CHAPTER THIRTEEN

Why Aren't More Women in Computer Science?

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"You cannot solve a problem from the frame of mind that created the problem in the first place."

—Albert Einstein

Consider the following statistics.

Girls receive higher grades than do boys, from kindergarten through college, including grades in mathematics. In the latest year for which we have data, girls comprised 48% of all college math majors, took 56% of all Advanced Placement exams, and took 51% of AP calculus exams [College Board 2008]. Yet, only 17% of AP computer science test-takers in that year were female [College Board 2008].

Likewise, although 57% of all 2008 undergraduate degree recipients were female, women comprised only 18% of computer science (CS) and information (IT) degree recipients [National Center for Education Statistics 2008].

Curiously, 23 years earlier (in 1985), 37% of computer science bachelor's degrees were awarded to women [National Center for Education Statistics 2008]. Between 2001 and 2008 alone, there was a 79% decline in the number of incoming undergraduate women interested in majoring in computer science [Higher Education Research Institute 2008].

Why are so few women in computer science? Should we care? And, if we should, can anything be done to reverse these trends? Debates over these issues fall into three major categories.

Some argue that women are less likely than men to possess cognitive abilities at the extreme right tail of the distribution, which are necessary to compete in computer science (see [Ceci and Williams 2007], [Ceci and Williams 2010], and [Halpernet al. 2007]).

Others say that women are not as interested in computer science and simply prefer to study other subjects [Ferriman et al. 2009]; [Durndell and Lightbody 1993]; [Seymour and Hewitt 1994], and still others argue that women are directed out of the field by stereotypes, biases, and "male culture" [American Association of University Women 2000]; [Margolis et al. 2000].

This chapter reviews the research pertaining to each of these three positions and follows each argument through to its logical implications.

Why So Few Women?

First, we'll review the common explanations given for this situation and the formal research that investigates them.

Ability Deficits, Preferences, and Cultural Biases

Much research has been done on innate ability differences, preferences, and cultural biases as reasons for the underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields. Ceci, Williams, and Barnett developed a framework to understand how these all interact [Ceci et al. 2009]. Next, we address the research on each factor and then work it through Ceci et al.'s more integrative framework. The picture that emerges (see Figure 13-1) gives the reader a feel for the complexity of the interactions between the contributing factors. Although there are certainly biologically rooted gender differences at work, the research suggests that there also may be some detrimental gender biases involved, which raises further questions.

Evidence for deficits in female mathematical-spatial abilities

Innate ability differences between males and females (as well as environmentally mediated differences traceable to experiences during childhood) have been explored as one possible reason for the declining number of women in computer-related fields. Substantial evidence supports the argument that women are not as capable at highly math-intensive pursuits as are men. This sex asymmetry is found at the very upper end of the ability distribution. For example, the top 1% of scores on the mathematics SAT shows a 2-to-1 ratio of males to females, and the top .01% shows a ratio of 4-to-1 [Hyde and Lynn 2008]; [Lubinski et al. 2001]. Males also earn most of the very low scores, meaning that males' performance is simply more variable overall.

Ceci, Williams, and Barnett [Ceci et al. 2009] divide the evidence on cognitive sex differences into mean differences (at the midpoint of the distribution) and right-tail differences in proportions in the top 10%, 5%, and 1%, the latter being a better representation of those in the science, technology, engineering, and math (STEM) professions. Based on a national probability sampling of adolescents between 1960 and 1992, Hedges and Nowell found that the distribution of test scores for male and female test-takers differed substantially at the top and bottom 1%, 5%, and 10% [Hedges and Nowell 1995]. Males excelled in science, mathematics, spatial reasoning, social studies, and mechanical skills. Females excelled in verbal abilities, associative memory performance, and perceptual speed. These findings raise the possibility that biology accounts for some of the observed gender patterns of participation in related fields of STEM, CS, and IT.

