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## TAKING STOCK: WHERE WE'VE BEEN, WHERE WE ARE, WHERE WE'RE GOING

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*Focusing on “where we’ve been, where we are, and where we’re going,” the authors examine minority women’s and White women’s progress in science, mathematics, engineering, and technology (SMET) over the past decade. Starting from an exploration of participation and achievement data, the authors move on to cover the theories behind SMET gender differences, including those based on testing, biology, social-psychology, and cognitive sciences. Looking at practice as well as theory, the authors explore the impacts that interventions and contextual influences, such as societal change and education reform, have had on efforts to achieve gender parity in SMET. The article concludes with the recommendation of logical next steps to preserve and expand the gains made by women in these fields.*

### INTRODUCTION

The purpose of this article is to trace the trajectory of women’s progress in science, mathematics, engineering, and technology (SMET) over the past decade and suggest directions for the future of women’s participation in these fields. To do this, we track indicators of women’s progress toward attaining parity, review the research and theories that attempt to explain reasons for male-female differences in SMET participation, consider the role of intervention approaches (on the basis of the findings of research) in addressing these inequities, and discuss contextual influences such as societal change and education reform on efforts to achieve gender parity in SMET. We ask the question, Given the advances made by women in SMET up to this point, what are logical next steps to preserve and expand the gains made by women in these fields so that true parity<sup>1</sup> may be achieved? Answering this question will require an identification of gaps that still remain to be closed, as well as fundamental premises that may need to be reexamined. Figure 1 shows the conceptual framework that guides our thinking about these issues.

According to our framework, differences between males and females in terms of SMET course taking, performance, degree attainment, and workforce participation have generated a number of theories to explain the differences. These theories can be grouped under four main headings: testing-based theories, biologically-based theories, social-

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<sup>1</sup>True parity will be achieved when an individual’s sex or race/ethnicity is not a predictor of his or her job or profession.

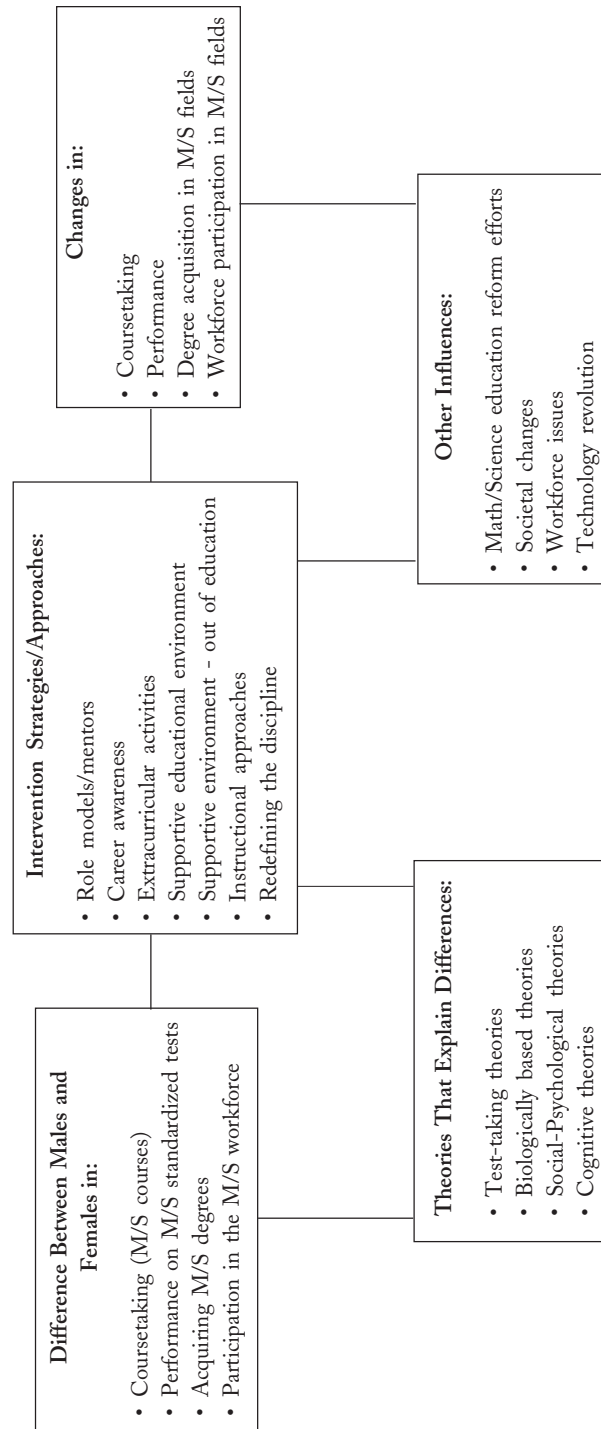


Figure 1. Conceptual framework.

psychological theories, and cognitively based theories, each of which attempt to explain the differential participation of women and girls in SMET fields. The theories and research studies suggest intervention approaches to address the problem of gender inequity in SMET. Some of these interventions have been widely implemented and may have contributed over time to the narrowing of gender equity gaps in course taking, performance, degree acquisition, and workforce participation. Concurrently, other influences, such as those of education reform, changes in society such as the women's movement, workforce pressures, and the technological revolution, may have also helped promote gender-equitable policies and practices. Finally, in a feedback loop, gender equity changes in SMET participation inform the explanations (theories) that we have constructed, resulting in the enhancement of our knowledge about the problem, which in turn results in changes in our approaches to the solution (intervention approaches).

### WHAT DO THE NUMBERS TELL US? PLUS ÇA CHANGE . . .

Over the past 20 years, there have been many changes in terms of girls' and women's achievement and participation in SMET. However, as the following overview of the most recent data on sex similarities and differences in mathematics and science participation and achievement indicate, the more things change, the more they remain the same.

#### Precollege Mathematics and Science Achievement and Course Taking

*National Assessment of Educational Progress (NAEP).* Between the 1990 and the 2000 NAEP, there was an impressive gain in mathematics scores for both 4th and 8th grade girls and boys. The percentage of 4th grade boys scoring at or above the proficiency level doubled to 28%, while the percentage of girls at that level doubled to 24%. Eighth grade results were similar, with an increase from 17% to 29% for boys and from 14% to 25% for girls. The 8th grade gender gap stayed fairly constant, while the 4th grade gender gap increased to 4%. At the 12th grade level, the percentage of boys at proficient or above increased from 15% to 20%, while the percentage of girls increased from 9% to 14%. While mean scores increased for 4th and 8th grade girls and boys, at the 12th grade level, boys' scores stayed stagnant and girls' scores decreased. There were small but statistically significant differences between boys' and girls' mean scores at the 8th and 12th grade levels, but not at the 4th grade level (National Assessment of Educational Progress, 2001a).

Science did not have the achievement gains found in mathematics. Between 1996 and 2000, mean science scores for 4th graders did not change significantly; neither did the percentage of students scoring at proficient or above. In 1996, 4% more boys than girls were at this level; in 2000, the figure was 7%. At the same time, 8th grade boys' mean scores increased significantly, from 151 to 154, while girls' scores did not, increasing the gender gap from two to seven points. The percentage of 8th grade boys scoring at or above the proficient level increased from 31% to 36%, while the percentage of girls at that level stayed at 27% (National Assessment of Educational Progress, 2001b). Twelfth grade boys' scores decreased significantly, while girls' scores did not, causing a minor change in the gender gap from four points to three. There was also a decrease in the percentage of 12th grade boys scoring at or above proficient (25% to 21%), with little change in the percentage of girls scoring at that level (17% to 16%).

NAEP reports do not break out mathematics or science scores by race and sex. This is a serious weakness that should be remedied in future reports released by the NAEP and by other governmental agencies. NAEP data from 1996, however, were broken out by race/ethnicity and sex in a 2001 Educational Testing Service (ETS) report (Coley, 2001). This report showed that in 1996, there were no gender differences in mean mathematics scores for all racial and ethnic groups, other than in fourth grade, in which White boys scored significantly higher than White girls. As Figure 2 indicates, however, on the basis of the 2000 data, NAEP mathematics achievement gaps between White students and African American and Hispanic students were much greater than those between girls and boys (National Assessment of Educational Progress, 2001a).

