Chapter 1
Narrowed but Persistent Gaps: Background for Research

Gender and racial/ethnic gaps in science and engineering (S&E) postsecondary education have been gradually narrowing over the past 3 decades, but are far from completely eliminated. Relative to men and whites, women and minorities (other than Asian American) are still underrepresented in S&E disciplines at higher education institutions. This general pattern is evident in an array of indicators such as S&E major selection, program attrition, undergraduate degree completion, graduate program enrollment, master's and doctor's degree completion, and S&E workforce participation.

Before providing a snapshot of these measures as a background for the analyses in chapters 3 and 4, it must be mentioned that the federal statistics and other sources that document these persistent gaps differ according to agency purpose. One example of this is that researchers and statistical agencies use different definitions of S&E fields. National Science Foundation (NSF) documents usually include social sciences and psychology in S&E, whereas other sources may exclude these areas from the definition and use the term science to refer to *natural sciences*. When the definition of S&E encompasses the social sciences and psychology, the gender and racial/ethnic differences tend to be smaller than when the definition refers only to natural sciences and engineering. However, much of the national analysis to date has relied upon the NSF definition. Thus, the national statistics cited below use the NSF definition of S&E, which includes social sciences and psychology, unless otherwise noted.

Since including social sciences and psychology could confuse the understanding of the racial/ethnic- and gender-related gaps that legislation and policies intend to address, these disciplines are excluded from the data analyses in chapters 3 and 4. (Our definition of S&E otherwise follows NSF's definition of subfields, see appendix I.)

A Snapshot of Female Underrepresentation in 1996

Gender stratification in education and occupation occurs somewhere along the way between early childhood education and entry into the labor market (Hanson 1996). While learning about gender differences in early life requires in-depth research, national statistics are available to document the gender difference in postsecondary S&E education and in the related workforce.

Gender differences in choice of academic major and future career are apparent in the early years of college. For example, a national study of freshmen (Astin, Korn, Sax, and Mahoney 1994) found that women of all racial/ethnic groups were less likely than men to choose to study S&E. Even among those who had chosen to study S&E, fewer women than men were willing to pursue a career as engineers or research scientists (Astin et al. 1994). This can be seen in the rates of degrees awarded in S&E fields in 1996 (see table 1).

Table 1.—Women as a percentage of science and engineering bachelor's, master's, and doctor's recipients and of graduate enrollment, by major field group, 1996

		Science and Engineering fields							
	All fields	*Total*	Engineer-ing	Earth, atmos-phere, & ocean sciences	Mathe-matical/ computer sciences	Physical sciences	Biologi-cal/ agricul-tural sciences	Social sciences	Psychol-ogy
Associate's[1]	60.6	50.9	13.1	30.7	47.6	46.8	51.1	66.0	74.4
Bachelor's[1]	55.2	47.1	17.9	33.3	33.9	37.0	50.2	50.8	73.0
Graduate Enrollment[2]	--	38.9	17.7	36.1	28.5	28.0	47.3	48.4	71.0
Master's[1]	55.9	39.3	17.1	29.3	30.3	33.2	49.0	50.2	71.9
Doctor's[1]	40.0	31.8	12.3	21.7	18.1	21.9	39.9	36.5	66.7

[1] The associate's, bachelor's, and master's degree data are obtained from universe institution surveys of the National Center for Education Statistics (NCES). The data on doctor's degrees are obtained from the Survey of Earned Doctorates, a universe survey of individual doctorate recipients, sponsored by the National Science Foundation (NSF) and four other federal agencies. These data cover earned degrees conferred in the aggregate United States, which comprises the 50 states, the District of Columbia, and the U.S. Territories and Outlying Areas. Degree data are compiled for a 12-month period, July through June of the following year.
[2] The data on graduate enrollment are derived from the National Science Foundation/National Institutes of Health (NSF/NIH) Survey of Graduate Students and Postdoctorates in Science and Engineering (graduate student survey), Fall 1996. These data represent estimates of total enrollment in S&E programs in approximately 11,592 graduate departments at 603 institutions in the United States and outlying areas.
SOURCE: Burrelli (1998), *Graduate Students and Postdoctorates in Science and Engineering: Fall 1996* (NSF 98–307), tables 1 and 3. Hill (1999a), *Science and Engineering Degrees: 1966–96* (NSF 99–330), tables 11, 18, and 25. U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS) 1996 Completions Survey data file.

