (2013) found that Worcester Polytechnic Institute's

longstanding project-based learning curriculum, centered on getting students out of the classroom to solve real-life, open-ended problems, has been particularly effective for its female alumni. In a survey of its engineering graduates during a 38-year period, women were more likely than men to report that their project-based learning experiences had a positive impact across a wide variety of personal and professional development measures, including understanding the connections between technology and society, feeling connected to their community, and feeling as though they can make a difference.

Engineering students who perceived that ethical and social issues were de-emphasized in engineering programs placed a low value on social consciousness and public welfare beliefs at the end of their college career. When students perceived that their engineering programs emphasized ethical and social issues, however, they were more likely to believe that social consciousness and other public welfare measures were important (Cech, 2014). While more research is needed on this topic, the preliminary lesson seems to be that when engineering programs incorporate a clear emphasis on ethical and social issues, they produce engineers who prioritize social responsibility.

One additional way to attract more women to engineering and computing programs is to couple degrees in these majors with degrees in other fields that allow individuals to pursue multiple interests. For example, at Georgia Tech in 2014, 18 percent of bachelor's degrees in computer science were awarded to women, while women earned 45 percent of bachelor's degrees in computational media, a joint degree between computing and the school of literature, media, and communications (Guzdial, 2014).

INCORPORATE COMMUNAL VALUES INTO THE WORKPLACE

Can employers do anything to attract individuals, including many women, who value working with and helping people to technical jobs that don't have clear social contributions? For example, would providing opportunities for mentoring students, junior-level engineers, or technical workers; building workers' awareness of the ultimate beneficiaries of their research or design efforts; or providing progressive work-family policies help engineering and computing workers fulfill their communal goals? As Diekman told AAUW:

> If your communal goals are not fulfilled at work, then extra activities outside of work become especially important. Whether that's family or caregiving or some kind of community service or volunteering, communal activities that are outside of your engineering career might actually have profound implications for your engineering career, because if you can fulfill communal goals in other places, then it may not be as important to have them fulfilled at work.

This research suggests that organizations might benefit from advancing progressive work-family policies or enabling employees to volunteer for a social cause of their choice.

In addition, individual engineers and computing professionals can prioritize the availability of opportunities for communal goal achievement when they are looking for jobs. Diekman and her colleagues' research suggests that considering potential for working with and helping others, along with technical aspects, when deciding on a job can help communally oriented engineers and computing professionals find more job satisfaction. In tandem, the leaders of engineering and computing organizations should be proactive in clarifying the value accorded to communal activities and be particularly aware of the common subtle and overt devaluing of those activities (Diekman, Weisgram et al., 2015).

CULTIVATE A SENSE OF BELONGING

A sense of belonging has measurable effects on an individual's physical and mental states. Even minimal indications of social connectedness can increase feelings of belonging (Cwir et al., 2011; Walton, Cohen et al., 2012). For women in engineering and computing, having a strong sense of belonging has been found to help alleviate the stress that arises from stereotype threat (Shnabel et

al., 2013; Richman et al., 2011; London, Rosenthal et al., 2011; London, Ahlqvist et al., 2014).

One way to increase a sense of belonging among women in computing is to introduce them to computing at an early age. Offering, and possibly requiring, computing courses in elementary, middle, and high school can result in more girls feeling that they belong in computing.

Creating a genuinely welcoming environment is a critical step for organizations seeking to attract and retain women and people of other underrepresented groups. Subtle cues can send a message to women that they don't belong in an environment. For example, exposure to gender-stereotypical commercials has been shown to undermine women's aspirations and performance in math and science (Davies et al., 2002). As mentioned in chapter 2, a stereotypically "geeky" masculine setting has been shown to undermine women's sense of belonging and interest in computing (Cheryan et al., 2009). Changing the representations people are exposed to, endorsing a philosophy that explicitly values

ADVANCING WOMEN IN ACADEMIC ENGINEERING AND COMPUTING

Survey data and interviews with tenured professors identify a sense of community and the presence of a support network as some of the most important factors in job satisfaction and retention of female STEM faculty (Tyson & Borman, 2010; Young, 2012). The National Science Foundation's Advance program has funded the efforts of dozens of academic institutions to develop systemic approaches and innovative ways to increase the participation and advancement of women in academic science and engineering careers. Both academic research and strategies developed by Advance programs, such as the Stride program at the University of Michigan and the WISELI program at the University of Wisconsin, consistently identify mentoring and effective, fair leadership as two areas that improve the workplace experience for female academics in science and engineering.

the social identity of women (Derks et al., 2007), and increasing the representation and visibility of women can create an environment in which women feel welcome, which can increase motivation, commitment, and persistence (Walton, Spencer et al., 2013).

Research has identified a number of strategies that women in engineering and computing fields use to increase their sense of belonging, not all of which are effective. In male-dominated workplaces, the culture sometimes encourages women to engage in "discursive positioning" (positioning oneself as an exception to the rule) by distancing themselves from other women (Rhoton, 2011; Faulkner 2009a, 2009b; Servon & Visser, 2011). Individuals may also suppress their beliefs and opinions to better fit in. While this may work for a while, self-silencing as a coping mechanism ultimately results in individuals feeling alienated and less motivated, which hinders performance and may lead to disidentification with the work or field (London, Downey et al., 2012). Separating one's work identity from one's outside identity is another mechanism women may use to fit into engineering and computing work environments, but that can also have negative results, such as increased depression and lowered life satisfaction (von Hippel, Walsh et al., 2011).

While these individual strategies are not effective, organizations can take steps to cultivate a sense of belonging among women in engineering and computing. For example, college engineering or computing department educators can convey the message that their program will require significant effort from everyone, both women and men. In one study, when undergraduate women heard that a program would require significant effort from everyone, they reported an increased sense of belonging in STEM fields (Smith, J. L., et al., 2013). Along the same lines, encouraging a "growth mindset" (a belief in the malleability of intelligence and an awareness that difficulties and challenges are a normal part of earning an engineering or computer science degree and working in these fields) has been shown to increase women's sense of belonging (Walton & Cohen, 2007).

Providing an environment free from discrimination where women have social support is also important (Richman et al., 2011). Female engineers report that having friendly social interactions with co-workers increases their feeling that they belong (Hatmaker, 2013). Finally, interventions to minimize disparities and encourage positive relations between groups (women and men, for example) have been shown to help promote engagement and prevent feelings of isolation and devaluation that can lead women to feel as if they don't belong in engineering or computing fields (London, Ahlqvist et al., 2014).