In science at ages 13 and 17, White boys had higher average scores than White girls, and at age 17, Hispanic boys had higher scores than Hispanic girls on the 1996 NAEP Science Assessment. There were no other significant gender gaps by racial and ethnic groups (Coley, 2001). As was the case in mathematics, NAEP science achievement gaps between White students and African American and Hispanic students were much greater than those between girls and boys. For example, on the 2000 NAEP Science Assessment, on average, 12th grade White students scored 30 points higher than African American students, while boys scored 3 points higher than girls (National Assessment of Educational Progress, 2001b).

*Scholastic Assessment Test (SAT) and American College Test (ACT).* Over the past 20 years, there have been increases in both girls' and boys' scores on the SAT: Mathematics (SAT I: Math), although overall, girls' scores have remained 35 points below those of boys (The College Board, 2001b). Among girls, mean SAT I: Math scores range from a high of 550 for Asian American girls to a low of 419 for African American girls. Across different racial and ethnic groups, with the exception of African Americans, for whom the sex difference is 17 points, the size of the sex difference is around 35 points (The College Board, 2001b).

Sex differences in ACT Mathematics scores are smaller (21.4 compared with 20.2), but almost twice as many boys as girls score at the two highest ACT levels (14% compared

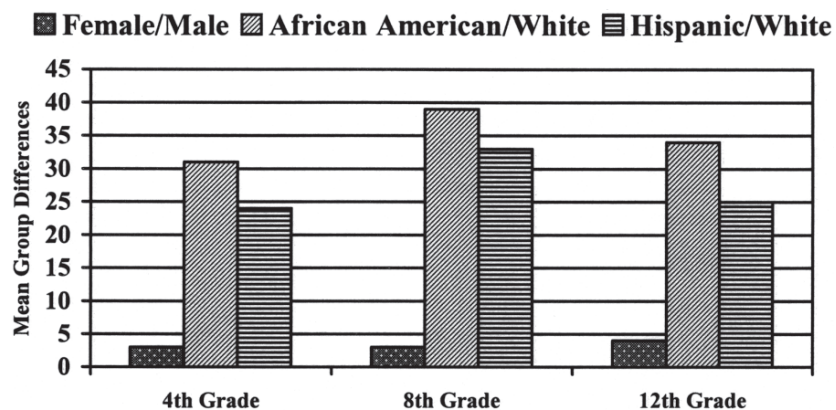


Figure 2. Group differences in National Assessment of Educational Progress 2000 Mathematics Scores.

with 8%) (ACT Inc., 2001). While the SAT I does not test for science, the ACT does. There are minimal sex differences in the mean ACT Science Reasoning scores (21.6 compared with 20.6), although again, almost twice as many boys as girls score at the top two levels of the ACT Mathematics test (12% compared with 7%) (ACT Inc., 2001). ACT data are not reported by race and by sex. As was the case with NAEP data, race differences on ACT scores were much greater than sex differences (ACT Inc., 2001).

To provide a more complete picture of sex and mathematics and science achievement, it is also necessary to look at the variability of scores by sex as well as at mean scores. There has been some indication that there is greater variability in boys' scores than in girls' (i.e., Bielinski & Davison, 1998). However, Willingham, Cole, Lewis, and Leung (1997) found little difference in the variability of scores on cognitive tests, including math tests that were given in the earlier grades. By Grade 12, they found very small sex differences in the variability of mathematics test scores over national samples. For every five boys in the top 10% of scores, there were more than four girls. For students in the bottom 10%, there were also more than four girls for every five boys.<sup>2</sup>

*Precollege mathematics and science participation.* Up through Advanced Placement (AP) courses, there are few sex differences in the mathematics courses girls and boys take in high school. Among high school graduates, girls are slightly more apt than boys to have taken geometry (77% compared with 74%), algebra II (64% compared with 60%), and trigonometry (10% compared with 8%), and are taking precalculus (23%) and calculus (11%) in the same proportions (Huang, Taddese, & Walter, 2000). Among college-bound seniors by 1999, about the same numbers of White, African American, and Asian American girls and boys were taking 4 or more years of high school mathematics, although Hispanic boys were more apt than Hispanic girls to take 4 or more years of mathematics (Coley, 2001).

Although girls make up the majority of those who take any AP exams, the percentages of girls and boys vary greatly by content area. There are some differences in the percentages of girls and boys taking AB calculus, with girls representing 57% of the students taking the exam. There are greater differences in the more advanced BC calculus, for which girls represent 39% of those taking the exam. The differences are far greater in AP computer science, where girls represent 17% of those taking the computer science A exam and 11% of those taking the more advanced computer science AB exam. Boys' mean exam scores in these areas were higher than girls', although the difference was minimal for AB computer science AB (The College Board, 2001a). To put the percentages in context, in spring 2001, approximately 800 girls and 6,500 boys took the computer science AB exam.

Among high school graduates, girls are slightly more apt than boys to have taken high school science courses in biology (94% compared with 91%) and chemistry (64% compared with 57%) and slightly less apt to have taken physics (26% compared with 32%) (Huang et al., 2000). In a pattern similar to that found in mathematics, among college-bound seniors by 1999, about the same numbers of White, African American, and Asian American girls and boys were taking 4 or more years of high school science, as were Mexican American students. Puerto Rican and other Hispanic boys were more apt to take 4 or more years of science than Puerto Rican or other Hispanic girls (Coley, 2001).

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<sup>2</sup>This assumes that the distributions are normal. If distributions are not normal, the imbalance could be smaller or larger.

There continue to be differences among those taking science AP courses. Boys represent the majority of students taking AP chemistry (55%) and AP physics B (65%), while girls represent the majority of those taking AP biology (56%). Boys' mean exam scores were higher than girls' in all three areas (The College Board, 2001a).

With some exceptions, sex differences in achievement and course taking are minimal, yet sex differences in SMET careers and in career aspirations are not. Among those taking the ACT or the SAT in 2001, 9% of boys and 2% of girls were planning to major in computer science, and 2% of girls and 11% to 12% of boys were planning to major in engineering. Percentages were much closer in the physical and biological sciences, in which between 4% and 5% of boys and of girls were planning to major (ACT Inc., 2001; The College Board, 2001b).

### College and Beyond

*Undergraduate and graduate enrollment and graduation.* Although in 2000, women entered college at a rate higher than men, overall, women in all racial and ethnic groups enrolled in science and engineering (S&E)<sup>3</sup> majors at a rate lower than men, as shown in Table 1. Women in some racial and ethnic groups, however, chose majors such as biological and agricultural sciences, mathematics and statistics, and social and behavioral sciences at similar or at greater rates than men. For example, for African American 1st-year students at 4-year institutions, 5.8 % of men compared with 8.6% of women intended to major in biological and agricultural sciences (Higher Education Research Institute, University of California, Los Angeles, 2000, cited in National Science Foundation, in press). A recent study by the U.S. Department of Education, National Center for Education Statistics (Bae, Choy, Geddes, Sable, & Snyder, 2000), also showed a substantial gender gap favoring men in enrollment in S&E among students attending 4-year colleges. This gap occurred mainly for White and Asian students and was larger than that between underrepresented minority students and White and Asian students. The enrollment rates of 25.4% for men compared with 12.3% for women in 1993 and 1994 showed only a slight narrowing of the gender gap from 1989 and 1990, when the comparable rates were 23.6% and 10.1%.

The gap widens considerably in specific S&E fields. In 1999, women represented only 20% of the total undergraduate enrollment in engineering programs, although this represents an increase from 16% in 1990.<sup>4</sup> Nevertheless, women still make up a small percentage of the engineering enrollments, although Asian, African American, Hispanic, and American Indian women constituted larger percentages of the engineering enrollment of their respective racial and ethnic groups than White women (National Science Foundation, in press). An encouraging development is that once women enroll in S&E, they are more likely to complete within 5 years (48.6% compared with 40.4%) and less likely than men to switch majors (11.5% compared with 19.4%). Although they are slightly more

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<sup>3</sup>S&E will be used in lieu of SMET because S&E is the term used by the two main sources of postsecondary data cited in this section to designate SMET fields. National Science Foundation data for S&E fields include the social sciences, while U.S. Department of Education data do not.

<sup>4</sup>Increases in the proportion of women enrolling in engineering programs may be inflated by the fact that women's enrollment increased each year from 1990 to 1999, while the number of men in these programs declined.