In 1996, women received 55 percent of all bachelor's degrees (Hill 1999a) and 47 percent of the bachelor's degrees awarded in science and engineering (Hill 1999a). That is, in 1996, 651,815 women and 528,000 men received bachelor's degrees. Of those, 181,333 women and 203,341 men received bachelor's degrees in science and engineering (Hill 1999a). However, their degrees were not evenly distributed among S&E fields. As shown in table 1, women received:

- 18 percent of engineering degrees (11,316 women and 51,798 men);
- 33 percent of earth, atmosphere, and ocean science degrees (1,485 women and 2,972 men);
- 34 percent of mathematical and computer science degrees (12,764 women and 24,857 men);

- 37 percent of physical science degrees (5,702 women and 9,694 men);
- 50 percent of biological and agricultural science degrees (39,369 women and 39,100 men);
- 51 percent of social science degrees (56,834 women and 54,955 men); and
- 73 percent of psychology degrees (53,863 women and 19,965 men).

A review of national surveys of college students (Astin, Astin, Parrott, Korn, and Sax 1996) reported that, while the career interests of men and women have been becoming increasingly similar during the last 3 decades (1966 to 1996), one of the largest remaining gender gaps was still engineering, a field in which few women intend to study and work. The 1996 numbers cited above bear this out: far fewer women than men earned bachelor's degrees in engineering.[2] Women also earned fewer bachelor's degrees in earth, atmosphere, and ocean sciences; mathematical and computer sciences; and physical sciences. Women slightly outnumbered men in number of degrees earned in biology and agriculture and in the social sciences.

Nonetheless, the gender gap in S&E education has shrunk over the years. From 1966 to 1996, the proportion of women among S&E degree earners rose dramatically: for bachelor's degrees, it rose from 25 percent to 47 percent; for master's degrees, from 13 percent to 39 percent; and for doctor's degrees, from 8 percent to 32 percent (Hill 1999a). The changes are shown field by field in table 2.

Table 2.—Women as a percentage of science and engineering bachelor's, master's, and doctor's degree recipients, by major field group, in 1966 and 1996

	Bachelor's degrees		Master's degrees		Doctor's degrees	
	1966	1996	1966	1996	1966	1996
Total	24.8	47.1	13.3	39.3	8.0	31.8
Engineering	0.4	17.9	0.6	17.1	0.3	12.3
Earth, atmosphere, and ocean sciences	9.4	33.3	5.9	29.3	3.0	21.7
Mathematical and computer sciences	33.2	33.9	20.3	30.3	6.1	18.1
Physical sciences	14.0	37.0	11.5	33.2	4.5	21.9
Biology and agriculture	25.0	50.2	20.8	49.0	12.0	39.9
Social sciences	34.3	50.8	20.2	50.2	10.5	36.6
Psychology	40.8	73.0	32.9	71.9	21.5	66.7

SOURCE: Hill (1999a), *Science and Engineering Degrees: 1966–96* (NSF 99–330), tables 11, 18, and 25.

Consistent with the degree award data, enrollment statistics also suggest a narrowing gender gap. The recent NSF Survey of Graduate Students and

[2] The numbers are similar throughout the 1990s, although the number of women earning engineering degrees has gradually increased (Hill, 1999a, tables 7 and 9). In 1991 women earned 9,665 bachelor's degrees in engineering and men earned 52,522; in 1992, it was 9,636 women and 52,305 men; in 1993, 9,981 women and 52,724 men; in 1994, 10,403 women and 52,609 men; and in 1995, 10,950 women and 52,421 men.

Postdoctorates in Science and Engineering (Burrelli 1998, tables 1–3) indicates that, while the number of men enrolled in graduate S&E programs fell 3 percent from 1995 to 1996, the number of women rose 1 percent (these percentages hold even when the students enrolled in social sciences and psychology are not counted).