In sum, organizations, educators, and individuals can do many things to reduce bias, make engineering and computing more socially relevant, and encourage a sense of belonging among women.

RECOMMENDATIONS

To increase women's representation in engineering and computing occupations, AAUW offers the following recommendations, which are based on an extensive review of relevant research and on the findings highlighted in this report.

FOR EMPLOYERS

Employers are able to influence the representation of women in engineering and computing by changing the workplace climate and hiring and promotion practices. For more information, see chapters 3 and 4 on bias in hiring and evaluations, chapter 6 on the importance of communal values, and chapter 9 on the workplace environment.

MAINTAIN GOOD MANAGEMENT PRACTICES THAT ARE FAIR AND CONSISTENT AND THAT SUPPORT A HEALTHY WORK ENVIRONMENT

- Communicate clear responsibilities, goals, and paths toward advancement.
- Assign employees challenging projects that help them develop and strengthen new skills.
- Provide training and development opportunities for employees.
- Acknowledge and reward employees' contributions.

- Ensure that employees have manageable workloads and are not expected to routinely work excessive hours.
- Provide and encourage the use of work-life balance support such as on-site daycare, flexible work schedules, paid parental leave, and telecommuting.
- Provide opportunities for senior technical workers to mentor students or junior-level technical workers.
- Put in place anti-harassment policies such as that instituted by the Ada Initiative, adainitiative.org/what-we-do/conference-policies.
- Work to establish welcoming environments through inclusive workplace policies.

MANAGE AND PROMOTE DIVERSITY AND AFFIRMATIVE ACTION POLICIES

- Ensure that job advertisements, mission statements, and internal communications explicitly convey that your organization values diversity and gender inclusiveness.
- Assign responsibility for diversity to a diversity committee or full-time diversity staff.
- Involve men, especially white men, in gender diversity efforts.
- Conduct effective diversity training for employees.
- Monitor your progress in increasing women's representation in technical roles.

REDUCE THE NEGATIVE EFFECTS OF GENDER BIAS

- Make job qualifications clear and apply them evenly to all candidates.
- Base hiring decisions on objective past performance information when possible.
- Purposely remove gender information from evaluation scenarios when possible.
- Allow sufficient time to make in-depth and individualized evaluations of applicants.
- Ensure that hiring managers and other employees are aware of their own potential gender biases, such as by taking the gender-science Implicit Association Test at implicit.harvard.edu.

- Survey employees to assess the level of gender bias within your organization.
- Hold managers and recruiters accountable for their hiring and promotion decisions.

ENCOURAGE A SENSE OF BELONGING

- Create a welcoming environment for all employees.
- Encourage a supportive, friendly, and respectful environment.
- Root out uncivil and undermining behaviors.
- Increase the number of women at all levels of management.
- Provide opportunities for women to develop a support network of other technical women.
- Formally recognize necessary nontechnical work such as working well with others and mentoring—work that is not male-stereotyped—along with technical work.
- Be proactive and vocal about management's commitment to increasing the representation of technical women in your organization.

FACILITATE OPPORTUNITIES FOR EMPLOYEES TO WORK ON PROJECTS OR ISSUES THAT ARE SOCIALLY RELEVANT

- Pursue projects with clear social impacts whenever possible.
- Showcase how professionals' everyday work aligns with the societally beneficial outcomes that are the ultimate goals of engineering and technology.
- Establish social service days where employees volunteer in their communities.

FOR WOMEN WORKING IN ENGINEERING AND COMPUTING

Women engineering and computing professionals face challenges navigating stereotypes and gender biases in environments in which they are often the minority. They are also well placed to attract other women to these fields.

- Seek a support network. Some possibilities include participating in a Society of Women Engineers chapter, the Systers e-mail list (hosted by the Anita Borg Institute for Women

and Technology), or a women-in-engineering or computing group on campus or at work.
- Prioritize working in jobs that allow you to work with others on socially relevant problems if you place a high value on communal goals.
- Seek opportunities to serve as a role model for girls and young women considering engineering and computing careers.
- Share with students at all levels how you work with and help people.

FOR MEN WORKING IN ENGINEERING AND COMPUTING

Because they make up the majority of workers in engineering and computing, men play important roles in creating the workplace climate and in recruiting and influencing prospective professionals. Importantly, the recommendations for increasing the representation of women in engineering and computing often benefit the men in these professions as well.

- Seek opportunities to serve as a role model for girls and young women considering engineering and computing.
- Refuse to participate on all-male conference panels. Encourage conference organizers to recruit at least one female panelist.
- Share with students at all levels how you work with and help people.

FOR EDUCATORS

Educators at all levels influence how students perceive the fields of engineering and computing, as well as how students view themselves. The following recommendations come from the literature reviewed on bias (chapters 2, 3, and 4), stereotype threat (chapters 2 and 5), and values and career choice (chapters 6, 7, and 8).

- Spread the word that engineering skills and competencies are learned, not innate (in other words, cultivate a growth mindset). In engineering and computing classrooms, reduce the assumption that technical competence is innate by reinforcing the idea that successful engineers or computing professionals are willing

to practice to develop their skills and persist through difficulties.

- Frame adversity as a common experience for everyone so that challenging coursework does not selectively signal to students that they do not belong in engineering or computing.
- Teach students about the effects of stereotype threat to lessen its effects.
- Give a broad range of people exposure to computing. Move away from the idea that certain people (often with strong programming skills) are cut out for computing while others are not.
- Highlight the broad applications of engineering and computing.
- Highlight the ways in which engineering and computing help people and provide opportunities for working with others.
- Provide opportunities for girls and young women to interact with women and men with whom they can identify in engineering and computing.
- Create welcoming environments for girls in math, science, engineering, and computing with gender-neutral decor; by endorsing a philosophy that explicitly values the social identity of women; and by increasing the representation and visibility of girls and women.
- Provide girls with opportunities to tinker and build confidence and interest in their design and programming abilities.

FOR COLLEGES AND UNIVERSITIES

Because most engineers and computing professionals are trained in their professions in institutions of higher education, colleges and universities have a special role to play in increasing the representation of women in engineering and computing.