Table 1. Percentage of American Freshmen Choosing Science and Engineering Majors, by Race or Ethnicity and Sex, 2000

Race or Ethnicity	Total	Physical Sciences	Biological and Agricultural Sciences	Mathematics and Statistics	Computer Sciences	Behavioral Sciences	Social and Behavioral Sciences	Engineering
White	29.3	2.0	6.6	0.7	3.0	8.7	8.3	8.3
Men	37.0	2.5	6.0	0.9	5.6	6.7	15.3	15.3
Women	23.5	1.5	7.5	0.6	0.8	10.6	2.5	2.5
Asian/Pacific Islander	41.8	1.5	10.2	0.6	8.3	7.4	13.8	13.8
Men	51.8	1.7	8.5	0.7	13.3	5.5	22.1	22.1
Women	33.3	1.3	11.7	0.7	4.0	8.9	6.7	6.7
Black	34.7	1.2	7.5	0.5	6.0	11.1	8.4	8.4
Men	38.3	1.4	5.8	0.4	9.0	6.5	15.2	15.2
Women	33.0	1.2	8.6	0.5	4.2	14.1	4.4	4.4
Chicano/Puerto Rican	32.2	1.4	7.1	0.6	2.7	12.3	8.1	8.1
Men	38.4	1.7	7.1	0.6	5.1	7.7	16.2	16.2
Women	27.2	1.2	6.9	0.5	1.1	15.3	2.2	2.2
Other Hispanic	33.3	1.3	7.6	0.3	3.8	12.7	7.6	7.6
Men	40.1	1.8	6.8	0.3	7.4	8.5	15.3	15.3
Women	29.2	0.9	8.5	0.3	1.4	15.3	2.8	2.8
American Indian/ Alaskan Native	32.0	2.6	6.7	0.4	2.7	11.8	7.8	7.8
Men	36.6	3.6	4.9	0.4	5.1	8.2	14.4	14.4
Women	28.4	1.8	7.9	0.3	0.9	14.4	3.1	3.1

Source: Higher Education Research Institute, University of California, Los Angeles, cited in National Science Foundation (in press).  
 Note: Includes 1st-year students at all 4-year colleges. Because of rounding, percentages may not add up to 100.

likely to drop out (24.2% compared with 21.8%), this difference is not statistically significant (Bae et al., 2000).<sup>5</sup> The lower completion and higher switching rates, overall, of underrepresented minorities—both male and female—when compared to their White and Asian American counterparts suggests that underrepresented minority women are less likely to complete S&E bachelor's degrees than White and Asian American women. Completion, drop-out, persistence, and switching rates, however, are not available by sex within racial and ethnic groups (Bae et al., 2000a).

Women in 1998 earned close to half (48.7%) of all S&E bachelor's degrees (although they remained severely underrepresented in certain fields), up from 42.5% in 1990. African American, Hispanic, and American Indian women, in contrast to their White and Asian counterparts, received more than half of the S&E bachelor's degrees earned by their respective racial and ethnic groups in 1998. The narrowing of the gap in S&E degree attainment may also reflect the lower rate of increase among men who were awarded S&E degrees from 1990 to 1998. The number of women earning S&E degrees increased by 50,385 from 1990 to 1998, while the increase for men over the same period was a mere 11,139 (National Science Foundation, in press).

Once the degree attainment data are disaggregated, however, a different story emerges. In computer science, the proportion of bachelor's degrees awarded to women actually dropped from 30% in 1990 to 27% in 1998. And in fields such as aerospace engineering, electrical engineering, mechanical engineering, and physics, women still earned fewer than 20% of bachelor's degrees (National Science Foundation, in press).

In 1999, women represented 41% of all first-time, full-time S&E graduate students, an increase from 35% in 1990. Beginning in the late 1990s, they were more likely than men to enter graduate school after obtaining S&E bachelor's degrees (National Science Foundation, in press). Although women are enrolled at rates equal to or greater than those of men in S&E graduate programs in some fields, mainly the biological sciences, psychology, and the social sciences, they are extremely underrepresented in the physical sciences (29%), engineering (20%), computer science (30%), and mathematics and applied mathematics (36%). From 1990 to 1999, female graduate enrollment increased in all major S&E fields except mathematical sciences, while the number of men declined each year since peaking in 1992 (National Science Foundation, in press). Women do not seem to be more likely than men to drop out of S&E graduate study and have attrition and completion rates similar to those of men. Large differences between underrepresented minority students and Asian American and White students (favoring the latter) in terms of degree attainment and attrition suggest that underrepresented minority women may have lower completion rates than their Asian American and White sisters (National Science Foundation, in press).

In 1990, women earned 34% of master's degrees in S&E, compared to 41% by 1998. But female S&E graduate students, more than their male counterparts, are likely to expect to stop at a master's degree (72% compared with 58.1%), and they are less likely to expect to earn doctoral degrees (28% compared with 42%) (National Science Foundation, in press).<sup>6</sup> Nevertheless, the percentage of all S&E doctoral degrees awarded to women has risen over the years—from 28% in 1990 to 35% in 1999. In 1999, African American

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<sup>5</sup>These figures should be interpreted with caution, however, because of low cell frequencies for female persisters and switchers, though not for completers and dropouts.

<sup>6</sup>These data are based on the responses of male and female S&E graduate students who indicated their degree aspirations in the 1995 to 1996 National Postsecondary Student Aid Study.



women earned more than half and Hispanic women earned half of the S&E doctorates that were awarded to their respective racial and ethnic groups, while women in other groups earned fewer than half. From 1998 to 1999, however, the number of both men and women receiving S&E doctoral degrees dropped for the first time since 1980 (National Science Foundation in press). In spite of a steady increase in the number and percentage of the total S&E doctoral degrees earned by women from 1990 to 1999, women were still underrepresented in all S&E broad fields except for psychology, in which they earned 67% of all doctoral degrees in 1999. In several other S&E fields, women were sorely underrepresented, earning a much lower percentage of doctoral degrees than men in the physical sciences (23%, or 831), computer sciences (18%, or 156), and engineering (15%, or 791) (National Science Foundation, in press).

*In the S&E workforce.* Of people with S&E degrees, 35% of those employed and 24% of those employed in S&E occupations in 1999 were women. The percentages of life scientists, physical scientists, social scientists, and engineers who were female remained stagnant from 1993 to 1999; women, moreover, made up a smaller percentage of computer and mathematical scientists in 1999 than they did in 1993 (National Science Foundation, in press). Women with S&E degrees were less likely to be part of the labor force,<sup>7</sup> and those in the labor force were more likely than men to be unemployed (2% compared with 1.6% in 1999). Female scientists and engineers, moreover, whether unemployed or not in the labor force, were far more likely to cite family responsibilities, while men were more likely to cite retirement, as a reason for unemployment. Employed women with S&E degrees were less likely than their male counterparts to be employed in S&E occupations (22% compared with 38%); more likely to be employed part-time (19% compared with 6%); less likely to be employed in the private, for-profit sector (49% compared with 65%); and more likely to be employed in 4-year colleges or universities (21% compared with 12%). Within occupations, however, the percentages of women and men working in business and industry were similar.

Women who are employed full-time in S&E usually earn less than men (\$47,000 compared with \$62,400, median overall salary in 1999), with sex differences favoring men occurring across all racial and ethnic groups, most broad occupations, and age groups. Salary differentials between men and women in S&E have been largely attributed to differences in age, length of experience, type of occupation, and highest degree attained (National Science Foundation, in press).<sup>8</sup> The profile of the female S&E professional differs from that of the male professional. Women tend to be younger (for example, in 1999, a little under half were younger than 40), are less likely to be married, and are more likely to have problems in accommodating dual careers; they are almost twice as likely to have spouses who work full-time. Men and women in S&E careers, however, are equally likely to have children living at home (National Science Foundation, in press).

*So what do the numbers tell us?* At the precollege level, there remain some small differences between boys' and girls' scores on NAEP tests and college entrance exams, and the course-taking gap has almost closed, thus enabling women to enter SMET college majors at the same rate as men. Women, however, choose SMET majors at less than half

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<sup>7</sup>That is, either employed or seeking employment.