Research on relative brain size, brain organization, and hormonal differences is also relevant. Ceci and Williams review the recent biological work on cognitive sex differences, investigating brain size, brain organization, and hormonal differences [Ceci and Williams 2010]. Discussing Deary et al.'s finding of a modest correlation (.33–.37) between intelligence and brain volume [Deary et al. 2007], in which men on average have slightly bigger brains, Ceci and Williams note that "in most of the research on biological correlates of sex differences, the focus is on means, whereas the focus on sex differences in the STEM fields is on the extreme right tail (the top 1% or even the top .1% or the top 0.01%)." In other words, many studies of average brain differences are not pertinent to our question, because strong evidence of mathematical and spatial ability differences between men and women appear only at the very top (or bottom) of the range of ability scores.

Other research cited in Ceci and Williams' review suggests that males and females use different parts of their brains to complete the same tasks [Haier et al. 2005]. Ceci and Williams conclude that "with additional independent replications and representative sampling, it can be concluded that men and women achieve the same general cognitive capability using somewhat different brain architectures."

Additionally, Ceci and Williams cite research that investigates the role of pre- and postnatal hormones in understanding cognitive sex differences. In one study, male rats were superior at figuring their way around a maze, compared with female rats. Once the male rats were castrated, their superiority disappeared. Ceci and Williams also review research in which biological females, given estrogen-suppressing drugs coupled with large doses of male hormones during sex-change operations, developed enhanced spatial abilities. The large body of research in this area suggests that hormonal factors might affect professional choices of women. However, it is unclear how much. Ceci and Williams conclude that the evidence is "not strong and consistent enough to justify claiming that hormones are the primary cause of sex differences in STEM careers."

Before we leave the subject of hormonal differences, however, we should consider the possibility that they underlie some behavioral differences that predispose women not to be as attracted as men to working in computer science.

Statistics show that women are committed to the professional work force. They hold 57% of all professional occupations in the U.S. in 2008 [Ashcraft and Blithe 2009]; [National Center for Education Statistics 2008], and they are also successful in math (as measured by grades), a closely related academic discipline. Thus, it seems important to go beyond the explanation of ability deficits and to ask about women's choices. The statistics call for a gender-sensitive analysis of the factors influencing women's decisions to participate in the field of Computer Science—or not—and we also need to address the possibility that women find themselves disenfranchised by the male culture of CS. If, in fact, significant reasons for a gender imbalance lie here, then here, too, may exist an opportunity to reverse a portion of this trend.

The role of preferences and lifestyle choices

Accordingly, some researchers have addressed preferences and cultural forces. Some claim that culturally inscribed career and lifestyle choices are the major reason for the small number of women in computer science, and others claim more strongly that discouraging cultural forces are the most instrumental causes. Next, we review evidence for each of these positions.

With respect to career choice, gender shifts within professions have occurred throughout history, notably within teaching, secretarial work, and medicine [Ceci and Williams 2010]. These shifts are easily explained by changes over time in these careers' prestige levels and financial remuneration, rather than by hormones or genes. Repeatedly, men have taken over whatever kind of work is considered more economically valuable, suggesting that gender workforce patterns are driven more by cultural and political forces rather than simple biological differences. In a recent longitudinal study of women's choices to work in health-related careers, we can find an interesting parallel case in which cultural values drive career choices. Jacqueline Eccles and colleagues at the University of Michigan found that even when mathematical ability was taken into consideration, young women were more attracted to health-related careers because they placed a higher value on a people/society-oriented job than did their male peers [Eccles et al. 1999].

Margolis, Fisher, and Miller [Margolis et al. 2000] provide further evidence of a "female" inclination—or values choice—to serve people and society in their 2000 study involving 51 male and 46 female computer science majors at Carnegie Mellon University (comprising a total of 210 interviews). A representative quote from a female computer science interviewee resonates with Eccles's research:

> The idea is that you can save lives, and that's not detaching yourself from society. That's actually being a part of it. That's actually helping. Because I have this thing in me that wants to help. I felt the only problem I had in computer science was that I would be detaching myself from society a lot, that I wouldn't be helping; that there would be people in third-world countries that I couldn't do anything about...I would like to find a way that I could help—that's where I would like to go with computer science.