Education is not the sole factor leading to women's marginal position in science occupations; workplace discrimination is a consistent barrier to women scientists (Hanson 1996), and S&E workforce participation and employment is the ultimate measure of the S&E pipeline outcome. In 1995, women represented 51 percent of the U.S. population and 46 percent of the nation's labor force, but constituted only 22 percent of the S&E workforce. This difference reflects the gender gap in S&E participation at the higher education level. Data from the 1995 Surveys of Science and Engineering College Graduates (National Science Board 1998) shows that among employed scientists and engineers (including postsecondary teachers), women make up 22 percent of the total S&E workforce, but 50 percent of the social scientists and 9 percent of the engineers (see table 3).

Table 3.—Percentage of women employed as scientists and engineers (includes postsecondary teachers), by occupation: 1995

22.4	All S&E occupations
28.9	Computer and math scientists
34.7	Life scientists (agriculture, biology, and environmental life)
21.5	Physical scientists (chemists except for biochemists, earth scientists, physicists and astronomers, and other physical scientists)
49.9	Social scientists (economists, political scientists, psychologists, sociologists and anthropologists, S&T historians, and other social scientists)
8.6	Engineers (aerospace, chemical, civil and architectural, electrical and related, industrial, mechanical, and other engineers)

SOURCE: National Science Board (1998), *Science and Engineering Indicators—1998* (NSB–98–1), appendix table 3–10.

Women's representation in the S&E workforce has improved in the last two decades. For example, the National Science Board overview of women and minority progress in the S&E workforce (National Science Board 1996, 1998) shows the overall academic employment of women with a Ph.D. in S&E more than doubled from 1979 to 1995, rising from 19,200 to 52,400. The number of women active in research and development work tripled from 1979 to 1993, increasing from 10,200 to 30,500. Due to this high growth rate, women made up 20 percent of all scientists and engineers in academia in S&E in 1993, compared with 11 percent in 1979. In 1995, 28 percent of the scientists and engineers employed in 4-year colleges and universities and 39 percent of the S&E workers in other educational institutions were women. However, many of these were employed in the life and social sciences and psychology fields.

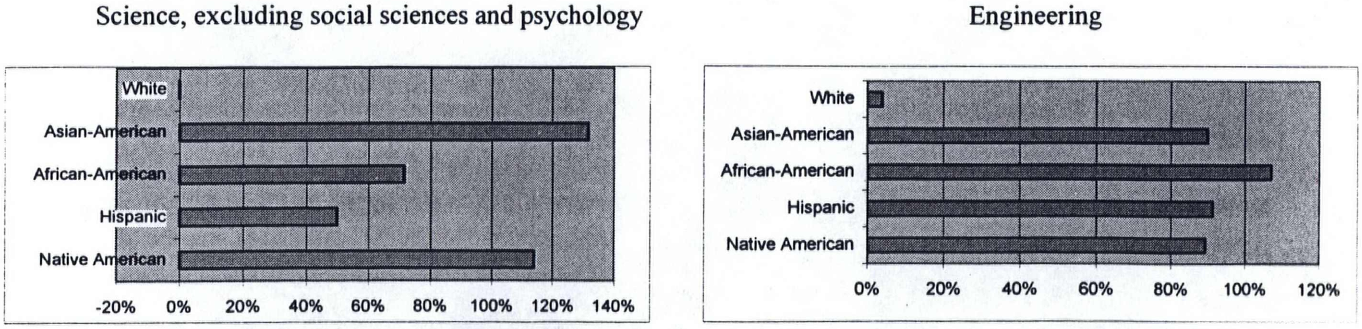
A Snapshot of Racial/Ethnic Underrepresentation in 1996

The underrepresented racial and ethnic minorities, with the exception of African-Americans, have obtained a fairly equal footing at the S&E associate's and bachelor's degree level, but the racial/ethnic gap is still visible at the higher levels of S&E education and in S&E occupations (see table 4). (These results also show the increasingly higher proportion of Asians who receive higher degrees. This is an interesting issue, but not a subject for this report.)

Minority underrepresentation in the S&E educational pipeline leads to the low participation rates of minorities in S&E occupations. For example, look at African-American participation in S&E education (excluding social sciences and psychology): at the end of the 1995–96 academic year, African-Americans had earned 9 percent of the associate's degrees and 6 percent of the bachelor's degrees, were 4 percent of the graduate enrollees, and had earned 4 percent of the master's degrees and 2 percent of the doctor's degrees. However, African-Americans ages 18 to 29 at the start of that academic year accounted for 14 percent of the U.S. resident population, 12 percent of the U.S. labor force, and 8 percent of the S&E workforce.