<sup>8</sup>A study by Olson (1999) that examined gender differences in academic tenure and rank showed, however, that except for women in biology or at comprehensive universities, women in S&E academic positions with certain characteristics were less likely to receive these rewards than their male colleagues with similar characteristics.

the rate of men, and the gender enrollment gap in S&E has remained relatively stable since 1989. The disparity is even more striking in fields such as engineering, physics, and computer science, though it is not present in biological and agricultural fields. Those women who do choose SMET majors, however, are somewhat more likely than their male counterparts to complete bachelor's degrees in SMET. Relatively few African American, Hispanic, and American Indian students—male or female—graduate from high school with the skills and knowledge necessary to continue on in SMET.

Women's enrollment in S&E graduate programs has increased steadily, but women are still acutely underrepresented in several fields, most notably the physical sciences, engineering, computer science, and mathematics and applied mathematics. Women are less likely to expect to earn doctoral degrees, and this is reflected in their low representation among S&E doctoral candidates. As with the undergraduate degree, however, once they enroll in a graduate program, women are as likely as men to earn the degree. Again, African American, Hispanic, and American Indian students, both female and male, who go on to college in SMET are much less apt to graduate than White and Asian American students.

Not much has changed in terms of women's representation in the S&E workforce. The proportion of women has remained relatively stagnant in recent years—and even declined in some occupations—in spite of increases in women's overall participation in the labor force. Lower salaries, more family responsibilities, the inequitable distribution of career rewards, and difficulties posed by dual careers are negative factors associated with women's employment in S&E occupations.

### WHAT EXPLAINS GENDER DIFFERENCES IN ACHIEVEMENT AND PARTICIPATION IN SMET?

Research that attempted to explain differential achievement and participation of men and women in SMET intensified in the mid-1970s, fueled by attention-getting reports that focused on women's participation in mathematics. A flood of research studies followed, funded by federal and private sources. We briefly review and summarize this large body of research in the following pages.

#### Testing-Based Theories: Measuring Man . . . or Woman?

It has long been known that it is possible to create or eliminate differences in test scores by selecting different test items. As early as 1942, test developers working on the revision of the Stanford-Binet IQ test knew that "intellect can be defined and measured in such a manner as to make either sex appear superior" (McNemar, 1942, p. 43). To "produce a scale which will yield comparable IQs for the sexes," the test developers "sought to avoid using test items showing large sex differences in percents passing" (p. 45).

Since McNemar's time, there has been much research and discussion on gender differences in test content and format and how this might contribute to gender differences in mathematics and science achievement. It has generally been accepted that girls tend to score better on open-ended or essay items (also called constructed response items), while boys tend to do better on multiple choice items (i.e., Bielinski & Davidson, 1998; Cole, 1997); nevertheless, Hamilton (1998) found boys having the advantage on high school

science achievement test constructed response items, while Supovitz (1998) did not find differences in girls' and boys' performance on science essay and performance tests.

A variety of studies have shown that girls score better on items dealing with algebra and boys on those dealing with geometry. Girls tend to score higher on more abstract items and those more directly related to the textbooks or "school-based knowledge," while boys tend to do better on visual spatial items and those "real-life" items dealing with problem solving and reasoning (e.g., Bielinski & Davidson, 1998; Burton, 1996; Garner & Engelhard, 1999; Hamilton, 1998). As former ETS president Nancy Cole concluded in 1997, the "degree of gender differences in test performance is often affected by the types of skills measured within the test" (p. 172).

Items favoring boys have tended to call on the application of knowledge commonly acquired through extracurricular activities, while girls were "least disadvantaged" on items most heavily dependent on school-based knowledge (Gallagher & DeLisi, 1994; Hamilton, 1998). It may be that sex differences do not result from differences in general or scientific reasoning ability or from teaching practices that favor men; rather, they may reflect in large part differences in outside-of-school experiences, particularly those that promote visual or spatial reasoning (Hamilton, 1998). There is an enormous gap in research of understanding the mathematics learning that children do outside the classroom (Hyde & Jaffee, 1998) and the implications that differences in out of school experiences may have on problem-solving methods just are not known.

Factors outside of test content and skills such as "stereotype threat" may have an impact on test results as well. Stereotype threat "refers to the experience of being in a situation where one recognizes that a negative stereotype about one's group is applicable to oneself" as in the stereotype that women do not do well in advanced mathematics. "When this happens, one knows that one could be judged or treated in terms of that stereotype, or that one could inadvertently do something that would confirm it...this threat of being negatively stereotyped can be upsetting and distracting" (Steele, 1998). Spencer, Quinn, and Steele (1999) found that being subjected to stereotype threat about women and mathematics depressed the scores of female students on a difficult math test, while being told that this was not the case improved their performance.

When looking at sex differences in test item, content, or context, it is important to remember, as Damarin (1995) pointed out, that there is a tendency to describe all female behavior as less competent than male behavior. There is a long history of this in mathematics:

In the 19th century calculation and computation were thought to be mathematics and outside the domain of acceptable female activity. When there was a need for cheap labor to "keep the books" arithmetical competence was no longer beyond the abilities of women nor dangerous for them! Today the same competence is associated with females and is a lower level skill. (p. 251)

Even today we call those skills "lower level computational skills" rather than labeling these same skills with higher status names such as "concern with, attention to, and appreciation of numerical detail" or "competence in handling numerical systems and their operators" (p. 246).

### **Biologically Based Explanations: Is Biology Destiny?**

Some theories are based on the assumption that biological or genetic differences directly account for most sex differences in mathematics- and science-related achievement

and thus participation. Most of the theories center on sex differences in spatial areas. Sample theories include the following:

- “Since both spatial and mathematical abilities are functions considered more efficiently carried out by the right hemisphere [of the brain], males’ significantly higher right than left hemispheric ratios for neuronal density and neuronal numbers could contribute to gender differences in these areas” (De Courten-Myers, 1999, p. 223).
- “Different prenatal or pubertal hormone exposure causes gender differences in visuo-spatial and verbal ability” (Rosser, 1997, p. 92).
- “Boys’ greater variability in test scores, which leads to more boys scoring at the highest achievement levels, may be the result of the natural selection and adaptation necessary for survival in early human history” (Buss, 1995, quoted in Bielinski & Davison, 1998, p. 458).
- “The section of the brain dealing with visuo-spatial ability being more tightly and exclusively organized in males than in females results in visuo-spatial differences” (Moir & Jessel, 1991, p. 89).

Some researchers, such as Benbow and Stanley (1980), strongly believe that sex differences in achievement and performance are due to fundamental, biologically based, differences in cognitive skills, while others, such as Noddings (1998, p. 17), are not so sure but feel that “the genetic argument” must be acknowledged as a possible cause of sex differences in mathematics.

Proponents of biological explanations for gender differences in mathematics, science, and engineering accept sex differences as extremely difficult, if not impossible, to change. Thus, they tend to have little interest in programs or efforts to increase girls’ and women’s participation in mathematics and science and little to contribute to theory or program design in these areas. Indeed, none of the 80 programs to encourage girls in math and science looked at by Rosser (1997) drew on biological theories of differences in their designs or implementations. Growing out of these findings and other work focusing on the unequal treatment of girls and boys in school, however (i.e., Bailey et al., 1992), has been a belief that whether because of classroom climate, inappropriate pedagogy, discrimination, or the very presence of boys, coeducation is responsible for at least some of the gender differences in mathematics and science. There has been great interest but little research on single-sex classes in mathematics and science. The few studies comparing girls’ performance and participation in these subjects in coed and single-sex environments have tended not to look at what was taught or how (Campbell & Sanders, 2002). On the basis of the current research, it would appear that in terms of achievement, Leder’s (1990, p. 16) conclusion that “research evidence to date does not warrant an unreservedly enthusiastic advocacy or adoption of long-term sex-segregated mathematics classes” still holds.

### **Social-Psychological Theories: What Is the Role of Nurture?**

A large body of research has addressed the influence of society and the community on girls’ and women’s participation in SMET. Theories emerging from this research suggest that girls’ and women’s perceptions of SMET and themselves as practitioners of SMET profoundly influence their decisions to participate in SMET. According to these

theories, teachers, counselors, peers, parents, the general public, and the media can have a deep impact on the way girls and women view SMET as suitable for women or as encompassing professions in which women can succeed. The way instruction in mathematics and science is structured and conveyed also has important consequences for girls' and women's success in learning these subjects.