ENGINEERING AND COMPUTING PROFESSORS

- Emphasize the social impact of engineering and computing work.
  - Apply concepts that students are learning in class to community needs, incorporating project-based learning or service learning components into engineering or computing curricula.

- Apply engineering and computing to real-world problems.
- Emphasize ethical and social issues when teaching engineering and computing.
- Encourage a supportive environment in the classroom and in the program.
- Encourage and assist early contact between students and professionals.
- Emphasize the wide variety of expertise necessary to be successful as an engineer or computing professional.
- Highlight as early as possible the different facets that make up engineering and computing.

ENGINEERING PROFESSORS

- Expand examples beyond those that involve stereotypically male applications such as cars or rockets. The NSF-funded Engage project has a collection of gender-neutral Everyday Examples in Engineering that professors can use.
- Introduce students to experiences in the field early in undergraduate coursework to allow students to see the differences between textbook problems and the creativity and critical thinking necessary for actual engineering problem solving.

COMPUTING PROFESSORS

- Split classes by experience, providing students with less experience in computing with the time and environment they need to build their skills and interest.
- Question the idea that certain people (often with strong programming skills) are cut out for computing while others are not.
- Send female students (a mix of students interested in computing and those not considering computing as a major) to the Grace Hopper Celebration of Women in Computing or similar conferences. Taking even a few students can change the mindset of those students, who can then have a large effect on a program.

SOCIAL SCIENCE PROFESSORS

- Conduct research on how to counteract the effects of gender bias and the effects of diversity on outcomes.
- Conduct more research in field settings, in engineering and computing workplaces, and in classrooms.

ADMINISTRATORS

- Require researchers who receive federal funds to participate in bias training.
- Require all undergraduate students to take at least one computer science course, no matter what their major.
- Provide opportunities for female students in engineering and computing to develop a support network of other technical women.
- Offer and promote dual-degree programs for students interested in engineering or computing who also have strong interests in other fields.
- Engage in active public relations campaigns that make it clear to young women that engineers and technical professionals work cooperatively with others on problems that have impacts on the well-being of people, for example, by using the National Academy of Engineering's *Changing the Conversation* materials (2008).

FOR POLICY MAKERS

Policy makers can help improve the representation of women in engineering and computing through education programs and research funding, as well as by ensuring that federally funded programs comply with civil rights laws designed to tackle sex discrimination. Congress enacted Title IX to make sure that federal resources are not used to support discriminatory practices in education programs and to provide individual citizens effective protection against such bias. In addition, state and local governments can adopt and promote education and workplace policies that can narrow the achievement gap for girls and women in STEM.

FEDERAL GOVERNMENT

- The U.S. Department of Education should issue guidelines for Title IX coordinators that outline their responsibilities for ensuring equity in STEM education. The guidelines should cover concerns from elementary and secondary education through postdoctoral studies and workforce training. These guidelines should be broadly disseminated and publicized.
- The executive branch should lead efforts to increase awareness, comprehensiveness, and transparency of federal agency Title IX compliance reviews. Such reviews, which all federal agencies should conduct, not only those in the Department of Education, are critical to leveraging change when recipients of federal funds are found lacking in the placement, advancement, and retention of women in STEM disciplines. Compliance reviews and mechanisms for enforcement of Title IX are available during pre-award reviews, post-award compliance reviews, and investigations of complaints.
- To comply with Title IX, federal agencies should ensure that educational institutions receiving grant funding or other financial assistance provide policies to maintain safe climates to prevent sexual harassment (including gender-based harassment and sexual assault) and nondiscriminatory policies for health insurance benefits and other services.
- Federal grant processes should allow for flexibility relative to academic engineers' and computer scientists' life events (such as birth or adoption of a child), and paid family leave and paid sick days should be encouraged.
- Congress should direct and provide adequate funding for federal, state, and local agencies to establish outreach and retention programs at the elementary, secondary, and postsecondary levels to engage women and girls in STEM activities, courses, and career development. For example, Congress should strengthen the gender-equity provisions of the America Competes Act reauthorization, which authorizes science and technology research programs for five years and contains provisions to support education and training aimed at addressing gender discrimination in the STEM fields.
- Congress should ensure that federal laws, such as the Carl D. Perkins Vocational and Technical

Education Act, that fund and affect STEM education and workforce training also hold states and programs accountable for moving women and girls into training that is nontraditional by gender.

- Congress should include in STEM education laws provisions for support services, such as dependent care, transportation assistance, career counseling, tuition assistance, and other services that allow individuals to successfully complete training programs. In addition, federally funded career guidance and counseling must be provided to all students and delivered in a fair manner that ensures that students are receiving unbiased information about high-skill, high-wage careers in nontraditional fields.

- *Rising above the Gathering Storm, Revisited* (National Academy of Sciences et al., 2010), commissioned by Congress, states that U.S. advantages in science and technology have begun to erode and discusses the need to improve math and science education. Unfortunately the report largely ignores the issue of girls and women in STEM fields. Congress should request a follow-up report on what effect increasing the number of women in STEM fields would have on enabling the United States to remain a leader in the global marketplace. This should illustrate the important contributions women can make to STEM fields and put weight behind efforts to increase opportunities for women and girls.

- Additional funding should be provided to better understand the underrepresentation of women in engineering and computing and to develop interventions that increase the representation of women in these fields.

STATE AND LOCAL GOVERNMENTS

- States should pass legislation to allow computing classes taught in secondary education to count toward graduation requirements.

- States should establish high-quality, uniform, and rigorous K–12 education standards, such as Common Core State Standards and Next Generation Science Standards or equally rigorous standards, to ensure that all students are taught to the same high expectations.

- State and local education agencies must be held accountable for improving the successful access to, and outcomes of women and girls in, career and technical education programs, especially in programs that are nontraditional for women and lead to high-skill, high-wage employment.

- All education funding should include support for teacher training to include recognition of implicit gender bias, awareness of stereotype threat, and ways to promote a growth mindset in students.

- All data regarding STEM study and workforce participation collected by state and federal governments should be disaggregated and cross-tabulated by gender and race.

FOR PARENTS

Parents, like educators, influence how girls perceive the fields of engineering and computing as well as their own abilities and can encourage their daughters to develop interest and confidence in these fields. Parents also play an important role in exposing their children both to the fields of engineering and computing generally and to women in these fields at early ages, when their implicit biases are forming.

