Defining and Redefining Gender Equity in Education

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CHAPTER 6

GENDER EQUITY AND TECHNOLOGY

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Author's Note: *This chapter contains an overview of gender equity and technology, reviews what we know about the status of girls and women in technology education and occupations, and discusses what the research tells us about the causes of and remedies for women's relatively sparse participation in the technology field.*

We are writing this review of current literature in 2001, a time when, according to predictions made by feminists in the 1970s and 1980s, the new field of computers, unlike the trades, would surely be fully sex-integrated. In the year 2000, women were 2.7% of electricians, 1.7% of carpenters, and 1.2% of car mechanics. Compared to that, women's representation among computer programmers at 26.5% is wildly successful (Bureau of Labor Statistics, 2001).

But is it? In fact, the percentage of women enrolled in computer science programs and embarking on high-tech careers has declined steadily since the mid-1980s and engineering has increased only slightly. For example, while women earned 37.1% of the computer science degrees awarded in 1984, only 26.7 percent of those degrees were awarded to women in 1998 (Camp, 2001).

The shortage of computer personnel has reached such a critical stage that the National Science Foundation characterizes the under-representation of women and minorities in computer science as "a serious national problem" (2001, p. 4). Given that computer technology is the primary technical gateway to the economy of the twenty-first century, society as a whole benefits by increasing the number of women in computer science careers.

According to the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (2001), the absence of women and under-represented populations deprives corporations of skills and competencies that translate directly into economic gains, stating, "This competitive advantage holds true not just for American industry, but for the national scientific and engineering enterprise as a whole" (p. 12).

Let's first review the current situation of girls and women in computing and other major technologies, to get a baseline understanding. We will examine the statistical data, followed by a review of what educators across the country have found in studies at K-12 level and in institutions of higher education.

THE CURRENT STATUS OF GIRLS AND WOMEN IN TECHNOLOGY

There are several sources of data on course-taking, degrees, and occupations. Together they give us a fairly coherent picture of the situation.

High School

College Board figures show that among high school students who took the SAT exams in 2000, girls were more likely to take computer courses in applications, and boys were more likely to take programming (see Table 1).

Another way to look at programming, the most generative computer activity and the one that typically leads to careers in computing, is to look at Advanced Placement exam scores in computer science. In recent years the AP CS exam language has been C++ (see Table 2).

Table 1. Computer Course Work or Experience of SAT test-takers, 2000

Course	% male	% female
Computer literacy	45	55
Word processing	60	40
Spreadsheets and databases	48	52
Internet activity	46	54
Using computer graphics	53	47
Programming	60	40

Source: www.collegeboard.org/sat/cbsenior/yr2000/nat/natcom00

Table 2. Computer Science Advanced Placement Exams Taken by Girls

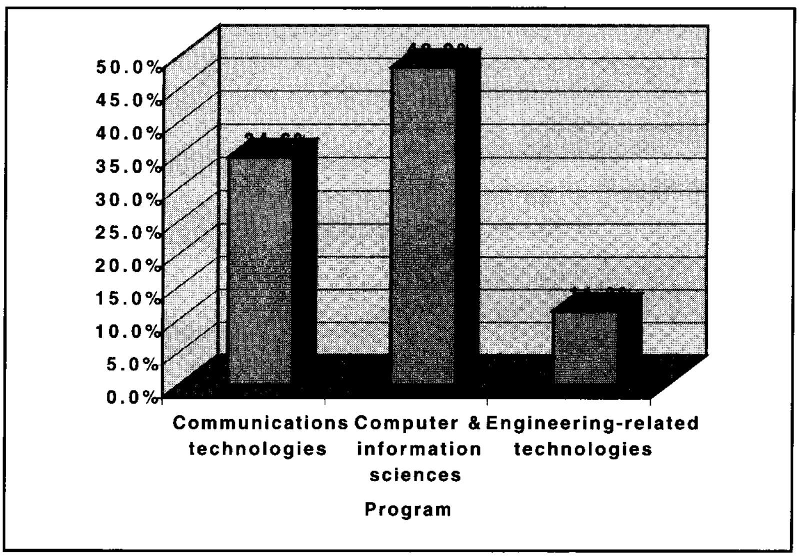
Exam	Girls as test-takers, 2001
A (one-term course)	17.1%
AB (full-year course)	9.1%

Source: College Board, 2000 and 2001

The one-term "A" course showed a small increase (0.5%) in girls' participation from 2000 to 2001, but in the two-term "AB" course, which is taken by many fewer students nationally, considerably fewer girls took the test in 2001 than in the year before: 9.1% vs. 10.8%. In fact, there were so few girls taking the AB exam in 2001 that they averaged only 16 per *state*, compared to 132 per state for boys.