Margolis, Fisher, and Miller found that women's quest for people-oriented purposes for computers was in concordance with other research in the field of computer science [Honey 1994]; [Martin 1992]; [Schofield 1995]. They report that 44% of the female students in their study (as compared to 9% of the male students) emphasized the importance of integrating computing with people through projects with a more human appeal. Overall, women preferred computing for medical purposes (e.g., pacemakers, renal dialysis machines, and figuring out diseases), communication, and solving community problems over computing for the sake of computing, developing better computers, or programming for games.

Tagging some similar values issues, Ferriman, Lubinski, and Benbow point to gender differences in lifestyle preferences and orientation toward life as the main reason for women's underrepresentation in high-intensity STEM careers [Ferriman et al. 2009]. Their research is unique in that they were able to hold ability constant and narrow the population down to only those who excel in STEM careers. By following mathematically precocious youth over 20 years, they found that "following the completion of their terminal graduate degrees, men seem to be more career-focused and agentic, whereas women appear to be more holistic and communal in their orientation toward life and more attendant to family, friends, and the social well-being of themselves and others more generally." By this argument, then, there are few women in CS simply because women are more interested in and prefer other disciplines and areas.

Biases, Stereotypes, and the Role of Male Computer-Science Culture

Some researchers reject the notion that any inherently female quality (whether ability or interest) causes women's underrepresentation in CS and IT careers. They argue instead that the culture of CS and IT discourages women. In "The Anatomy of Interest: Women in Undergraduate Computer Science," Margolis, Fisher, and Miller focus on how women students who enter CS with high enthusiasm and interest in computing quickly lose their ability and interest in the subject [Margolis et al. 2000]. They looked at factors beyond intellectual preference that influenced interest in an abstract body of knowledge. For example, they explored how gender-biased norms eroded confidence, and also how a masculinized standard for success shaded women's interest and ability in computing. The authors suggest that there may be some "pernicious ways in which male behavior and interest become the standards for 'the right fit' and success," and this, in turn, contributes to women's waning enthusiasm in the subject. In other words, as their interviews showed, women who refused to conform to the image of the myopically focused "computer geek" who "hacks for hacking's sake" might feel out of place.

For those who perceive the culture of computing as one in which the "boy wonder" icon is up all night programming feverishly in isolation, Margolis, Fisher, and Miller offer this insight from a female computer science teacher:

> My point is that staying up all night doing something is a sign of single-mindedness and possibly immaturity as well as love for the subject. The girls may show their love for computers and computer science very differently. If you are looking for this type of obsessive behavior, then you are looking for a typically young, male behavior. While some girls will exhibit it, most won't. But it doesn't mean that they don't love computer science!

Shortcomings of the Margolis, Fisher, and Miller case study include the fact that it examines just one small subset of the general population of students pursuing computer science, and thus, we should be wary of extrapolating these personal accounts to the broader population. We should not make broad assumptions based on this small sample. Furthermore, even though their interview questions were designed to elicit students' own experiences rather than their abstract thoughts, the authors admit that this interviewing technique was not conducive to assigning relative weight to different detachment factors, as "factors frequently shifted and appeared enmeshed with one another" [Margolis et al. 2000].

At the same time, these findings resonate with other studies of computer culture, such as one by the Educational Foundation of the American Association of University Women (AAUW), which combines input from its 14 commissioners (researchers, educators, journalists, and entrepreneurs) in cyberculture and education. Their report covers the Foundation's online survey of 900 teachers, qualitative focus research on more than 70 girls, and reviews of existing research, in order to provide insight into perspectives on computer culture, teacher perspectives and classroom dynamics, educational software and games, computer science classrooms, and home community and work [AAUW 2000]. Like Margolis, Fisher, and Miller, the AAUW found cultural deterrents to female participation in computer science. They found that girls are concerned about the passivity of their interactions with the computer as a "tool." Additionally, they found that girls rejected the violence, redundancy, and tedium of computer games and expressed dislike for narrowly and technically focused programming classes. Furthermore, the AAUW contends that these concerns are dismissed as symptoms of anxiety or incompetence that will diminish once girls "catch up" with the technology.