- Cultivate a growth mindset in your children. Teach them that the brain is like a muscle that gets stronger and works better the more it is exercised. Teach them that passion, dedication, and self-improvement, not simply innate talent, are the roads to genius and contribution.

- Introduce your daughters to engineering and computing.

- Encourage your daughters to pursue mathematics and take calculus.

- Introduce your children to women and men with whom they can identify in engineering and computing fields.

- Question the idea that certain people (often with strong programming skills) are cut out for computing while others are not.

- Provide girls with opportunities to tinker, take things apart, and put them back together.

- Encourage your daughters to play and work with boys.
- Encourage your sons to play and work with girls.

FOR GIRLS

Girls should learn about engineering and computing so that they can make informed decisions about whether either of these fields is a good fit for their abilities and interests.

- Learn about the fields of engineering and computing. AAUW offers opportunities such as Tech Trek and Tech Savvy programs that provide opportunities for learning about these fields.

- Get to know women in engineering and computing.
- Tinker with things, take things apart, and put them back together.
- Cultivate a growth mindset. When you challenge yourself, work hard, and learn new things, your brain forms new connections, and over time you become smarter.
- Consider pursuing a dual-degree program in college, coupling a major in engineering or computing with a major in another field such as liberal arts or social science to allow in-depth pursuit of more than one interest.

APPENDIX

FIGURE A1. ENGINEERING OCCUPATIONS

Aerospace engineers

Agricultural engineers

Biomedical engineers

Chemical engineers

Civil engineers

Computer hardware engineers

Electrical and electronics engineers

    Electrical engineers
    Electronics engineers, except computer

Environmental engineers

Industrial engineers, including health and safety

    Health and safety engineers, except mining safety engineers and inspectors
    Industrial engineers

Marine engineers and naval architects

Materials engineers

Mechanical engineers

Mining and geological engineers, including mining safety engineers

Nuclear engineers

Petroleum engineers

Miscellaneous engineers

Note: All occupations listed under "Engineers" minor group 17-2000.
Source: U.S. Department of Labor, Bureau of Labor Statistics (2009).

FIGURE A2. COMPUTING OCCUPATIONS

Computer and information research scientists

Computer and information analysts

    Computer systems analysts
    Information security analysts

Software developers and programmers

    Computer programmers
    Software developers, applications
    Software developers, systems software
    Web developers

Database and systems administrators and network architects

    Database administrators
    Network and computer systems administrators
    Computer network architects

Computer support specialists
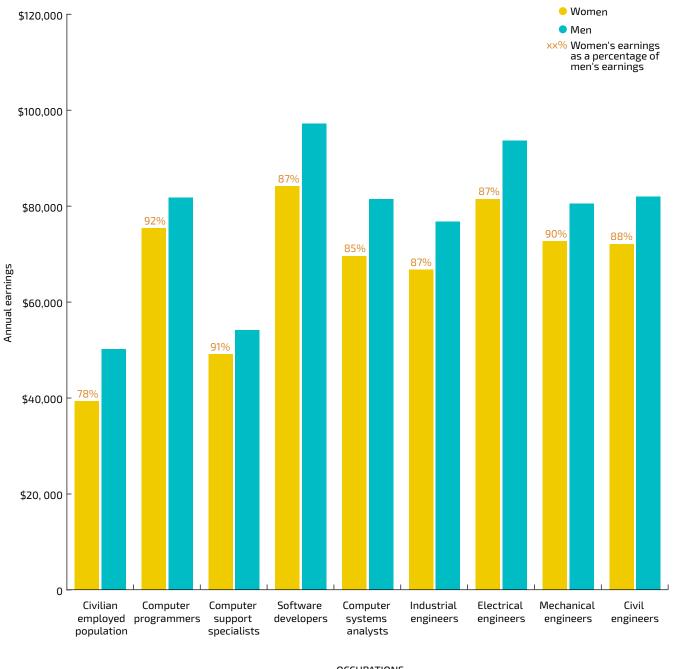
    Computer user support specialists
    Computer network support specialists

Miscellaneous computer occupations

Note: All occupations listed under "Computer Occupations" minor group 15-1100.
Source: U.S. Department of Labor, Bureau of Labor Statistics (2009).

FIGURE A3. PAY GAP IN SELECTED ENGINEERING AND COMPUTING OCCUPATIONS, 2013
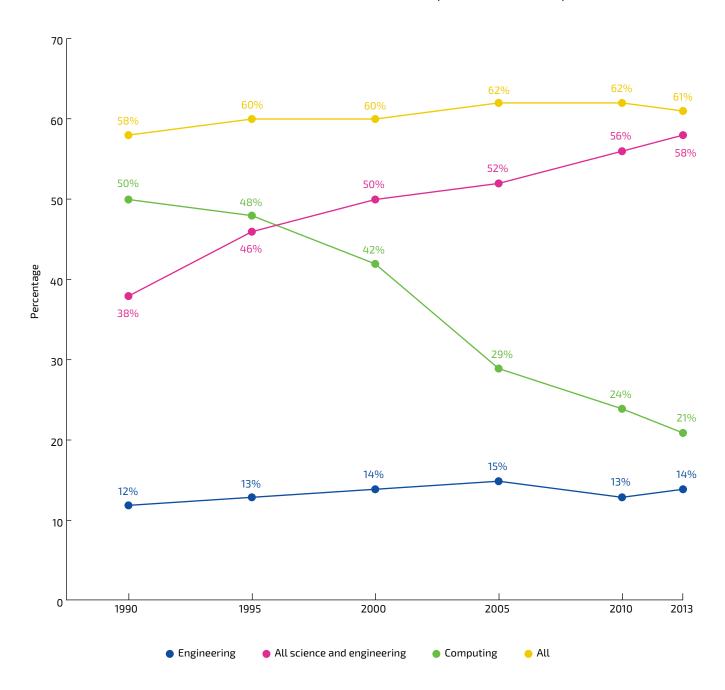
Notes: Includes full-time, year-round civilian population. Not all computing and engineering occupations are included because of large margins of error associated with occupations in which the numbers of workers (especially women) were relatively low. "Software developers" includes applications and systems software. "Industrial engineers" includes health and safety. "Electrical engineers" includes electronics engineers.
Source: L. M. Frehill analysis of U.S. Census Bureau (2014c).
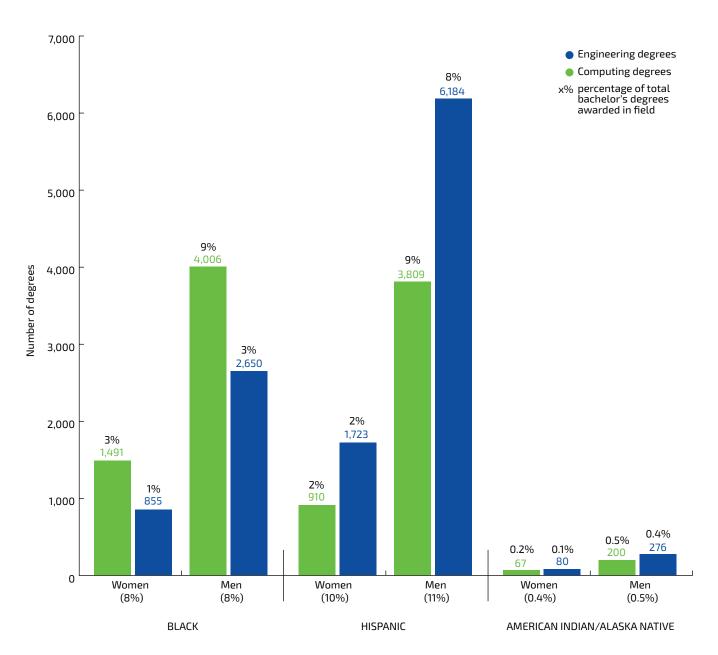
FIGURE A4. ASSOCIATE DEGREES EARNED BY WOMEN, SELECTED FIELDS, 1990–2013