Recent decades have witnessed improved minority representation in S&E education and in the S&E workforce. African-Americans, for example, have increased their graduate enrollment 71 percent in science and 107 percent in engineering since 1985 (see figure 1). Nonetheless, the underrepresented minorities' share in S&E graduate school attendance is still, proportionally, less than half of their share in the U.S. population (see tables 4 and 5).

Figure 1.—Percentage change in S&E graduate enrollment, by field and race/ethnicity of U.S. citizens and permanent residents: 1985–1995



SOURCE: National Science Foundation (1999), *Women, Minorities, and Persons with Disabilities in Science and Engineering: 1998* (NSF 99–338), figure 4–7 and appendix tables 4–15 through 4–20.

Table 4.—Percentage of U.S. resident population and percentage of S&E participation, by race/ethnicity, 1995–96

Race and ethnicity, U.S. citizens and permanent residents	U.S. resident pop.[1]		Associate's degrees: S&E, excluding social sciences/psych.[2]	Bachelor's degrees[2]		
	18–29 age group	18–64 age group		Total	S&E, including social sciences/ psychology	S&E, excluding social sciences/ psychology
White	75.4	79.5	74.6	77.4	75.4	74.9
Asian-American	1.4	1.3	4.2	5.5	7.9	10.6
Underrepresented minorities, total	22.9	18.9	17.3	14.7	14.1	12.2
African-American	14.3	12.2	9.1	7.8	7.4	6.2
Hispanic	8.1	6.1	7.2	6.2	6.1	5.5
Native American	0.5	0.5	1.0	0.6	0.6	0.5
Unknown	0.4	0.2	2.0	2.4	2.5	2.3

Race and ethnicity, U.S. citizens and permanent residents	Graduate school enrollment[3]: S&E, excluding soc. sci./psych.	Master's degrees[2]: S&E, excluding soc. sci./ psych.	Doctor's degrees[2]: S&E, excluding soc. sci./ psych.	U.S. labor force[1]		S&E workforce[1,4]	
				18–29 age group	18–64 age group	18–29 age group	18–64 age group
White	72.1	74.1	71.7	78.9	81.6	83.0	87.8
Asian-American	14.2	12.3	21.4	1.5	1.4	4.0	2.3
Underrepresented Minorities, total	7.7	7.7	5.5	19.3	16.8	12.8	9.7
African-American	3.8	3.9	2.2	11.8	10.8	7.7	6.2
Hispanic	3.6	3.5	2.8	7.1	5.5	4.9	3.3
Native American	0.3	0.3	0.4	0.4	0.4	0.2	0.2
Unknown	6.0	5.8	1.4	0.3	0.2	0.2	0.2

NOTE: Columns may not add to 100 percent due to rounding.

[1] October 1995 Current Population Survey, public-use data file.

[2] The associate's, bachelor's, and master's degree data were collected by the National Center for Education Statistics (NCES) from all accredited institutions of higher education. The data on doctor's degrees are from the Survey of Earned Doctorates, a universe survey of individual doctorate recipients, sponsored by the National Science Foundation (NSF) and four other federal agencies. These data cover earned degrees conferred in the aggregate United States, which comprises the 50 states, the District of Columbia, and the U.S. Territories and Outlying Areas. Degree data are compiled for a 12-month period, July through June of the following year.

[3] The data on graduate enrollment are derived from the National Science Foundation/National Institutes of Health (NSF/NIH) Survey of Graduate Students and Postdoctorates in Science and Engineering (graduate student survey), Fall 1996. These data represent estimates of total enrollment in S&E programs in approximately 11,592 graduate departments at 603 institutions in the United States and outlying areas.