Associates' Degrees

Data on associates' degrees suffer from a great deal of aggregation. For example, the data on Computer and Information Sciences aggregates such dis-



Source: Digest of Education Statistics 1999 (Table 252).

Figure 1. Percentage of Associates' Degrees Awarded to Women, 1995

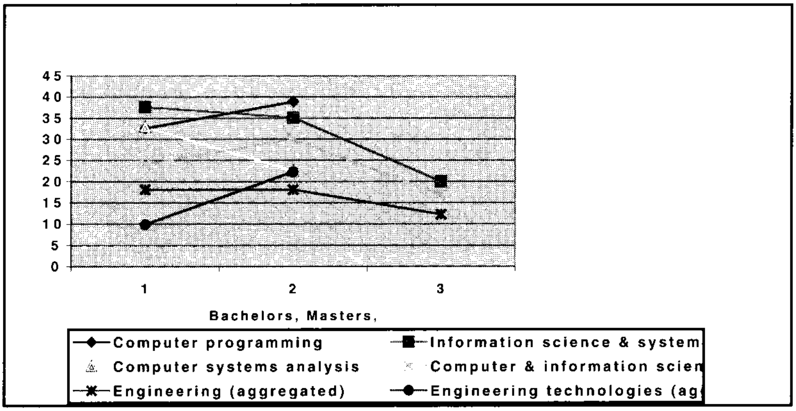
parate areas as programming and computer-based office applications, and as such is not especially valid for our purposes. It may be that the figures for the less aggregated Engineering-Related Technologies is a better example of women's presence in these technical fields.

Bachelor's, Master's, and Ph.D. Degrees

Data on bachelor's, master's and doctoral degrees are reported separately from associate's degrees by the National Center for Education Statistics, so we present them separately here. The more technical science degrees awarded to women are variable, depending on the field. The typical pattern of lower female participation rates with higher degrees is beginning to change with the reality that women are increasingly earning a larger percentage of masters' degrees than bachelors' degrees. In other words, more of the women who enter the pipeline are staying for a master's. Women's participation rate tends to drop precipitously for the doctorate. In Figure 2, there are no Ph.D.s shown for computer programming and engineering technologies because these are not doctoral fields.

Occupations

Data on women in computing careers is unsatisfactory. To the best of our knowledge, there is no reliable, wide-scale, disaggregated source of such



Source: Digest of Education Statistics 1999 (Table 258).

Figure 2. Science Degrees Awarded to Women, 1997

information available. According to Tracy Camp, an expert on the pipeline aspect of women and computing, the lack of data may be due to employers' reluctance to publish the actual figures (Camp, personal communication, October, 2001). We think it might also be a question of non-comparable job titles that make comparisons difficult. Be that as it may, here are the figures for women's presence in computing careers according to the U.S. Department of Labor. Occupational data are unfortunately quite aggregated in terms of job titles, and therefore of limited usefulness.

Table 3. Women in Computing Occupations, 2000

Occupation	Total Employed	Women as % of Total
Computer programmers	699,000	26.5
Computer systems analysts & scientists	1,797,000	29.2
Operations & systems researchers and analysts	227,000	45.5

Source: U.S. Department of Labor, Bureau of Labor Statistics. Household Data Annual Averages, Table 11.

From the national statistics we can draw several conclusions. First, according to the Bureau of Labor Statistics (2001, Table 14), women tend to enter technological fields at slightly older ages than men. They often have family obligations making it harder for them to obtain a new skill set. Second, women remain a minority in most areas of computing. And finally, the percentages of women in upper-level degree programs and in computer occupations in general are not likely to increase radically any time soon, given the pipeline realities above.

WHAT WE KNOW ABOUT WHY FEMALE PARTICIPATION IN COMPUTING IS LOW

In thinking about the reasons for women's low participation in computer science, it is helpful to make a distinction between low recruitment results—factors that discourage women from enrolling computer science in the first place—and low retention, or factors that operate to discourage women once they are in computer science programs. At this point, we actually know quite a lot.