Note: "All science and engineering" includes biological and agricultural sciences; earth, atmospheric, and ocean sciences; mathematics and computer science; physical sciences; psychology; social sciences; and engineering.
Source: AAUW analysis of National Science Foundation, National Center for Science and Engineering Statistics (2014a).

FIGURE A5. ENGINEERING AND COMPUTING BACHELOR'S DEGREES, BY RACE/ETHNICITY AND GENDER, 2013

Notes: Parentheses show the percentage of 20–24-year-olds in the general population. 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: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2014b).

FIGURE A6a. ENGINEERING BACHELOR'S DEGREES AWARDED TO WOMEN AT THE 25 LARGEST U.S. ENGINEERING SCHOOLS, 2012

Rank	Institution	Women earning engineering degrees	Total engineering degrees conferred	Percentage of engineering degrees awarded to women
1	Georgia Institute of Technology, Main Campus	346	1,663	21%
2	Pennsylvania State University, Main Campus	248	1,462	17%
3	Purdue University, Main Campus	293	1,391	21%
4	Texas A&M University, College Station	260	1,346	19%
5	University of Illinois, Urbana-Champaign	218	1,289	17%
6	North Carolina State University, Raleigh	315	1,270	25%
7	University of Michigan, Ann Arbor	276	1,198	23%
8	Virginia Polytechnic Institute and State University	208	1,151	18%
9	Ohio State University, Main Campus	172	1,128	15%
10	University of Texas, Austin	232	1,065	22%
11	University of Florida	223	1,062	21%
12	California Polytechnic State University, San Luis Obispo	142	995	14%
13	Iowa State University	132	898	15%
14	University of California, Berkeley	197	883	22%
15	Missouri University of Science and Technology	141	804	18%
16	University of Minnesota, Twin Cities	155	801	19%
17	Arizona State University	142	715	20%
18	University of Washington, Seattle Campus	157	704	22%
19	University of Maryland, College Park	112	703	16%
20	University of California, San Diego	134	702	19%
21	Auburn University	106	699	15%
22	Rutgers University, New Brunswick	128	683	19%
23	University of Central Florida	83	664	13%
24	Rensselaer Polytechnic Institute	165	657	25%
25	University of Wisconsin, Madison	125	656	19%

Note: Ranking includes only institutions that conferred at least 20 engineering bachelor's degrees in 2012.
Source: L. M. Freehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2013).

FIGURE A6b. ENGINEERING BACHELOR'S DEGREES AWARDED TO WOMEN BY U.S. ENGINEERING SCHOOLS WITH THE HIGHEST REPRESENTATION OF WOMEN, 2012

Rank	Institution	Women earning engineering degrees	Total engineering degrees conferred	Percentage of engineering degrees awarded to women
1	Smith College	22	22	100%
2	Prairie View A&M University	69	105	66%
3	Harvard University	28	60	47%
4	Massachusetts Institute of Technology	201	453	44%
5	California Institute of Technology	44	101	44%
6	Howard University	24	56	43%
7	George Washington University	40	94	43%
8	Tuskegee University	18	43	42%
9	Franklin W. Olin College of Engineering	28	69	41%
10	Rice University	83	215	39%
11	Harvey Mudd College	25	65	38%
12	Stanford University	125	335	37%
13	Humboldt State University	13	35	37%
14	Princeton University	64	177	36%
15	Yale University	24	67	36%
16	Tulane University of Louisiana	16	45	36%
17	Northwestern University	108	305	35%
18	University of Pennsylvania	100	286	35%
19	University of Alaska, Anchorage	20	58	34%
20	Hope College	11	32	34%
21	Cornell University	196	577	34%
22	Tufts University	65	192	34%
23	North Carolina A&T State University	61	183	33%
24	Eastern Michigan University	15	45	33%
25	University of Puerto Rico, Mayagüez	193	580	33%

Note: Ranking includes only institutions that conferred at least 20 engineering bachelor's degrees in 2012.
Source: L. M. Freehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2013).