[4] The following 1980 Standard Occupational Classifications were used to define an S&E workforce: Engineers: aerospace (1622), metallurgical and materials (1623), mining (1624), petroleum (1625), chemical (1626), nuclear (1627), civil (1628), agricultural (1632), electrical and electronic (1633, 1636), industrial (1634), marine (8244), mechanical (1635), operating (8312), stationary (part 693, 7668), engineers, n.e.c. (1639); computer systems analysts and scientists (171); computer programmers (3971, 3972), computer operators (4612); operations and systems researchers and analysts (172); statisticians (1733); scientists: mathematical, n.e.c. (1739), physicists and astronomers (1842, 1843), chemists, except biochemists (1845), atmospheric and space (1846), geologists and geodesists (1847), physical, n.e.c. (1849), biological and life (1854), forestry and conservation (1852), medical (1855); teachers: earth, environmental, and marine science (2212), biological science (2213), chemistry (2214), physics (2215), natural science, n.e.c. (2216), engineering (2226), math. science (2227), computer science (2228), agriculture and forestry (2234); technicians: electrical and electronic (3711), industrial engineering (3712),

mechanical engineering (3713), engineering, n.e.c. (3719), biological (382), chemical (3831), science, n.e.c. (3832, 3833, 384, 389), technicians, n.e.c. (399); farmers, except horticultural (5512–5514), horticultural specialty farmers (5515); inspectors, agricultural products (5627); forestry workers, except logging (572).
SOURCE: Burrelli (1998), *Graduate Students and Postdoctorates in Science and Engineering: Fall 1996* (NSF 98-307), table 12. Hill (1999b), *Science and Engineering Degrees, by Race/Ethnicity of Recipients: 1989–96* (NSF 99-332), tables 4, 7, and 10. U.S. Department of Commerce, Bureau of the Census, Current Population Survey, October 1995. U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS) 1996 Completions Survey data file.

Table 5.—Racial/ethnic groups as a percentage of S&E graduate enrollment and master's and doctor's degree recipients, by field, in 1989 and 1996

	Science, excluding social sciences and psychology					
	Graduate enrollment		Master's degree		Doctor's degree	
	1989	1996	1989	1996	1989	1996
White	81.2	86.0	72.6	69.4	68.7	60.5
Asian-American	6.0	5.6	7.3	10.0	5.1	16.0
African-American	2.9	2.5	2.2	3.9	1.2	1.8
Hispanic	2.8	2.0	2.0	2.8	1.8	2.3
Native American	0.2	0.2	0.4	0.3	0.3	0.3
Unknown	5.1	2.8	6.5	5.3	1.8	1.2
	Engineering					
	Graduate enrollment		Master's degree		Doctor's degree	
	1989	1996	1989	1996	1989	1996
White	74.3	69.9	67.6	65.4	40.9	42.0
Asian-American	8.7	12.0	10.5	12.6	8.6	16.6
African-American	2.3	4.1	1.9	3.2	0.8	1.4
Hispanic	2.5	4.2	2.4	3.6	1.1	1.8
Native American	0.2	0.3	0.2	0.3	0.2	0.3
Unknown	9.2	6.5	6.9	5.3	1.3	0.8

SOURCE: Burrelli (1998), *Graduate Students and Postdoctorates in Science and Engineering: Fall 1996* (NSF 98-307), table 12. Hill (1999b), *Science and Engineering Degrees, by Race/Ethnicity of Recipients: 1989–96* (NSF 99-332), tables 7, and 10.

The growth of underrepresented minority employment in S&E fields is consistent with the increase of underrepresented minority Ph.D.s since the late 1970s (National Science Board, 1996). Among doctor's degree holders, the relative employment gains and consequent increase of researchers have been greater for underrepresented minorities than for the white and Asian-American majority. Employment of underrepresented minorities doubled from 1979 to 1993, and the number of researchers from underrepresented groups tripled. Gains for specific fields varied, with the physical, environmental, and life sciences close to the average in all S&E fields, and with mathematics, the computer sciences, psychology, and engineering exceeding the average (National Science Board, 1996). However, as shown in table 4, underrepresented minorities are still underrepresented in the S&E workforce.

The gains in underrepresented minority participation in S&E are not of the same magnitude at each level in the education process. As shown above, the more advanced the level of training, the lower the rates of underrepresented minorities in the programs. A question facing researchers then is what contributes to the uneven pipeline leakage across education levels.