*Teachers' attitudes, beliefs, and behavior.* Teachers—through their behaviors and interactions with students—have long been considered important influences on girls' attitudes and achievement in SMET (Fennema, 1990; Kahle, Parker, & Rennie, 1993). Researchers have hypothesized that teachers' stereotyping of SMET as “male” affects their expectations, which in turn results in differential behavior toward girls and boys in mathematics and science classrooms. In view of the potential importance of teacher influence on female participation and performance in SMET, several researchers have pointed out that there is a paucity of research dealing with teachers' beliefs and attitudes and their effects on student gender differences in SMET (Fennema, 1990; Kahle et al., 1993; Li, 1999; Plucker, 1996). Many of the studies on this topic that do exist use small samples that include disproportionate numbers of female teachers and/or biology teachers, do not provide comprehensive documentation of the nature and extent of the beliefs and attitudes, and rarely focus on secondary school teachers. As a result, extant studies have limited generalizability to teachers in various quantitative disciplines and at the secondary level (Plucker, 1996).

Li (1999), in summarizing the research on teachers' beliefs about gender differences in student mathematics learning, concluded that existing studies show that teachers hold disparate beliefs about male and female students, tending to stereotype mathematics as a male domain, to overrate male students' capacity to do math, to hold higher expectations for male students, and to have more positive attitudes toward male students. Plucker's (1996) study of 56 high school mathematics and science teachers had similar results, finding that teachers believed boys to be more interested, more confident, and higher achievers in SMET than girls. Teachers, moreover, did not feel that they had responsibility for *causing* gender differences.

Several studies have suggested that within the classroom, boys and girls receive different educations. Researchers have attributed the differential treatment of girls and boys by their teachers to different expectations of students based on gender (Jones & Wheatley, 1990). Performance differences in science and mathematics gave rise to studies of interaction patterns in mathematics and science classrooms. Koehler (1990), for example, followed the progress of that work as it pertained to math. The first studies examined external factors such as sex-stereotyped language, gender of teacher, or sex-biased textbooks but were not able to establish either causal or correlational relationships. The next set of studies, termed “differential treatment studies” by the researcher, examined the interactions between teachers and students. Summarizing these studies, Koehler concluded that boys and girls are treated differently from elementary through high school and that those differences usually favor boys. Jones and Wheatley (1990), in a statistical study of 30 physical science and 30 chemistry classes, found gender differences favoring boys in teacher-student interactions. Irvine (1985) reported that a girl's race affected the amount of feedback she received from her teacher. In her study, White girls received the least classroom feedback of any type, although overall, girls received less feedback than boys.

In a more recent study of classroom questioning practices, Altermatt, Jovanovic, and Perry (1998) assessed whether student volunteering rates could account for sex-differentiated

student-teacher exchanges. They found that although teachers in half the classrooms did call on boys significantly more often, this may have been due to higher rates of volunteerism by boys. Arambula Greenfield (1997), however, investigated the existence of traditional science-related gender differences within the context of a nontraditional situation in which girls outnumbered and outperformed boys in high-level science and math courses. A surprising finding of this study was that although girls asked more questions than boys at higher grade levels, initiated more work-related contacts with teachers, and handled scientific equipment at the same rate as boys, boys still received more teacher attention than girls.

Fennema, in discussing the research on teacher differential treatment of boys and girls, concluded in 1993 that

there still is not sufficient evidence to allow us to conclude that interacting more or differently with girls and boys is a major contributor to the development of gender differences in mathematics. I believe that differential treatment of boys and girls is merely a symptom of many other causes of gender differences in mathematics and that...treating the symptom is not sufficient to change the underlying cause. (p. 3)

Nevertheless, a number of intervention programs at both the preservice and in-service levels have been implemented to help teachers realize how they treat boys and girls differently and to promote gender equitable instruction (Bailey, Scantlebury, & Letts, 1997; Scantlebury, 1994).

*Girls' beliefs and attitudes.* Beginning with the Fennema-Sherman studies of the 1970s, research on affective or attitudinal variables pertaining to girls' and boys' differential feelings about mathematics have contributed much to the gender equity literature. There has been extensive documentation of the fact that girls perceive the fields of math and science to be the domain of White boys, that they do not see these subjects as useful to either themselves or humanity in general, that they do not see themselves as successful practitioners of math and science, and that they do not enjoy these subjects (Catsambis, 1995; Fennema & Sherman, 1977; Jones, Mullis, Raizen, Weiss, & Weston, 1992; Kelly, 1987; Riesz, McNabb, Stephen, & Ziomek, 1994; Schibeci & Riley, 1986; Sherman & Fennema, 1977; Simpson & Oliver, 1985).<sup>9</sup> Boys, on the other hand, consistently report more positive attitudes toward science than girls (Weinburgh, 1995) and believe even more strongly than girls in gender stereotypes in math and science (Farenga & Joyce, 1999; Arambula Greenfield, 1997; Kelly, 1985; Riesz et al., 1994; Steinback & Gwizdala, 1995).

How do girls' beliefs and attitudes toward mathematics and science affect their participation and achievement in these subjects? In their expectancy-value model of academic decision making, Eccles and her colleagues (1983, 1985) strove to explain the decisions made by girls that influence their entry into scientific fields of study. According to their theory, the motivation to achieve in a given field is jointly determined by a person's expectation of success and the value that he or she places on succeeding. Because women and girls do not expect to succeed in math and science, nor do they value success in these fields, they have little motivation to achieve. Krist (1993) tested the utility of Eccles and her colleagues' academic choice model of achievement for high-ability African American

<sup>9</sup>Although African American girls and Latinas hold more positive views of science and mathematics than White girls, within all racial and ethnic groups, boys seem to surpass girls in liking mathematics. Among African American and Latino students, science preference shows little gender difference, while the difference between White girls and boys—favoring boys—is much larger (Clewell & Ginorio, 1996).

women and confirmed that achievement behavior for this group also involved choices made by the individual, influenced by cultural norms and socialization experiences. Interestingly, Krist's study also found higher self-esteem and confidence among these women than among their White counterparts, together with the expectation to succeed in traditionally male-dominant fields.

Ma and Kishor (1997) sought to assess the magnitude of the relationship between attitude toward mathematics and achievement in mathematics by conducting a meta-analysis of the findings of 113 primary studies. They found that the effect of attitudes on achievement was not strong; a related finding was that the effect of achievement on attitudes was insignificant as well. These researchers did acknowledge, however, that defects (such as very crude attitudinal measures) and omissions (of indirect causes) in the studies they reviewed may have been responsible for their findings.

It seems, therefore, that although we know that girls and women hold more negative attitudes toward math and science than their male counterparts, we do not know conclusively how these attitudes affect girls' and women's participation in these fields. Nevertheless, several intervention approaches to improve girls' attitudes toward mathematics and science subjects and careers have been implemented on a national level: exposure to role models and mentors, career information, job shadowing, the use of "real-life situations" in problem solving, and the introduction of more "female-friendly" instructional strategies. These efforts may have contributed to increasing the confidence girls and women feel about doing mathematics and science and may have helped to increase their entry into higher level courses. A recent study by Arambula Greenfield (1997) found that girls in levels K-12 had relatively high levels of science self-concept and science lab participation; furthermore, although boys outnumbered girls in the three schools in the study, girls' enrollment in the most advanced science and mathematics high school classes equaled or surpassed that of boys. The researcher attributed these results to elementary-level classes based on instructional strategies that had been suggested by previous studies to enhance girls' science attitudes and participation.

The recent increase in taking higher level courses in math and science by girls and higher performance levels in these subjects may be an indication that intervention approaches are working to the extent that they lead to such outcomes. We are at a loss, however, to account for the low numbers of women who choose majors and careers in S&E, particularly in specific fields such the physical sciences, computer science, and engineering. In alluding to this dilemma, Catsambis (1995) wrote, "[The data] show that gender differences in scientific and technical careers may be due to girls' attitudes and career orientations and not to their levels of achievement. Girls' attitudes toward science develop independently of their levels of achievement" (p. 253).