Observational studies and interviews with school-age children tell us a great deal about how children use computers in classrooms and who is likely to use them. At the post-secondary level, statistical data such as grade point averages, SAT scores, and scores on the Advanced Placement Examinations provide a basis for numerical comparison between men and women. We can also compare the students' previous experience with computers and prior coursework completed in high school. When added to data obtained through interviews, surveys, and observations, we can get a good picture of what factors affect the enrollment and retention of women in post-secondary computer science programs.

Recruitment Factors

We must start with the environmental factors that are present in the society at large that shape the attitudes and expectations of all of us, adolescents and young adult included. Children's toys have been and remain sex-stereotyped, with electronic and computer games marketed primarily to boys (Carver, 2000; Spertus, 1991). Software games for the home have been and remain of primary interest to boys, featuring war, violence, and competition (Pearl, Pollack, Riskin, Thomas, Wolf, & Wu, 1990). Home computers have just recently been found to be used equally by girls and boys aged six to 17 (Roper, 1999); in all earlier surveys they were used more by boys. It has been reported that when parents hold gender stereotypes about computing favoring sons, their attitudes adversely affect daughters more than sons (Shashaani, 1994).

The AAUW Educational Foundation conducted focus groups with 70 East Coast middle school girls and learned that many of them expressed disinterest in computer careers because they saw the field as boring (AAUW Educational Foundation, 2000). Specifically, they objected to the way boys tend to substitute the computer for the world (p. 8). They said that computers are a waste of time (p. 8). They saw computer workers as lonely, with lone workers sitting by themselves in a cubicle all day (p. 9). Girls tended to be disinterested in the computer's insides or capabilities apart from what they want the computer to do for them, again as opposed to many boys' patterns (p. 9).

According to Jan Harding (1996), unconscious stereotyping on the part of school staff plays a role in perpetuating inequity. The unstated assumptions often contribute to inequitable computer use patterns. The Northwest Educational Technology Consortium (NETC, 2000), suggests that assumptions like these play a role:

- Girls do not like programming.
- Boys are more interested in computers and technology than are girls.
- Girls are not interested in computers because they associate them with math, machines, and programming—subjects in which they are also less interested.
- Girls are only interested in what a computer can do, not in computers as subjects of study.

Teachers with these attitudes subtly transmit them to girls. They unconsciously discourage girls from taking more computer courses and eventually from pursuing degrees in technical fields (NETC, 2000).

Another factor that discourages enrollment and recruitment is the chicken-and-egg factor of lesser experience with computing. As Dryburgh put it in her review of the research, "Prior computing experience is associated with greater success in computer education at the post-secondary stage. All studies indicate that women are less prepared than men entering CS, or they believe themselves to be less prepared" (Dryburgh, 2000, p. 193).

Several studies have identified women's lower self-confidence with respect to computing as a factor that discourages enrollment (Blum, 2001; Higher Education Research Institute, 2001; Margolis, Fisher, & Miller, 1999; Shull & Weiner, 2000;). This factor must be seen against the background of years of research in cognitive psychology showing that women tend to undervalue their ability and men to overvalue theirs, leading respectively to under- and over-confidence (Arnold, 1995; Sax, 1995; Margolis et al., 1999). Computer specialists are perceived in our society to be highly intelligent—along the stereotypical lines of brain surgery and rocket science—and women rarely perceive themselves as highly intelligent (Arnold, 1995). "Women are half as likely as men are to rate their computer skills as 'above average' or 'top 10%' relative to people their age" (Higher Education Research Institute, 2001). Indeed, Ware and Dill (1986) found that the most salient difference among same-ability male and female science students lay in their level of self-confidence, with females reporting lower levels (Seymour & Hewitt, 1994; Camp, 2001).

Girls have less high school preparation in computing than do boys, which in turn discourages them from enrolling in college-level computer science programs (Margolis & Fisher, 2001). Given the competitiveness of many college computer science departments, students without adequate background in mathematics and science are likely to be rejected as applicants. For example, Carnegie-Mellon University's Department of Computer Science, before and during the period of their four-year study, accepted only one-sixth of their applicants (Margolis & Fisher, 2001).