**FIGURE A6c. COMPUTING BACHELOR'S DEGREES AWARDED TO WOMEN
AT THE 25 LARGEST U.S. COMPUTING SCHOOLS, 2012**

| Rank	Institution	Women earning computing degrees	Total computing degrees conferred	Percentage of computing degrees awarded to women
1	University of Phoenix (38 campuses)*	838	3,288	26%
2	DeVry University (25 campuses)*	297	1,667	18%
3	ITT Technical Institute (86 campuses)*	209	1,512	14%
4	Art Institute (33 campuses)*	368	1,009	37%
5	University of Maryland, University College	220	806	27%
6	Strayer University (17 campuses)*	193	683	28%
7	Pennsylvania State University, Main Campus	140	582	24%
8	Kaplan University, Davenport Campus*	152	553	27%
9	Western Governors University	49	518	9%
10	ECPI University*	79	497	16%
11	Westwood College (17 campuses)*	93	419	22%
12	Full Sail University*	68	375	18%
13	Rochester Institute of Technology	27	363	7%
14	George Mason University	60	348	17%
15	American Intercontinental University Online*	83	320	26%
16	Purdue University, Main Campus	46	297	15%
17	University of Maryland, Baltimore County	43	278	15%
18	Arizona State University	40	261	15%
19	American Public University System*	38	258	15%
20	University of Maryland, College Park	57	255	22%
21	Indiana University, Bloomington	47	234	20%
22	Bellevue University	36	207	17%
23	Capella University*	55	207	27%
24	University of Central Florida	15	204	7%
25	Rutgers University, New Brunswick	32	201	16%
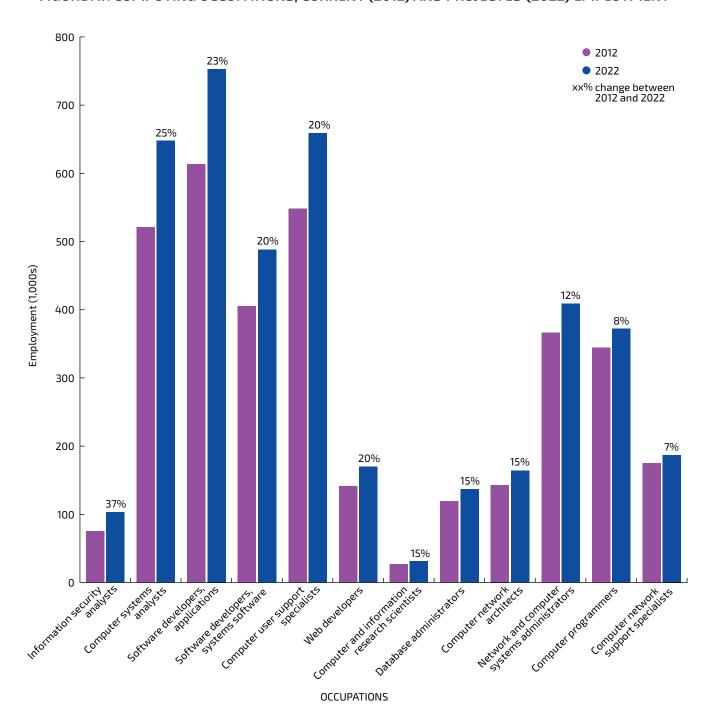
Note: Asterisks indicate private, for-profit institutions. Ranking includes only institutions that conferred at least 20 computing bachelor's degrees in 2012.
Source: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2013)

FIGURE A6d. COMPUTING BACHELOR'S DEGREES AWARDED TO WOMEN AT U.S. COMPUTING SCHOOLS WITH THE HIGHEST REPRESENTATION OF WOMEN, 2012

| Rank	Institution	Women earning computing degrees	Total computing degrees conferred	Percentage of computing degrees awarded to women
1	International Academy of Design and Technology, Online Campus*	14	21	67%
2	Johnson C. Smith University	15	23	65%
3	Westwood College, Chicago Loop*	12	22	55%
4	Academy of Art University*	31	58	53%
5	Art Institute of California/Argosy University, San Diego*	40	76	53%
6	Art Institute of California/Argosy University, Sacramento*	11	21	52%
7	Southern University and A&M College	12	23	52%
8	Art Institute of Las Vegas*	18	35	51%
9	North Carolina Central University	13	28	46%
10	North Carolina Wesleyan College	11	24	46%
11	Northwest Missouri State University	11	24	46%
12	Art Institute of Phoenix*	16	36	44%
13	Ohio University, Main Campus	86	195	44%
14	Guilford College	11	25	44%
15	Indiana Wesleyan University	11	25	44%
16	Quinnipiac University	17	39	44%
17	Kentucky State University	9	21	43%
18	Art Institute of Pittsburgh, Online Division*	20	49	41%
19	Harvey Mudd College	13	32	41%
20	Art Institute/Miami International University of Art and Design*	17	42	40%
21	Art Institute of California/Argosy University, Orange County*	19	47	40%
22	Art Institute of California/Argosy University, Inland Empire*	16	40	40%
23	Brandeis University	8	20	40%
24	Art Institute of Seattle*	14	36	39%
25	Grand View University	10	26	38%
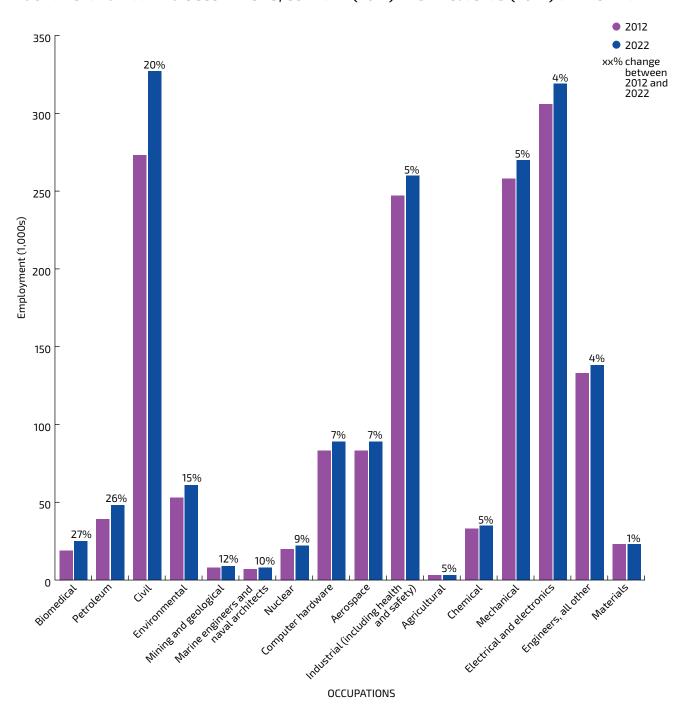
Note: Asterisks indicate private, for-profit institutions. Ranking includes only institutions that conferred at least 20 computing bachelor's degrees in 2012.
Source: L. M. Frehill analysis of National Science Foundation, National Center for Science and Engineering Statistics (2013).