Farenga and Joyce (1999) pointed out that even within math and science, certain subjects are perceived as masculine or feminine by students as early as kindergarten. Other studies suggest that boys and girls exhibit distinct differences in terms of the type of science in which they choose to participate (Farenga, 1995). Subjects such as mathematics, chemistry, and physics—physical science in general—are considered masculine, while life sciences are perceived as feminine (Steinkamp & Maehr, 1983). In a striking example of the early divergence of boys' and girls' science interests, Adamson, Foster, Roark, and Reed (1998) found that boys in Grades 1 through 6 tended to choose physical sciences, while girls chose the biological and social sciences, for a science fair project. Out-of-school science experiences for boys and girls may help foster differential preferences, with boys tending to indulge in

play activities that involve tinkering with objects or investigating physical phenomena and girls tending to choose more biological science activities such as the study of flowers, bird watching, or butterfly collecting. A study of boys' and girls' choices of museum exhibits found that the former were more likely to choose games or competitive exhibits such as those focusing on physical science, while girls were more likely to use exhibits that involved sustained, less action-oriented activities (e.g., those featuring the human body and its functions, and puzzles) (Arambula Greenfield, 1995). Although there are a variety of hypotheses as to why these gender differences in interest in different science areas exist (e.g., parental and teacher stereotypes, media representations, even the appearance and actions of scientists themselves), little research has been done in this area.

*How math and science are taught.* A recent study that investigated predictors of women's participation in university-level courses in mathematics and science found the strongest link to be between the quality of the math or science experience and the amount of math or science preparation (Lips, 1995). This finding underscores the importance of developing and implementing instructional strategies that are effective in teaching girls and women. Strategies such as cooperative learning, small-group instruction, inquiry approaches, and activity-based instruction (including a laboratory program) have been cited as effective in teaching math and science to diverse groups of students, including girls (Clewell, Anderson, & Thorpe, 1992; Freedman, 2001; Johnson & Johnson, 1987; Linn & Thier, 1975; Lawson & Wollman, 1976; Saunders & Shepardson, 1987). Promoted by such influential publications such as *The AAUW Report: How Schools Shortchange Girls* (Bailey et al., 1992) and the mathematics and science education standards, these approaches have been incorporated into math and science reform classroom practices in the interests of improving learning for all students.

It is important, nevertheless, that studies be undertaken to assess the effect of reform-driven approaches on the actual performance and attitudes of girls. We cannot assume that because these strategies are being implemented in classrooms across the country that girls are benefiting from them at the same rate as boys. A group of recent studies have investigated the effect of specific science education reform strategies on students' attitudes toward, enjoyment of, and confidence in doing science. Jovanovic and King (1998) found that although being actively involved in performance-based science classrooms predicted positive student attitudes by the end of the school year, boys and girls did not participate equally in these classrooms. These researchers reported that boys tended to handle the equipment—and, in the words of the authors, “hog the resources” (p. 491)—more often than girls. The study also found for girls, but not boys, a decrease in science ability perceptions over the school year. The second study of the same performance-based science classrooms examined the science attitudes of students in classrooms of teachers who were exemplary performance-based science teachers (Jovanovic & Dreves, 1998). It found that in addition to a decrease in girls' ability perception, there was a decrease in girls' task value beliefs over the school year, suggesting that in these classrooms, girls and boys experience hands-on science differently.

The third study looked at changes in elementary students' enjoyment, ease, and confidence in doing science in an inquiry-based classroom (Kahle & Damjanovic, 1994). In response to an initial questionnaire, girls indicated that they would enjoy biological investigations, while boys indicated more interest in physical science. After the inquiry activities, however, which involved electricity, girls showed a significant increase in their enjoyment of electricity topics, suggesting that this strategy *can* improve girls' attitudes about physical science. Even though both boys and girls completed the activities, boys



responded that they were more confident in doing activities with electricity; they also perceived the activities to be easier than girls. And although similar numbers of girls and boys thought that they could become electricians, significantly more girls than boys felt that women could become electricians. This study also found differences between African American and White girls that suggest that the latter hold stronger sex role stereotyped views than their African American sisters. Although the sex differences described above occurred within both racial and ethnic groups (African American and White), the gender differences were greater for the White than for the African American students.

The findings of these studies suggest the need for further research on the efficacy of science and math reform-driven instructional strategies for girls. They also point to the need for teacher vigilance to ensure that the same kinds of inequities that existed in the traditional math and science classrooms do not continue in reform-oriented classrooms.

Related to teaching math and science are the amount and types of informal science experiences available to girls and boys. Researchers such as Kahle and Lakes (1983) have documented differential access to out-of-school and in-school science experiences that favor boys among 9- and 13-year-old White students. Catsambis (1995) found that at the eighth grade level, boys participated in more relevant extracurricular activities than girls. Children's at-home experiences when they are very young can affect future learning outcomes in science and math (Farenga, 1995; Harlen, 1992; Kahle, 1990). As elementary school girls and boys form gender-segregated peer groups outside of the classroom, different skills may be developed from group activities that are gender divergent (Adamson et al., 1998). We need to know more about how experiences outside of the classroom may affect girls' and boys' affinity for science and, more specifically, for different types of science. Although an expected benefit of the performance-based classroom was that it would compensate for these experiential disparities, we have seen that this is not always the case, as shown in Jovanovic and Dreves's (1998) study. Classroom instruction and informal science experiences, however, can form a two-pronged approach to learning, with teachers briefing parents on the school curriculum to enable them to coordinate classroom instruction and home activities (Farenga & Joyce, 1999).

A consequence of the lack of hands-on, extracurricular experiences of girls is that girls may suffer more than boys from a lack of access to physical science lab experiences. One study found that a lack of these experiences affected girls' but not boys' performance on a physical science test (Lee & Burkam, 1996). The researchers hypothesized that because boys are more apt to indulge on their own in out of school hands-on activities that resemble the lab experience, the added effect of the lab may be negligible. This is not so for girls, who are less likely to engage in such activities on their own, so such school-related activities are more important to their learning.

*The influence of parents and society.* One set of theories that has been used to explain girls' and women's lack of participation in math- and science-related fields suggests that skills, beliefs, and motivation that affect an individual's success develop in response to the environment and society. Girls and boys receive different messages from peers, parents, teachers, and society in general about appropriate roles in society and definitions of success.

Parents' expectations about their offspring's success in certain areas are a potent influence on their children's performance and attitudes vis-à-vis those areas. Unfortunately, parents tend to have low expectations for their daughters' success in math and science. Despite the similarity of boys' and girls' actual performance, parents' perceptions of their children's math aptitudes favored sons over daughters (Andrews, 1989; Parsons,

Adler, & Kaczala, 1982).<sup>10</sup> Researchers have also reported low parental expectations for middle school girls' performance in science (Kahle, 1982; Schreiber, 1984). However, girls who perceive greater encouragement from their parents are more likely to find mathematics less difficult, which results in higher levels of achievement (Ethington, 1992).

The role of parents in providing meaningful science and mathematics out-of-school experiences for their daughters and in integrating the lessons of the classroom with extracurricular experiences is important. They can do this by providing access to a variety of informal science experiences such as television programs, books, pets, hobbies, toys, museums, clubs, Web sites, and family vacations (Farenga & Joyce, 1999). Also, parents can transmit their attitudes and beliefs about the appropriateness of succeeding in math and science to their children via instructions or comments and may even influence the way young children learn these subjects in school (Carr, Jessup, & Fuller, 1999). In a study that looked at parents' and teachers' contributions to the sex differences in the mathematics strategies used by first graders, Carr et al. (1999) found that boys' strategy selections were influenced by their belief that parents like strategies indicating ability and by teachers' instruction on retrieval strategies. Girls' strategy selection was not related to perceived adult beliefs or actions. These researchers further concluded that much of the instruction given on strategy use seemed to either intentionally or unintentionally benefit boys.

A number of intervention efforts have sprung up to encourage parents to become involved in their children's learning experiences in math and science. Programs such as Family Math and Family Science actively engage parents in math and science activities with their children; many science museums also structure exhibits to get parents and children involved in science activities. Schools routinely recruit parents to assist their children in developing science fair projects.

The media are a good indicator of society's attitudes toward women's participation in mathematics and science. To what extent are women depicted in the national media as competent "doers" of math and science? Do television programs and movies show women as scientists? The 2002 report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (Morella Commission) cites several research studies involving children using the Draw-a-Scientist Test; virtually all of these studies found that women were absent from the students' drawings of scientists. Television has a particularly strong influence on children's attitudes and behaviors and has been shown to affect children's perceptions of who can be a scientist.<sup>11</sup> A study conducted for the U.S. Department of Commerce of commercial television from 1994 to 1998 found that 75% of scientists portrayed on television were White men (Gerbner & Linson, 1999). This study concluded that if children are influenced by examples from television, there will be very few women and minorities in science occupations in the next century. Film depictions of scientists show a pattern similar to that of commercial television. In a study of 122 films of scientists and inventors, only 19 were about women, the majority of these being about female nurses such as Florence Nightingale (Elena, 1993).