Finally, in a comprehensive compilation of research in IT, CS, and CE, McGrath Cohoon and Aspray integrated research from over 34 key researchers in the field [McGrath Cohoon and Aspray 2006]. Their potential explanations for the underrepresentation of women include experience, barriers to entry, role models, mentoring, student-faculty interaction, peer support, curricula, and pedagogy, as well as student characteristics such as academic fitness, values, confidence, and response to competition, plus the culture of computing.

In light of these culturally based concerns, we might ask what, exactly, high-ability women who opt out of disciplines such as CS *do* choose to do with their intellectual lives? Ceci, Williams, and Barnett remind us that women with high math competence are disproportionately more likely than men to also have high verbal competence, allowing them greater choice of professions [Ceci et al. 2009]. Hence, issues of culture and choice likely dovetail, directing capable women out of the computer field, thus revealing that more than biology, and factors other than raw ability, are at play. Figure 13-1 depicts the interplay of all these factors, both biological and cultural.

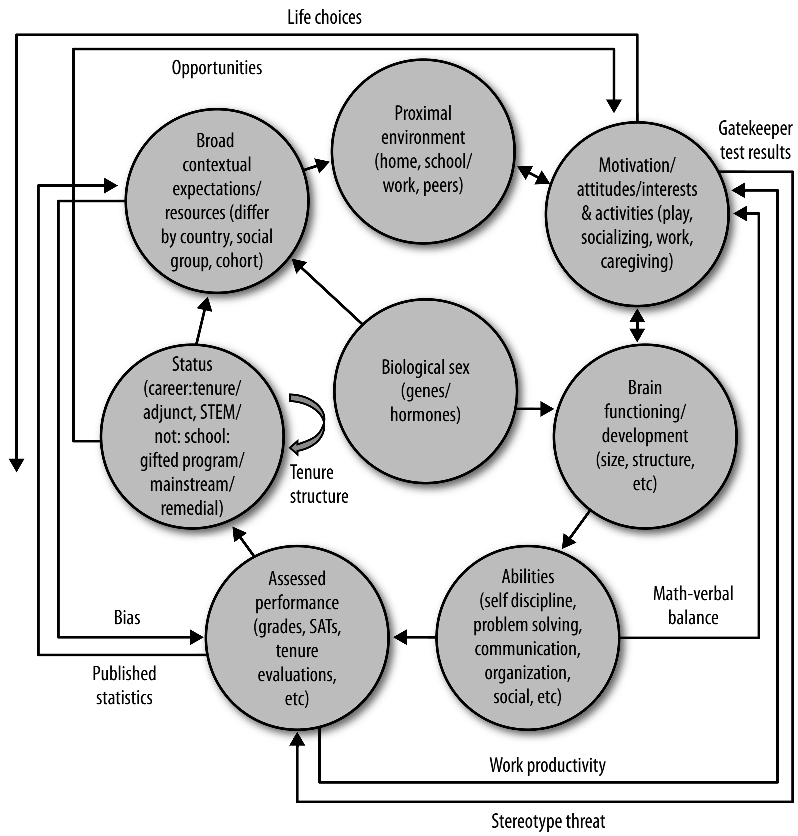

FIGURE 13-1. General causal model for gender disparity in science, technology, engineering, and mathematics. Figure copyright 2009 by Stephen J. Ceci, Wendy M. Williams, and Susan M. Barnett; used with permission.

With so many confounding factors, it is no surprise that we have no clear solution to the barriers that some women may face in CS and related fields. On the other hand, we do have an emerging picture of multiple and interacting forces potentially acting against women's full participation, which raises implications to which we now turn.

Should We Care?

To the extent that women do not choose CS because of troubling aspects of culture that could be changed, we must ask ourselves whether we ought to push for more women in CS, for instance, through educational policy. Since CS is a desirable professional field, women might benefit by enhanced opportunities to take part. Furthermore, insofar as CS is a key area for global competition, it may be beneficial for CS to become more gender-inclusive. Diversity may improve the products of computer and software teams.

Ultimately, however, the issue might go beyond any immediately measurable benefit. The inadequacies of the research at hand might actually suggest that we need to think within a different frame of mind: one that recognizes possible biological differences *and* a broad range of culturally determined qualities as key elements of a complex equation.