FIGURE A7. COMPUTING OCCUPATIONS, CURRENT (2012) AND PROJECTED (2022) EMPLOYMENT

Notes: Percentages are projected growth in number of workers in each occupation defined as a computer occupation by the U.S. Department of Labor, 2012–2022. National growth in computer occupations overall is expected to be 18 percent and in all occupations is expected to be 11 percent.
Source: L. M. Frehill analysis of data from U.S. Department of Labor, Bureau of Labor Statistics (2014d).

FIGURE A8. ENGINEERING OCCUPATIONS, CURRENT (2012) AND PROJECTED (2022) EMPLOYMENT

Notes: Percentages are projected percentage growth in number of workers in each occupation included under the heading "Engineers" by the U.S. Department of Labor, 2012–2022. National growth in engineering occupations overall is expected to be 9 percent and in all occupations is expected to be 11 percent.
Source: L. M. Frehill analysis of data from U.S. Department of Labor, Bureau of Labor Statistics (2014d).
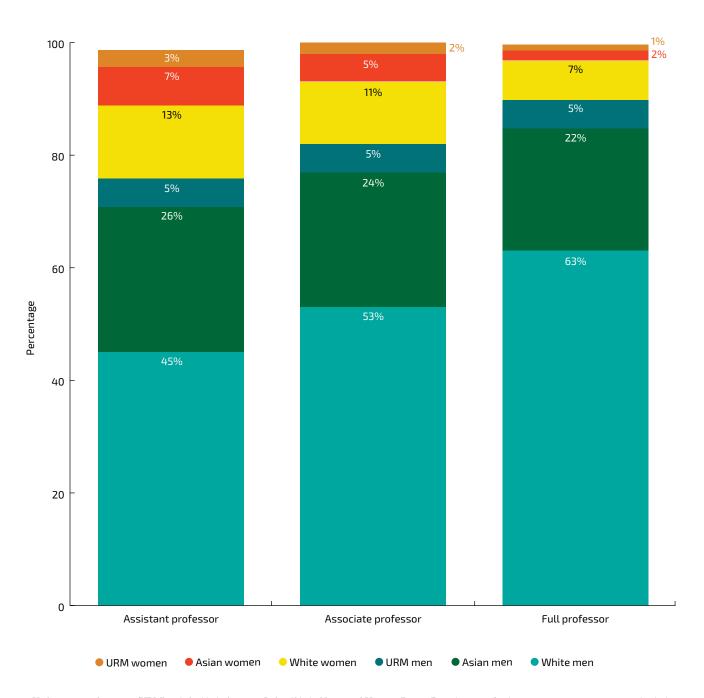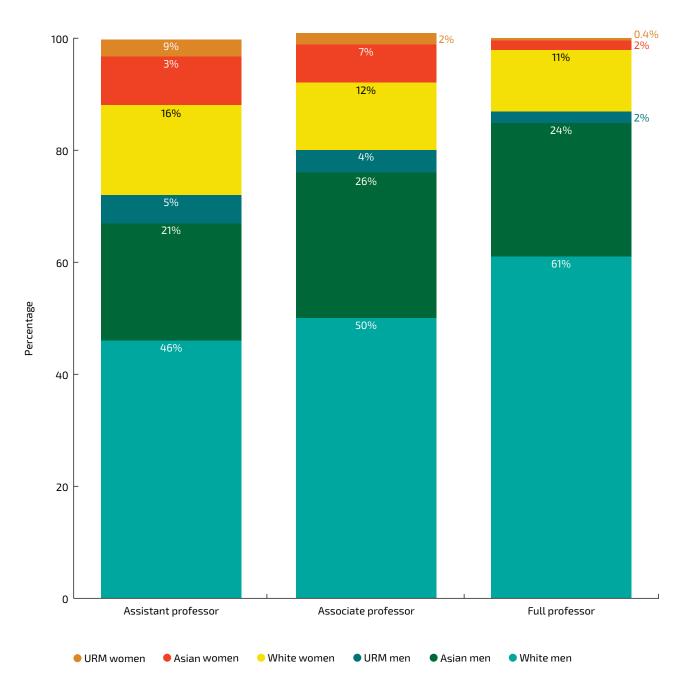
FIGURE A9. ENGINEERING FACULTY, BY RANK, GENDER, AND RACE/ETHNICITY, 2013

Notes: Underrepresented minority (URM) includes black, American Indian/Alaska Native, and Hispanic/Latino. Data shown are for the 328 participating engineering schools that reported faculty data broken down by gender, race/ethnicity, and rank.
Source: L. M. Frehill analysis of data from American Society for Engineering Education (2014).

FIGURE A10. COMPUTING FACULTY, BY RANK, GENDER, AND RACE/ETHNICITY, 2013

Notes: Underrepresented minority (URM) includes black, American Indian/Alaska Native, and Hispanic/Latino. Data shown are for the 143 participating computer science departments that reported faculty data broken down by gender, race/ethnicity, and rank. Responses from individuals who indicated that they were multiracial or nonresident aliens and those whose ethnicity is unknown or not reported were not included.
Source: L. M. Frehill analysis of data from Computing Research Association (2014).