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<sup>10</sup>There are racial and ethnic differences in terms of how parents view SMET subjects, which in turn affects their expectations for their offspring's success in these subjects. Asian American and Latino parents in a study conducted by Andrews (1989) tended to see mathematics as a male-dominated field more than African American or White parents, with African American parents being the least likely to hold such a perception.

<sup>11</sup>For an in-depth discussion of this, see Long, Boiarsky, and Thayer (2001).

There is some evidence that this stereotyping of female scientists in the media may be changing. Jodie Foster's portrayal of Ellie Arroway in the film *Contact* has been cited as a prototype of what a female scientist role model should be (Steinke, 1999). In a study to assess whether children's science education programs on both public and network television might be continuing the adult White male stereotype of scientists, researchers studied four programs (Long et al., 2001).<sup>12</sup> They found that the programs had made progress in counteracting stereotypical images of scientists. For example, female and male scientists who were main characters were treated equally. On the other hand, male visitor characters outnumbered female visitor characters by 50%. When on-screen time for male and female scientists was calculated, the study found that men had a much greater overall screen time. Also, two of the programs presented more adult men than adult women. The study's conclusions, nevertheless, strike a hopeful note in suggesting that the traditional image of scientists may be eroding in children's science education programming.

### Cognitively Based Explanations: Do Girls and Boys Learn Differently?

A related series of theories ascribe gender differences in mathematics, science, and engineering to gender differences in cognitive areas. There is not common agreement as to whether gender differences in these cognitive areas are biologically based. Some would argue, as did DeBeauvoir (quoted in Rosser, 1997), that these differences come from society's interpretation of biological differences rather than the actual differences themselves, while others would argue, as did Gilligan (1982), that factors of social status and power combined with reproductive biology shape the experience of men and women and the relations between the sexes. These researchers see differences as the result of differential treatment and reactions that men and women in our society receive on the basis of their biology (Rosser, 1997).

One of the best known theories in this area was developed in *Women's Ways of Knowing: The Development of Self Voice and Mind* (Belenky, Clinchy, Goldberger, & Tarule, 1986). Belenky and her colleagues (1986) posited that women come to know things in ways different from those of men, with women being more apt to be connected knowers who gain knowledge through access to others' experience. In related work De Courten-Myers (1999) reported men tending to consider facts in isolation, while women integrate them into a broader context. With this work as a rationale, girls' lower performance in mathematics can be traced to teaching math in a manner more consistent with separate learning that stresses deductive proof and absolute truth and certainty. Other aspects of mathematics teaching seen as targeting separate rather than connected learning include using algorithms and emphasizing abstraction, logic, and certainty. Girls, it is hypothesized, will perform better in mathematics if math teaching builds on the strengths of connected learners with more intuition and experience, conjecture, generalization, induction, creativity, and context (Jacobs & Rossi Becker, 1997).

Belenky and her colleagues (1986) also concluded that even the women who were extraordinarily adept at abstract reasoning preferred to start from personal experience. Building on this conclusion, Damarin (1995) suggested that to increase girls' mathematics achievement, more attention in the teaching of mathematics be given to the provision of opportunities to accumulate observations and experiences with diverse ideas before they are treated as obvious and formalized in definitions. Aspects of these theories have been used in

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<sup>12</sup>The programs were *Bill Nye, the Science Guy*, *The Magic School Bus*, *Newton's Apple*, and *Beakman's World*.

programs to encourage girls in mathematics and science, particularly those aspects related to accumulating personal hands-on experience, small-group work, and cooperative learning.

There has been a particular research focus on cognitive explanations for sex differences in mathematics related achievement and participation that has focused on problem solving and has looked at the use of conventional and unconventional strategies in problem solving. Carr et al. (1999) found that first grade boys were more apt than girls to be correctly using unconventional strategies such as “retrieval” strategies (pulling things from memory or saying the answer that popped into their heads) in solving mathematics problems, while girls were more apt to be correctly using overt strategies (using manipulatives or counting). This difference increased during first grade.

Working with the same students from first through third grades, Fennema, Carpenter, Jacobs, Franke, and Levi (1998) had similar results. Girls tended to use more modeling or counting strategies, while boys tended to use more abstract strategies such as derived facts or invented algorithms (rules they made up themselves), and this tendency increased through the years. By the end of third grade, 95% of the boys and 79% of the girls had used invented algorithms at least once in addition problems, and 80% of the boys and 45% of the girls had used invented algorithms in subtraction problems. “Using invented algorithms in the early grades seemed to provide a foundation for solving [complex mental calculation exercises that potentially assessed children’s understandings of number concepts]” (p. 10).

Among high school students scoring 670 or above on the SAT: Math, young women were more likely than young men to use “conventional problem-solving strategies” typically taught in the classroom. Students with less affinity for math reported using more conventional strategies to solve math problems, and indeed, the use of conventional strategies was correlated with negative attitudes toward math (Gallagher & De Lisi, 1994, p. 204).

There is reason to be concerned about these findings. Commenting on Fennema et al.’s (1998) results, Sowder (1998) maintained that

children who can invent strategies for computational tasks show a more advanced grasp of basic mathematical concepts than those children who are dependent on counting strategies . . . Their understanding will lead to deeper confidence in their ability to do mathematics. They have a better chance of succeeding mathematically. (p. 13)

However, Gallagher and DeLisi (1994) offered a caution to this interpretation reminding us that the “use of unconventional strategies does not always indicate that a particular student is better in mathematics, it simply indicates a willingness to independently come up with an answer” (p. 210).

## WHAT FACTORS HAVE AFFECTED CHANGES IN WOMEN’S STATUS IN SMET?

### Intervention Approaches

As we have mentioned above, research and theories regarding reasons for gender differences favoring men’s performance and participation in SMET have suggested intervention approaches and strategies to address these differences. Several of these approaches

have been described in the sections above that discuss theories and research to explain gender differences in SMET. It is difficult to say how effective interventions have been in equalizing the performance and participation of men and women in SMET. Although the prevalent interventions have been described in several publications (Clewell et al., 1992; Rosser, 1997), few evaluations have been conducted of individual strategies. There is evidence, nevertheless, that some national programs—such as EQUALS; Expanding Your Horizons in Science and Mathematics; Family Math; Family Science; Family Tools and Technology; GESA (Gender/Ethnic Expectations, Student Achievement); Girls in Science: Linkages for the Future; National Science Partnership for Girl Scouts and Science Museums; Operation SMART; and Playtime Is Science—have demonstrated short-term positive effects for girls and women (Campbell & Steinbrueck, 1996). The recent evaluation of the National Science Foundation's (NSF) Program for Women and Girls (PWG) described elsewhere in this issue (Darke, Clewell & Sevo, 2002), found evidence of effectiveness for the following intervention strategies in improving outcomes for women in SMET: mentoring and role modeling, provision of extracurricular activities, summer camps, professional development for educators, and activities for parents.

It is difficult, however, to determine how widespread the use of effective intervention approaches have been or to trace the effect of these approaches and strategies on the status of girls and women in SMET. We concur, nonetheless, with Fennema's (n.d.) statement that "intervention can make a difference." We think that it has made a difference, which is reflected primarily in the narrowing of the performance and course-taking gaps in the precollege years.

### Contextual Factors

The women's movement, which gained momentum in the 1960s, focused the attention of the nation on equity issues as they concerned women, including women's access to careers that had not previously been open to them. Indeed, the first research grant program on women and mathematics was part of a larger program on career development undertaken by the Career Awareness Division of the Education and Work Group at the National Institute of Education (Datta, 1985). The women's movement continued to influence the national consciousness during the years when much of the research on women in math and science was being conducted. It is possible that the movement helped to pave the way for intervention efforts to improve learning and course taking in math and science for women both in schools and outside of classrooms. Title IX of the Educational Amendments of 1972 helped provide a legal basis to fight for gender equity in education, including SMET education, while the passage of the Women's Educational Equity Act (WEEA) in 1974 and the Desegregation Assistance Centers (now called the Equity Assistance Centers [EAC]) established under Title IV of the 1964 Civil Rights Act provided some resources and training for those interested in implementing gender equity in SMET as well as other areas. However, the demise of National Institute of Education in the 1980s and the reduction of funds for the WEEA and the EAC limited the range, scope, and impact of these programs. The 1993 establishment of the NSF's PWG, now called the Program for Gender Equity, provided resources explicitly targeted toward increasing the participation of women and girls in SMET and filled an important gap, a role it continues to play in spite of its limited funding (see Darke et al., 2002, for further exploration of the role PWG has played).