Students' perceptions of computing in general might well affect enrollment statistics. One Australian study has identified secondary and post-secondary female computing students' misperceptions about computing and those who do it as one possible cause of their failure to enroll in computer science classes (Clarke & Teague, 1996). However, in a similar study in London, Schott and Selwyn (2000) found that while the stereotype of the "frequent computer user" is negative and discourages female participation, the actual personalities of frequent computer users are indistinguishable from those who are not computer users.

Finally, men are more likely to choose undergraduate majors based on projected income than are women. In a longitudinal study, researchers found that computer science and engineering were among the highest paying fields upon graduation with an undergraduate degree (Eide & Waehrer, 1996). By extrapolating the data from the National Longitudinal Study beginning in 1972, they determined that women were much less likely to select majors that led to lucrative careers than were men. Blakemore and Low (1984) theorized that women chose majors in the liberal arts that were less likely to lead to careers that interfered with marriage and child-rearing, although the reverse causation is also possible. Paglin and Rufolo (1990) found that mathematical ability was an important factor in the choice of academic major, and that differences in mathematical ability accounted for the gender differential in wages and occupational choices in recent graduates.

Retention Factors

In addition to the fact that women enroll in computer science programs at the college level in smaller numbers than men, they also drop out and transfer out of computer science in greater proportions than do men. Researchers at the City University of New York studied their attrition rate in computer science classes: 44 percent of the women switched to majors away from computer science, in comparison to 29 percent of the men (Sturm & Moroh, 1995). They found that the women students actually outperformed men by academic measures such as grades, but the women students attributed superior skills to male students. These findings are consistent with those from a national study, which reported that women's negative "self-reports are independent of actual performance levels (Seymour & Hewitt, 1997, p. 236).

One major barrier that has been identified is the "male culture" of computing. Women computer students at Carnegie Mellon University spoke openly about the "geek" culture in which they found themselves. The women's focus on computing was "less single-minded and intense than that of their male peers" (Margolis, Fisher, & Miller, n.d.-a, p. 2) and women were more interested in the uses of computers, or tools that could be used for social good, rather than as objects of fascination—"hacking for hacking's sake" (Margolis et al., n.d.-a, p. 2). This theme has been echoed by Turkle, who says that on the whole, men and women bring different interests and orientations to computer science (Turkle, 1988). Maria Klawe notes, "As a traditionally 'nerd' culture, we tend to teach computer science in ways that appeal to nerds (as students and as instructors). We tend to value abstractions rather than examples, technology rather than applications" (Klawe, 2001, p. 5).

As they progressed, women students began to feel that they didn't belong in the computer science department, and many switched majors rather than face continued marginalization. Women who were able to resist the cultural norm found they could define their personal relationship to computing and retain their self-confidence. These women concluded that they could become computer scientists without becoming "geeks" (Margolis & Fisher, 2001).

A related factor is the different experience level with computers reported by undergraduates, which plays an important role once students are actually in courses. Seymour & Hewitt (1997) discuss women's frequent frustration with their lower experience levels, with one woman saying, "The guys definitely have all the advantages ...Their fathers teach them useful stuff when they're little." (p. 242). The Carnegie Mellon interviews found women students who thought they were experienced with computers when they entered, but quickly discovered that many male students lived and breathed computers with a consuming passion that excluded all else. The women's computer experience paled in comparison. (Margolis & Fisher, 2001). In a survey of computer science undergraduates, males and females were equally frustrated over a perceived assumption on the part of the department that they were required to know more than they actually did upon entering (Bunderson & Christensen, 1995). However, Margolis found that foreign female students sometimes entered the CS program at Carnegie Mellon with no prior computer experience at all, and did well nevertheless because they had no other option if they wanted to stay (Margolis & Fisher, 2001).

Feeling themselves marginalized and inexperienced, women's self-confidence erodes. In a large national study of engineering students, it was found that "the perceived levels of self-confidence of females in engineering and physics courses is lower than that of male students in these areas. In addition, females report an overall lower level of academic confidence than do males" (Metz, Brainard & Gillmore, 1999). In the same survey, there was no sex difference in students' self-confidence levels in mathematics or chemistry.