First, let us address the potential benefits to women of participating in CS. First, IT jobs pay considerably more than most female-dominated occupations [Bureau of Labor Statistics 2004]; [National Center for Education Statistics 2008]. According to the National Association of Colleges and Employers, starting salary offers for graduates with a bachelor's degree in computer science averaged $61,407 in July 2009 [Bureau of Labor Statistics 2010]. For computer systems software engineers, the median annual wages in the industries employing the largest numbers in May 2008 were: scientific research and development services, $102,090; computer and peripheral equipment manufacturing, $101,270; software publishers, $93,5790; and computer systems design and related services, $91,610.

The Bureau of Labor Statistics classifies computer software engineers' prospects of landing a job as *excellent.* Projecting ahead from 2008 to 2018, the percentage change projections as indicated on the Bureau of Labor Statistics website are: computer software engineers and computer programmers show an increase of 283,000 jobs, representing a 21% increase; computer software engineers show an increase in 295,000 jobs, representing a 32% increase; and computer software engineers show an increase of 34%. The only decline in projected jobs occurs in computer programming, at 3%. Thus, CS is a burgeoning field, with good pay and good job prospects.

Compared to other STEM occupations, the computer industry will see the greatest percentage of growth and demand, projected to 2016 (Figure 13-2).

Technology job opportunities are predicted to grow at a faster rate than jobs in all other professional sectors, up to 25% over the next decade [Ashcraft and Blithe 2009]. Considering the huge demand and projected employment to 2018, it might not be optimal that a possibly male-focused work culture may prevent some women from reaping the benefits of a career in CS.

The financial benefits to women of greater participation in CS are clear, but beyond these are the benefits that might accrue across the board when women are enabled to participate in all professional fields, including CS. The United States needs competent people to fill computer-related jobs and do them well. The United States Department of Labor estimates that by 2016 there will be more than 1.5 million computer-related jobs available [Bureau of Labor Statistics 2004].

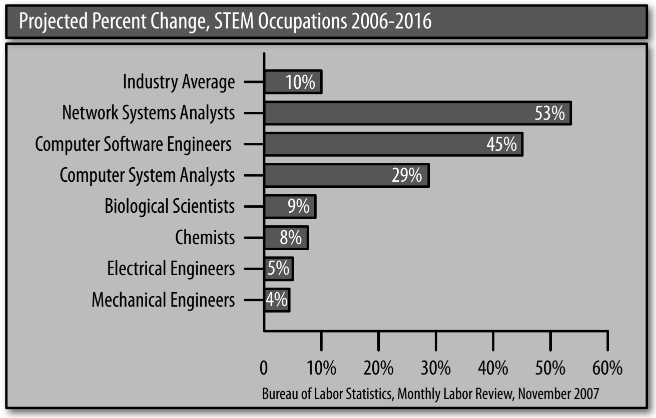

FIGURE 13-2. Projected percent change, STEM occupations 2006–2016

Despite the technology industry being one of the fastest growing industries in the U.S., if current trends continue, by 2016 the technology industry will be able to fill only half of its available jobs with candidates holding computer science bachelor's degrees from U.S. universities [Bureau of Labor Statistics, 2004]. In other words, we will benefit from participation by all people who show promise and capability, of both sexes.

Beyond this, gender balance might provide some benefits that some people have attributed to diversity. Indeed, some scholars have advanced the notion that diversity—including gender diversity—improves team performance, though not all scholars agree with this assertion, which frequently is made more on sociopolitical grounds than on scholarly ones. Research oriented around self-categorization/social identity and similarity-attraction tends to result in a pessimistic view of diversity, whereas the information-processing approach tends to give rise to more optimistic outcomes. As Mannix and Neale explain [Mannix and Neale 2005]:

> The self-categorization/social-identity and similarity-attraction approaches both tend to lead to the pessimistic view of diversity in teams. In these paradigms, individuals will be more attracted to similar others and will experience more cohesion and social integration in homogeneous groups. The information-processing approach, by contrast, offers a more optimistic view: that diversity creates an atmosphere for enhancing group performance. The information-processing approach argues that individuals in diverse groups have access to other individuals with different backgrounds, networks, information, and skills. This added information should improve the group outcome even though it might create coordination problems for the group.