Another influence was the education reform movement of the 1980s. This most recent attempt at education reform was given impetus by the efforts of the National Council of Teachers of Mathematics (1989) to push for national standards for the teaching of mathematics. This was followed by the publication of science standards by the American Association for the Advancement of Science's (1993) Project 2061 and the National Research Council's (1996) National Science Standards. The standards prescribed for teaching both mathematics and science and encouraged the use of instructional strategies such as small-group learning, inquiry-based instruction, and hands-on activities that had been suggested by research to enhance math and science learning for girls.

A third influence was the technological revolution of the past 50 years and the concomitant need for highly skilled domestic science, engineering, and technology (SET) workforce to fuel the new economy. With women making up an increasingly large proportion of the general workforce, attention became focused on their relative absence from the SET workforce.<sup>13</sup> In 1998, a bipartisan congressional commission was established to study ways of improving the representation of women in SET careers and issued a set of recommendations for policies and practices to achieve this goal (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000).

#### IDENTIFICATION OF MAJOR GAPS AND IMPLICATIONS FOR RESEARCH AND PRACTICE

As we explore the implications for research and practice of the "whats and whys" of the SMET gaps, it is important to keep in mind the enduring strength of our gender stereotypes. Prior to 1849, there were no female medical doctors in America; even 30 years ago, there were few female doctors. Today, close to half of medical students are women. The same characteristics that made women unfit to be doctors now make them well suited for medicine. It is not unthinkable that 30 years hence, the same thing will be written about women and engineering and other physical and quantitative sciences.

It is clear that girls graduate from high school with skills and knowledge comparable to boys, but few girls continue on in engineering and other physical and quantitative sciences. Relatively few African American, Hispanic, and American Indian students, female or male, graduate from high school with the skills and knowledge necessary to continue on in these fields. The young women who do go on in SMET majors as undergraduates and beyond tend to complete their degrees at about the same rates as young men, although women are less likely to enroll in graduate programs, especially doctoral programs. Both female and male African American, Hispanic, and American Indian students, however, have retention rates that are significantly lower than those of White or Asian students.

One course of action that seems indicated is that of improving the access of African American, Hispanic, and American Indian girls and boys to advanced mathematics and lab-based science courses taught by knowledgeable teachers. (This presupposes that

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<sup>13</sup>In 1997, women made up 19% of the SET labor force, compared to their representation in the general workforce of 46% (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000).

underrepresented minority students will also be provided with the earlier preparation for taking those advanced courses.) Having a high school curriculum of high academic intensity and quality is the strongest precollege predictor of college completion, especially for African American and Hispanic students (Adelman, 1999). If we do not provide at least that for students, other efforts will for the most part be unsuccessful.

The provision of high-quality courses has been shown to be “necessary but not sufficient” for most women students. Currently, thanks at least in part to the efforts of SMET retention programs, women’s lower representation in SMET majors (especially in the physical, engineering, and computer sciences) is much more a function of a failure to enroll in these majors than high attrition rates or switching majors.

What might be the sources of this underrepresentation? Girls and boys have similar in-school experiences. Because of differential access; choice; and even student, adult, and societal views of what are appropriate activities for girls and boys, however, math and science experiences may be different for the sexes, often leading to the building of different skill sets and preferences early on. Research studies have shown that girls and boys at a very early age tend to develop affinities for different types of science, with girls tending to favor the natural sciences and boys opting for the physical sciences. Some studies have suggested that differences in the types of out-of-school experiences available to girls and boys may influence these divergent preferences. Interventions to give girls more out-of-school exposure to activities where they can tinker with objects or investigate physical phenomena may help address some of the root causes of women’s aversion to the physical sciences.

A concerted effort must be made to increase women’s enrollment in SMET majors at the undergraduate level, which means intervening at the precollege levels to increase interest. Interventions at the college level to increase interest in SMET majors could be of value as well, but only in conjunction with efforts to make transferring into a SMET major as easy as transferring out.

Precollege programs that combine hands-on activities and the provision of role models through mentoring, internships, and career field trips tend to lead to girls’ increased self confidence and interest in SMET courses and careers as well as fewer sexist attitudes about these fields (Campbell & Steinbrueck, 1996; Clewell et al., 2000; Expanding Your Horizons, 1999). Because of the lack of longitudinal studies, however, little is known about the impact of these strategies on girls’ continuation in SMET courses, majors, jobs, and careers. The narrowing of the performance and course-taking gaps between girls and boys in mathematics and science up to the high school level suggests that although intervention efforts heretofore may have been successful in getting girls to the point at which they have the requisite academic skills to embark on an S&E career, these efforts have not been sufficient to get girls to want to be scientists or engineers. The finding that women who abandoned their intentions to major in engineering between 12th grade and college were capable academically of exploring this field while their male counterparts who made the same choice were not (Adelman, 1998) confirms the necessity to probe more deeply into the factors that lead women away from S&E majors.

While it would be foolish not to continue activities that have shown these very important short-term effects,<sup>14</sup> it would be equally foolish not to implement longitudinal

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<sup>14</sup>By “short-term,” we do not mean short lived but occurring within a shorter period of time after the intervention. These effects of increased performance and course taking are a necessary requirement for progress towards an eventual career in S&E.

research and/or evaluation on the possible impact of these and other activities on girls' continuation in SMET majors, jobs, and careers. Such work needs to look at intermediate as well as longer term effects following a model such as the following:

Program participation → intermediate effects → long-term  
effects/student data for different demographic groups

Resources need to be allocated to do well-controlled studies to determine the impacts of various strategies on long-term student outcomes. They must examine not just what works but what works for whom. They need to determine what, if any, long-term effects specific behaviors and strategies have on student SMET science achievement and participation and if these effects differ for students from different gender, race/ethnicity, disability, or socioeconomic groups. Once this is done, there is a great need to implement what is learned widely rather than as special programs providing remediation or "enrichment" for small numbers of girls and young women.

The preceding has focused primarily on affective areas. In addition, there is a need to delve more deeply into the differences between girls' and boys' problem-solving strategies. More research is needed to see if boys of different ages and in different settings are indeed more apt to solve problems using their own algorithms and if inventing and using one's own algorithms are correlated with longer term success. If so, research is badly needed to determine the implications of using one's own problem-solving strategies vis-à-vis "following the rules" in problem solving. Is this difference in behavior related to academic risk taking, a desire to please adults, or not wanting to take the chance of being wrong? Are adults' responses to girls' developing their own strategies different from adults' responses to similar behavior in boys?

Finally, in identifying the factors that discourage women from choosing S&E majors and careers, we must not only look backward to pre-K-12 experiences and influences but also forward to undergraduate and graduate education in S&E as well as to working conditions in both industry and academe for female scientists and engineers. Young women who are academically well prepared to enter S&E fields but do not do so may have considered their future in these fields and not liked what they have seen. Research by Sax (1994, 2001) has provided provocative insight into differences between men and women in terms of the factors that influence persistence in S&E through undergraduate and into graduate education. Other studies have documented negative educational experiences in S&E majors at both the undergraduate and graduate levels, inequitable distribution of rewards in the S&E workplace, and the ways in which scientific careers conflict with home and family life for women (see, e.g., Catalyst, 1999; Etzkowitz, Kemelgor, Neuschatz, & Uzzi, 1994; Fox, 1996; Massachusetts Institute of Technology, 1999; National Research Council, Committee of Women in Science and Engineering, 1994; Selby, 1999; Sonnert & Holton, 1995a, 1995b; Zuckerman, Cole, & Bruer, 1991). More of these studies, especially those using national databases, such as Olson's (2002) study in this issue, are called for.

Women and girls must believe that they can be comfortable participants in the world of science and engineering. To encourage such a belief, it is necessary to make a conscious effort to eliminate the barriers erected by society to women's equal participation in SMET fields and to rebuild the scientific enterprise as an environment where women and girls can flourish. And if we do this, they will come.



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