FIGURE A11. ACADEMIC DISCIPLINES INCLUDED IN ENGINEERING

| Discipline	Classification of Instructional Programs (CIP) Code	Discipline	Classification of Instructional Programs (CIP) Code
Engineering, general	14.0101	All other	
Aerospace, aeronautical and astronautical/space engineering	14.0201	Pre-engineering	14.0102
		Ceramic sciences and engineering	14.0601
Agricultural engineering	14.0301	Computer engineering, other	14.0999
Architectural engineering	14.0401	Engineering mechanics	14.1101
Bioengineering and biomedical engineering	14.0501	Engineering physics/applied physics	14.1201
Chemical engineering	14.07	Engineering science	14.1301
Civil engineering	14.08	Metallurgical engineering	14.2001
Computer engineering, general	14.0901	Mining and mineral engineering	14.2101
Computer software engineering	14.0903	Naval architecture and marine engineering	14.2201
Electrical, electronics and communications engineering	14.10	Ocean engineering	14.2401
Environmental/environmental health engineering	14.1401	Textile sciences and engineering	14.2801
		Polymer/plastics engineering	14.3201
Mechanical engineering	14.1901	Construction engineering	14.3301
Nuclear engineering	14.2301	Forest engineering	14.3401
Petroleum engineering	14.2501	Manufacturing engineering	14.3601
Systems engineering	14.2701	Surveying engineering	14.3801
Materials science and engineering		Geological/geophysical engineering	14.3901
Materials engineering	14.1801	Paper science and engineering	14.4001
Materials science	40.1001	Electromechanical engineering	14.4101
Industrial engineering and management		Biochemical engineering	14.4301
Industrial engineering	14.3501	Engineering chemistry	14.4401
Engineering/industrial management	15.1501	Biological/biosystems engineering	14.4501
		Engineering, other	14.9999
		Geographic information science	45.0702
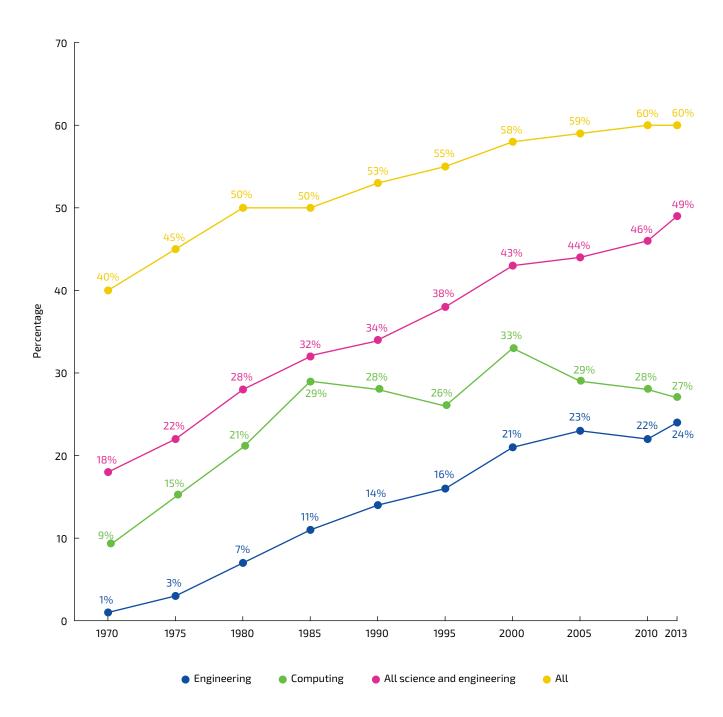
Source: U.S. Department of Education, National Center for Education Statistics (2010).

FIGURE A12. ACADEMIC DISCIPLINES INCLUDED IN COMPUTING

Discipline	Classification of Instructional Programs (CIP) Code
Computer and information sciences, general	11.01
Computer programming	11.02
Data processing	11.03
Information science/studies	11.04
Computer systems analysis	11.05
Computer science	11.07
Computer software and media applications	11.08
Computer systems networking and telecommunications	11.09
Computer/information technology administration and management	11.10
Computer and information sciences and support services, other	11.99

Notes: CIP code 11.06 (data entry/microcomputer applications) is the only discipline that the U.S. Department of Education includes under CIP code 11 that is not included here. CIP codes 11.03 and 11.99 are combined for the category "computer/information science support services, including data processing" in figure 8.
Source: U.S. Department of Education, National Center for Education Statistics (2010).

FIGURE A13. MASTER'S DEGREES EARNED BY WOMEN, SELECTED FIELDS, 1970–2013
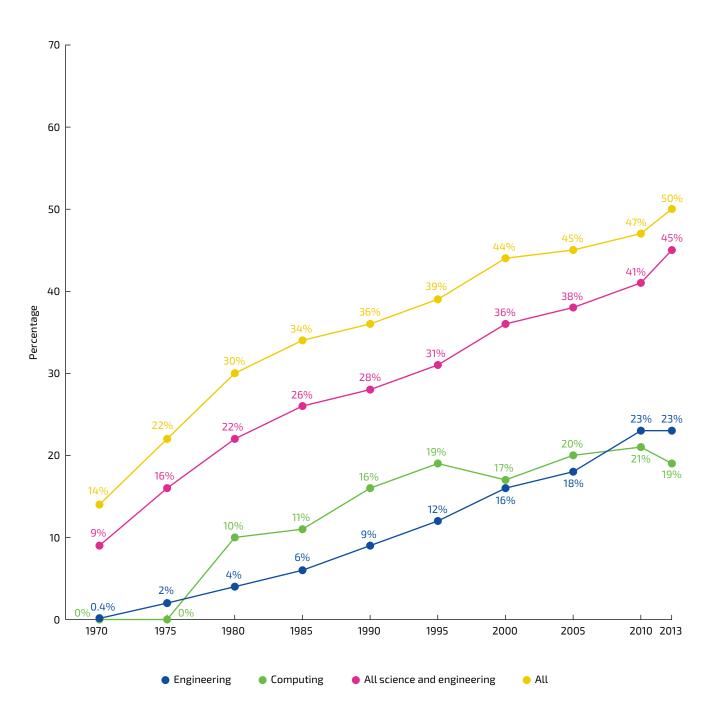
Note: "All science and engineering" includes biological and agricultural sciences; earth, atmospheric, and ocean sciences; mathematics and computer science; physical sciences; psychology; social sciences; and engineering.
Source: L. M. Frehill analysis of data from National Science Foundation, Division of Science Resources Statistics (2013), and National Science Foundation, National Center for Science and Engineering Statistics (2014a).

FIGURE A14. DOCTORAL DEGREES EARNED BY WOMEN, SELECTED FIELDS, 1970–2013


Note: "All science and engineering" includes biological and agricultural sciences; earth, atmospheric, and ocean sciences; mathematics and computer science; physical sciences; psychology; social sciences; and engineering.
Source: L. M. Frehill analysis of data from National Science Foundation, Division of Science Resources Statistics (2013) and National Science Foundation, National Center for Science and Engineering Statistics, (2014a).

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AAUW
empowering women since 1881

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MISSION
AAUW advances equity for women and girls through advocacy, education, philanthropy, and research.

VALUE PROMISE
By joining AAUW, you belong to a community that breaks through educational and economic barriers so that all women and girls have a fair chance.

VISION STATEMENT
AAUW empowers all women and girls to reach their highest potential.

DIVERSITY STATEMENT
AAUW values and seeks a diverse membership. There shall be no barriers to full participation in this organization on the basis of gender, race, creed, age, sexual orientation, national origin, disability, or class.

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