Discrimination plays an active as well as a subtle role. Many females report insults and putdowns from male classmates and instructors (Bunderson & Christensen, 1995). Spertus (1991) notes that the blatant discrimination that women find within computer science classes includes sexist and sexual humor (often on the part of professors and male students alike), sexual displays and discussions, different treatment for men and women students, and sexual harassment. Women report that male classmates tell them they are in the CS program "only because they are women" (Dryburgh, 2000; Margolis, Fisher, & Miller, n.d.-b). Told they don't belong there, many women naturally start to doubt their ability. This may be why some women resist special services for women: it calls attention to their "different-ness" (Spertus, 1991).

Poor teaching is a factor that affects both males and females, and is recognized equally as a problem by both males and females. However, females apparently perceive poor teaching as more of an insuperable barrier than males do, and switch out of technical majors more because of it (Seymour & Hewitt, 1997).

Robst, Russo, and Keil (1996) tracked the first-year retention rates of women students enrolled in science, mathematics, and computer science courses at Binghamton University for a four-year period. There was no significant overall difference in the retention of female students who took classes taught by women faculty and those that did not, but the researchers found a significant positive relationship between the retention rates and those women students that took math, science, and computing classes taught by women instructors. A dearth of women faculty in computer science classrooms may well underscore the lack of a significant source of support for women students (Pearl et al., 1990).

Successful Strategies and Programs

A great deal of effort has been dedicated to closing the "digital divide" and removing the reasons for the shrinking pipeline in computer science (Camp, 1997). However, much of this effort has been localized, with small, scattered projects rather than a truly collaborative effort among the research communities (Martin & Wardle, 1999).

To understand the kinds of changes that organizations and institutions are making around the country, we have to examine the recommendations that have come from research, professional organizations, and successful programs. The strategies listed here have been tried in a piecemeal fashion. Some of these strategies have resulted in increased enrollment of women students; others are recommended as best practices.

Strategies for girls at the **K-12 level** include:

- Inspire curiosity about computers by showing them to be fun and exciting (Rifkin, 1995).
- Demystify computer science by bringing girls into direct interaction with computer science professionals (Madison et al., 1999; Rifkin, 1995).
- Tell girls about the challenges and rewards of a career in computer science (Rifkin, 1995).
- Develop participants' confidence about their likelihood of success in computer science careers (Rifkin, 1995).
- Develop in-class computer software and projects that are interesting to girls (Harrelson, n.d.; NETC, 2000).
- Introduce teachers to practices that promote equity in the classroom (Madison et al., 1999; NETC, 2000).
- Develop mentoring programs with women in industry and with local computer science students at colleges and universities (Walker & Roger, 1996).

- Encourage local schools to complete a self-study on equitable treatment and allocation of computer resources (NETC, 2000).
- Give girls early, positive exposure to computers (Harrelson, n.d; Littleton, 1996.).
- Design software for a female audience (Littleton, 1996).

At the **postsecondary** level, perhaps the most comprehensive and the most widely disseminated program is the intense multi-year effort of Carnegie Mellon University's Department of Computer Science (Margolis, Fisher, & Miller, 1999). The initial approach to examining the dearth of women students began with a series of longitudinal interviews with both men and women students. Statistical data such as SAT scores, number of prior computer classes completed, job experience, grade point averages, and other numeric data enhanced the qualitative information. It became clear that:

- Men students were far more experienced with computers and programming than women students.
- The competitiveness of the department was supported by a white, male culture that appeared to be entirely focused on computers.
- The environment eroded the confidence of women students, who became marginalized.
- Once women students lost their self-confidence, a loss of interest in computing quickly followed, and at this point women left the department.
- The curriculum itself appeared to students to focus on programming and resulted from the dominant, male culture.

To counter these problems, the computer science department instituted sweeping changes. Admission to the department depended less upon the experience level of the applicants, and the department developed multiple points of admission. Administrators and faculty examined the pedagogy and curriculum, and changed courses. They added courses that linked computing to other subjects. They split large lecture courses into smaller sections differentiated by experience level. The objective was to offer introductory courses that did not make women feel inferior. Professors added meaningful, cross-disciplinary projects to their classes (Margolis & Fisher, 2001).

The department created numerous sources of support for women students, particularly through a body called Women @ SCS Advisory Council (Blum, 2001). This advisory council's goals included:

- Fostering a supportive peer environment.
- Organizing outreach activities for girls and women.

- Community-building and mentoring by pairing advanced women students with incoming women.
- Providing the department with advice on matters concerning women.