In a study of racial representation at S&E entry and exit (Astin et al. 1994), the percentage of African-American and Hispanic freshmen who intended to major in S&E was higher than that of whites. Likewise, the rates of minority freshmen who reported willingness to pursue S&E careers were equal or higher than that of whites. These entry level expectations contrast with S&E degree completion rates, which are consistently lower among the minority groups. The differences in entry and exit imply "pipeline leakage" *differentiated by race*; that is, relative to whites and Asian-Americans, proportionally more underrepresented minority students who initially intend to enter the S&E system wind up not majoring in S&E or leaving the programs without completion. Qualitative research has also revealed that minorities do tend to face more barriers to finishing the programs despite their strong motivation to study S&E (e.g., Seymour and Hewitt 1997; see also descriptions of prior research below).

Prior Research

The persistent underrepresentation of women and underrepresented minorities in S&E education has spurred a number of researchers to scrutinize the gaps occurring at the entry into and completion of S&E postsecondary programs because these two measures are crucial points leading to equity in the labor market. A number of theoretically significant factors have been identified. Those that will be discussed here are related to measures that can be addressed with data from the national surveys sponsored by the National Center for Education Statistics (NCES). These factors can be loosely organized in three categories: family environment and support factors; student behavior factors such as attitudes, aspirations, and academic preparation; and school/institution factors such as precollege curriculum and instruction or postsecondary special programs in recruitment, retention, and financial aid. These three categories of variables will form the multivariate model used to analyze data from two NCES surveys in chapters 3 and 4.

Family Environment and Support

Parental support has been identified as a predictor of the selection of an S&E major in college. Conceptually, parents' educational attainment and occupation do not directly affect their children's choice of a college major, but they influence the decisionmaking in indirect ways, including providing better financial support and encouraging career choices. Such parental influence differs across race: for whites, both parents' influence is substantial, whereas for African-Americans, only the mother's influence is discernible (Maple and Stage 1991; Gruca, Ethington, and Pascarella 1988).

Compared with white and Asian students, underrepresented minority students may be more likely to exit their S&E programs because of such barriers as financial difficulties and demanding family obligations. Hispanic students in particular tend to work while studying in college not only to financially support themselves but also to assist their families. Because of close family ties, they also are expected to provide services to their families when needed during their college years (Seymour and Hewitt 1997). Combined with the pressure of challenging S&E studies, family obligations and financial conditions may become crucial determinants of S&E program completion.

Student Behavior

The values, beliefs, perceptions, and attitudes the students themselves hold regarding mathematics, science, and engineering subjects and related careers differ across gender and race/ethnicity. Research suggests these psychological and social factors are useful for understanding the gender and racial/ethnic gaps in the S&E pipeline.

Attitudes and Aspirations

Self-confidence has been studied extensively in relation to women's mathematics and science education (e.g., Sax 1994, 1995; Seymour and Hewitt 1997; Hyde, Fennema, Ryan, Frost, and Hopp 1990; Ware and Lee 1988). These studies report that gender differences in S&E major selection and persistence are closely related to women's self-perceived ability to learn math and science. Low self-confidence in math-related subjects strongly predicts a non-S&E major, and declining confidence during the early years of college often leads to a switch from S&E to other fields (Ware and Lee 1988; Seymour and Hewitt 1997; Sax 1995).

Low self-confidence among women may be related to institutional factors such as S&E curriculum and instruction, faculty response to female students' needs, and institutional culture regarding equitable education (Seymour and Hewitt 1997). However, gender differentiated self-confidence in S&E learning varies across race. Research has found African-American women independent and assertive and, in some cases, expressing greater confidence than women in other racial/ethnic groups with regard to S&E education and education in general (e.g., see Hanson 1996). On the other hand, Hispanic women seem to lag behind Hispanic men in measures of both performance and confidence (Ware and Lee 1988; Catsambis 1994).

Attitudes regarding quantitative subjects are related to the gender difference in college major choice. Relative to men, women may be more sensitive to social relationships and value more human aspects of the environment. Also, women tend to dislike the highly abstract nature of S&E knowledge and the strong competitive environment in many S&E departments. Such attitudes seem to become apparent during the middle school years and are held by college women. It has been found that the extent of such gender-differentiated attitudes explain much of women's lower probability of choosing and completing S&E programs (Seymour and Hewitt 1997; Maple and Stage 1991; Ware and Lee 1988; Oakes 1990).