Page, an advocate of diversity, says that under the right conditions, teams comprising diverse members consistently outperform teams comprising "highest-ability" members [Page 2007]. From his extensive work in complex systems, economics, and political science, Page asserts that progress depends as much on our collective differences as it does our individual IQ scores.

The research on the benefits of diversity in the IT workplace suggests that teams with equal numbers of women and men are more likely (than teams of any other composition) to experiment, be creative, share knowledge, and fulfill tasks [London Business School 2007], and that teams comprising women and men produce IT patents that are cited 26–42% more often than the norm for similar types of patents [Ashcraft and Breitzman 2007].

Research on this topic often credits diversity with a myriad of positive outcomes for team performance, yet it must be acknowledged that 50 years of research by social scientists has shown that performance advantages are not so clear-cut. As Mannix and Neale [2005] on page 237 point out, whereas tenure diversity (diversity in employee length of service) has particularly negative effects on performance, diversity based on social-category variables such as age, sex, and race seems to produce mixed effects, and the effect particularly depends on proportions (ratios of minority to majority members). In a large-scale, four-study project in which the authors measured the effects of racial and gender diversity on team process and performance, Kochan and colleagues found that gender diversity had either no effect or positive effects on team process, whereas racial diversity tended to have negative effects [Kochan et al. 2003]. Although Kochan and colleagues reported few direct effects for either type of diversity on team performance, they did indicate that contextual conditions (such as high competition among teams) exacerbated racial diversity's negative effects on performance.

Interestingly, Sackett and colleagues pose the question of how, exactly, performance is being assessed throughout the literature evaluating the benefits of diversity [Sackett et al. 1991]. That is, the authors note that performance ratings are tricky. After controlling for differences in male-female cognitive ability, psychomotor ability, education, and experience, when the proportion of women was small, women received lower performance ratings. Sackett and colleagues found that when women formed less than 20% of a group, they received lower performance ratings than did men, but when their proportion was greater than 50%, they were rated higher than the men. The authors did not find any parallel effects of proportion of representation on the performance ratings of men. Because the sex of the rater was not recorded, other potentially plausible explanations, including fear of class-action lawsuits or claims of discrimination, are difficult to evaluate.

In other words, researchers may lack credible measures for valuing gender diversity, at least with respect to performance. Does proportion truly enhance performance, or is there some other underlying factor giving the perception of enhanced performance? How can overt diversity (male/female, black/white) be studied while also appropriately assessing values and attitudes for similarities and differences? Would a gender- or ethnically-diverse work group whose members share similar attitudes and values be considered homogeneous or heterogeneous? Clearly, parameters need to be defined, and creating valid measures is part of the difficulty for research in this area.

Amidst these confusions, the fact that potential benefits of a diverse workforce may also include financial rewards is worth noting. A 2006 Catalyst study found higher average financial performance for companies with a higher representation of female board members. The study claims that for return on equity, sales, and invested capital, companies with the highest percentages of women board members outperformed those with the least by 53, 42, and 66%, respectively [Joy and Carter 2007]. Previously, a 2004 Catalyst study indicated that companies with the highest percentage of women leaders experienced a 35.1% higher return on equity and a 34% higher total return to shareholders. However, it could be argued that these results stem from progressive attitudes, not gender per se. Furthermore, Adams and Ferreira found that the average effect of gender diversity on both market valuation and operating performance was negative [Adams and Ferreira 2008]. This negative effect, they explain, may be driven by companies with greater shareholder rights. In firms with weaker shareholder rights, gender diversity has positive effects. Therefore, given the Catalyst researchers' inability to control for variables such as business attitudes and shareholder involvement, we need to question their "face-value" conclusions.

Of additional concern should be politically forced and mandated measures creating gender diversity on boards. In 2003, the Norwegian Parliament passed a law requiring all public limited firms to have at least 40% women on their boards. Since then, researchers from the University of Michigan have investigated the consequences of this law. Ahern and Dittmar found negative impacts on firm value; however, they are quick to point out that the value loss was not caused by the sex of the new board members, but rather by their younger age and lack of high-level work experience [Ahern and Dittmar 2009]. Forcing gender diversity on boards for the sake of social equity produces inexperienced boards that can be detrimental to the value of individual companies, at least for the short run. What remains to be seen are the long-term consequences of such mandates.