Researchers also examined the characteristics of women who persisted. Those women (Margolis & Fisher, 2001):

- Looked past the male culture and established their own comfort levels with computing.
- Found sources of peer support with other women.
- Maintained confidence in the face of more knowledgeable peers. They didn't measure themselves against the male norms.

It may not be possible for all computer science departments to make these kinds of sweeping transformations, but there is no question of the impact of the changes. In 1995, women comprised 7 percent of the incoming class. By 1999, that number rose to 37 percent. Approximately 42 percent of the incoming 2000 class was female. The computer science department at CMU also experienced an increase in the retention of women students. At the beginning of the program, the attrition rate for women was nearly double that for men. According to Margolis & Fisher, drop out rates for both men and women have declined steadily (2000).

There were many other programs at the college and university level to attract and retain women students. Among them, they offer these strategies, some of which have resulted in increased retention rates and some that are recommended as best practices:

- Introductory computer science courses should respond to varying levels of experience. Projects should be real-life exercises that entail hands-on experience (Shull & Weiner, 2000).
- Fully use professional women's organizations such as Computer Research Association-Women (CRA-W) and the Association for Computing Machinery-Women (ACM-W). These organizations can serve as a source of visiting women speakers and role models for women students (Camp, 2001).
- Arrange cooperative learning projects with other departments and the community that involve combining other subjects and computing. These projects should develop a sense of community, build self-confidence, and discourage isolation (Blum, 2001; Klawe, 2001)
- Develop support groups among those women students who want them. Use e-mail lists to build electronic communities (Single, Muller, & Cunningham, 1999; Walker & Roger, 1996).

- Build in flexibility with course scheduling to allow students to take courses around the demands of their lives. Allow flexible, part-time enrollment options for students with family obligations (Hassoun & Bana, 2001).
- Increase the number of women faculty and encourage them to act as mentors for women students. Ensure that women are represented on all committees and at all departmental functions (Camp, 2001; Hassoun & Bana, 2001; Robst et al., 1996).
- Create a positive departmental atmosphere by encouraging the use of inclusionary language and educating faculty on gender equity in the classroom (Harrelson, n.d.; Pearl et al., 1990; Spertus, 1991).
- Encourage women to examine computer science career choices in terms of a financial return on their investment as well as sustain interest in the social aspects of computing (Eide & Waehrer, 1996).

There are a variety of ways that these recommendations can be implemented in programs to help women and girls. We have included examples of some of these programs so that you can determine strategies that could work for your institution. To be effective, your strategies have to respond to the needs, issues, and policies at your institution. Here are short descriptions of postsecondary programs that have claimed success:

NETC (2000) provides visitors to its website with a series of questionnaires that can be used in a self-study. The purpose of the study is to help educators determine if their computer resources are distributed and used equitably by all students regardless of gender or race.

Pipelink (Walker & Roger, 1996) was aimed at linking girls and women from high school through the Ph.D. level to create female role models for computer science students. The activities in this program included electronic lists, chat rooms, and bulletin boards, high school visits, workshops, and summer camps and institutes.

MentorNet (Single, Muller, & Cunningham, 1999) set up a series of e-mail lists for women in engineering to build electronic communities. Success varied widely and depended upon the number of people subscribed to the specific list, list topic, and list activity.

Shull and Weiner (1999) instituted a two-credit course in building a computer to introduce hands-on activities for women in introductory engineering courses. The class helped women students overcome their fears about inexperience, built self-confidence, and encouraged the women students to become "gurus not geeks."

Alternate Routes to Computing (ARC) is a two-year post-baccalaureate program (Klawe, 2001) designed to attract non-technical professionals, women, and mature students who want to combine their career fields with computer science. The coursework can form the basis for a degree in computer science. Graduates of the program, many of whom are older women (over 30), obtain positions in information technology.

Caltech (Rifkin, 1995) held a series of outreach programs for women, girls, and minority students. The purpose of the programs was to introduce these students to the real-world use of computers, demystify computers, and increase self-confidence. Presenters also told students about the benefits of a career in computer science.

In summary, then, there is a great deal of awareness of the gender gap in computer science, and programs are beginning to proliferate to close it. In terms of gender awareness and progress, technology may be at the same place now that mathematics was in the 1970's and science in general was in the 1980's. If this is so, history would indicate that substantial progress in women's participation in computing will occur soon. We hope that a chapter on the status of women in computing written ten years from now will show a much brighter picture.

NOTE

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