Finally, some have argued that a diverse workforce fosters innovation. Overall patenting in all IT subcategories grew substantially between 1980 and 2005, but U.S. female patenting grew even more dramatically. All U.S. IT patenting for both genders combined grew from 32,000-plus patents in the period from 1980–1985 to 176,000-plus patents—a five-fold increase [Ashcraft and Blithe 2009]. For the same period, U.S. female IT patenting grew from 707 patents to more than 10,000—a 14-fold increase. This is particularly noteworthy because the percentage of women employed in IT remained relatively flat [Ashcraft and Blithe 2009]. Also, because women influence 80% of consumer spending decisions, and yet 90% of technology products and services are designed by men, there is a potential untapped market representing women's product needs [Harris and Raskino 2007]. Including women in the technological design process may mean more competitive products in the marketplace.

W. A. Wulf, the president of the National Academy of Engineering, notes one perspective on diversity: "Without diversity, we limit the set of life experiences that are applied, and as a result, we pay an opportunity cost—a cost in products not built, in designs not considered, in constraints not understood, and in processes not invented." On the other hand, concerning the research on diversity, Thomas A. Kochan, MIT Professor of Management and Engineering Systems, has said: "The diversity industry is built on sand. The business case rhetoric for diversity is simply naïve and overdone. There are no strong positive or negative effects of gender or racial diversity on business performance." Kochan does, however, acknowledge, "there is a strong social case for why we should be promoting diversity in all our organizations and over time as the labor market becomes more diverse, organizations will absolutely need to build these capabilities to stay effective" [Kochan 2010]. The most parsimonious current summary is that there may be some benefits of gender diversity, but that there may be costs as well.

What Can Society Do to Reverse the Trend?

The research on the causes of the gender imbalance in CS professions has created many passionate debates that suggest a need for change. Some argue that women are choosing what they wish to do—and it is medicine (where women are 50% of new MDs), veterinary medicine (where women are 76% of new DVMs), and fields such as biology (where women are also at parity with men; see [Ceci and Williams 2010]). But if our society were to wish to explore options for encouraging more women to enter CS, what might we do? Can the trend toward an overwhelmingly male CS field be reversed? Fortunately, research has looked beyond why so few women are in CS; studies have also examined potential interventions dealing with culture, curriculum, confidence, and policy.

Research and initiatives at Carnegie Mellon serve as an excellent paradigm for evidence-based intervention in CS instruction at the post-secondary level. Some of these approaches include interdisciplinary courses that bring students of diverse backgrounds together to work on multifaceted problems, an undergraduate concentration on human-computer interaction, and a course that engages students with nonprofit groups in the local community, applying their skills to community issues [Margolis et al. 2000]. Additionally, Carnegie Mellon has found that directly recruiting women has a strong effect on increasing women's participation in computer science. Through their recruitment program and the programs previously outlined, they raised their proportion of women undergraduate CS majors from 7% in 1995 to 40% in 2000. Despite an overall decrease in enrollments in computer science across the country, in 2007, Carnegie Mellon represents a positive outlier, with 23% female enrollment.

Implications of Cross-National Data

In 2004, Charles and Bradley analyzed data from the Organization for Economic Cooperation and Development (OECD), focusing on higher-education degrees awarded in 21 industrialized countries. As expected, women predominated in traditionally female-typed fields such as health and education, and lagged behind in stereotypically masculine fields [Charles and Bradley 2006]. In all 21 countries, women were underrepresented in computer science (Table 13-1). What was surprising, however, were the results as far as egalitarian versus nonegalitarian countries are concerned. One might expect the underrepresentation of females (or the overrepresentation of males) to be greatest in nonegalitarian countries. However, Turkey and Korea, countries not known for equality of the sexes, have *smaller* male overrepresentation factors (see Table 13-1). This could, in part, be due to policy issues mandating both genders' participation in computer science experiences. Note that the overrepresentation values show the factor by which men are overrepresented in computer science programs in each respective country (see [Charles and Bradley 2006] for a complete discussion on how these values were calculated).

TABLE 13-1. Male "overrepresentation factor" in computer science programs, 2001[a]

Country	Factor of overrepresentation
Australia	2.86
Austria	5.37
Belgium	5.58
Czech Republic	6.42
Denmark	5.47
Finland	2.29
France	4.57
Germany	5.58
Hungary	4.66
Ireland	1.84
Korea, Republic	1.92
Netherlands	4.39
New Zealand	2.92
Norway	2.75
Slovak Republic	6.36
Spain	3.67
Sweden	1.95
Switzerland	4.66
Turkey	1.79
United Kingdom	3.10
United States	2.10

[a] Values give the factor by which men are overrepresented in computer science programs in the respective country. They are calculated by taking inverse values of the "computer science" parameters from previous calculations (see McGrath Cahoon and Aspray, 2006 in Chapter 6 and [Charles and Bradley 2006]) and converting the resultant positive values into exponential form.

Charles and Bradley's research does not support standard arguments of social evolution theory, since the most economically developed countries are not producing greater numbers of women in computer science. Likewise, the authors show that there is not a strong correlation between the number of women in the workforce or in high-status jobs and the number going into computer science. These findings again suggest that the reasons for women's underrepresentation in computer professions are more likely found in the realm of culture than biology, a realm in which change is possible. But it is critically important to note that this research also provides little evidence that women's representation in computer science programs is stronger in the most economically developed countries, or that it is stronger in countries in which women participate at higher rates in the labor market, higher education, or high-status professional occupations [Charles and Bradley 2006]. Thus, the role of women's preferences emerges as the most likely explanation for where women end up, as opposed to explanations implicating biases as preventing women from entering CS.

The underrepresentation of women in computer science in all 21 countries studied indicates that there is a deep, shared belief in a given culture that women and men are better suited for different jobs. What makes the work of Charles and Bradley so interesting is that, with so much cross-national variability, there is a lot of room for social and cultural influences to play out. In the United States, we emphasize free choice and self-realization as societal goals that education seeks to nurture; yet the prevailing stereotypes may secretly stifle students' "free" choice as they pursue fields that are in line with the conventional identity of being male or female in our culture. Charles and Bradley observed that the governments exerting strong controls over curricular trajectories, such as Korea and Ireland, had less female underrepresentation in computer science. This suggests that we may want to defer adolescents' career choices to a time when gender stereotypes do not have such a stronghold on them, and implement policies in which students explore math and science, including computer science, from kindergarten to 12th grade and beyond.

Conclusion

In this chapter we have provided recent evidence to help the reader navigate and explore the question of why so few women pursue CS careers, why we should care, and what, if anything, should be done about it. We have looked at areas of biological differences between males and females that are coupled with cognitive-ability differences, especially in gifted individuals; differences in career and lifestyle preferences; and the culture of the computer science milieu. Despite clear gaps in understanding about the relationship between gender and participation in CS/IT, it is worth debating the costs of acting versus not acting to encourage more women to participate in CS, within the context of the empirical literature on women in science.

In short, some in industry and business argue that the paucity of women in CS/IT-related fields is a detriment to the economic advancement of women and the economic development of our nation—and some have argued the opposite. Although some transnational comparisons of women's underrepresentation in CS [Charles and Bradley 2006] call into question the value of interventions, on the whole it does seem wiser for policy-makers to work toward broadening both genders' exposure to computers at an early age, when students are not so entrenched in gender identity roles. Given potential benefits to women and society, it seems advisable to consider steps that may encourage women to enter the fields of Information Technology, Computer Science, and Computer Engineering. Cultural, curricular, and confidence-oriented interventions have been suggested by various authors [Margolis et al. 2000]; [AAUW 2000]; [McGrath Cohoon and Aspray 2006], and should continually be assessed regarding whether they are effective in the first place, whether they advance or hinder female participation in the field of computer science, and whether these changes in fact enhance the field. The ultimate goal should be the quality, effectiveness, and advancement of the CS profession, regardless of whether this means that the futuristic view of CS is largely male, largely female, or somewhat more gender balanced.

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