Another attitudinal dimension examined by prior research regarding women in S&E concerns the clash between traditional and changing ***gender roles***. Many women confront the issue of prioritizing career versus marriage/family when choosing an S&E major. Research has not arrived at a consensus on which attitudes contribute to selection and persistence in S&E majors. For instance, Ware and Lee (1988), on the basis of national survey data, report that women who have a strong career commitment are more likely to select science, mathematics, and engineering majors. Other studies (Farmer, Wardrop, Anderson, and Risinger 1995; Maple and Stage 1991) report different evidence: women with strong career commitments are more likely to switch from science, engineering, and technological fields into other areas, whereas men's career aspirations are closely related to persistence in these fields.

Some minorities face a unique psychological difficulty in persisting in S&E programs, namely, a ***conflict between over-confidence and poor preparation*** (Seymour and Hewitt 1997). A substantial number of African-American and Hispanic students who choose majors in S&E are from high schools where they have been seen as academically outstanding *relative* to their severely disadvantaged peers. They have developed strong academic self-confidence but have not taken or been offered the advanced placement (AP) or similar coursework necessary for S&E programs at the college level—especially in highly selective universities (Seymour and Hewitt 1997). Overwhelmed, these minority students are often at high risk of switching from S&E programs or even dropping out of college.

Academic Preparation

Academic preparation has been studied extensively as a strong predictor of success in S&E undergraduate and graduate programs. It is widely accepted that the observable gender differences in learning and performance on quantitative-related subjects emerge in mid-adolescence and continue widening in subsequent schooling (e.g., Stipek and Gralinski 1991; Norman 1988; Kahle and Lakes 1983; Fennema 1980). Data from the National Assessment of Educational Progress (NAEP) have systematically identified racial gaps in math achievement as early as in fourth grade (e.g., Vanneman 1998; Reese, Miller, Mazzeo, and Dossey 1997; Campbell, Reese, O'Sullivan, and Dossey 1996). On the other hand, there is some evidence that the gender gap in secondary school science achievement is not as great as gender differences in science-related attitudes and activities (Hanson 1996). While numerous explanations of the learning gaps are available from the literature, academic preparation is often seen as a possible determinant of the gaps in S&E college major selection associated with race/ethnicity and gender. Even among college students intending to major in S&E, girls and underrepresented minorities tend to have taken fewer advanced courses of mathematics in high school than their male and white peers (e.g., Farmer, Wardrop, Anderson and Risinger 1995; Maple and Stage 1991).

Research seems still not fully certain about the extent to which gender and race/ethnicity gaps in secondary school math and science *achievement* are responsible for women and minorities' low rates of entrance to and completion of S&E postsecondary programs. Some have argued that college entrance tests (e.g., SAT) are probably biased toward underestimating the performance of underrepresented minorities and girls (e.g., Jencks and Phillips 1998; Fish 1994; Wainer and Steinberg 1992; Bridgeman and Wendler 1991; Williams 1989). Other research has shown that SAT scores may actually overpredict academic performance for African-Americans (e.g., Vars and Bowen 1998). Some studies have further suggested that female students in high school and college on average score similarly or even higher than male students (e.g., Catsambis 1994; Linn and Kessel 1995) and that their failure in entering or persisting in S&E programs is largely due to such psychological factors as low self-confidence and the male stereotype of the disciplines (Seymour 1995; Lips 1992; Oakes 1990; Ware and Lee 1988). Other investigations, while stressing gender and race/ethnicity gaps in math and science test scores, conclude that secondary school academic preparation has a *direct* effect on postsecondary S&E persistence and completion (for a review, see Seymour and Hewitt 1997). The challenge to S&E programs is perhaps how to deal with both inadequate academic preparation and psychological vulnerabilities among female and minority students.

School/ Institution Factors

Both secondary and postsecondary education systems set the basic conditions for women and minorities to participate in S&E vocations. While secondary education may be more predictive of the individual's entry into the S&E pipeline, postsecondary institutions impact the entire process, from entry to graduation.

Precollege Education

Elementary and secondary education is a salient factor in understanding the differential participation in postsecondary S&E programs by disadvantaged students. Because high school immediately precedes postsecondary school entrance, its impact on college major selection seems conceptually direct and empirically observable relative to the effects of earlier schooling. High school effects have been handled in prior research in a number of ways, as presented below.

Curriculum and instruction of high school mathematics are crucial conditions leading to majoring in S&E in college. Schools that provide advanced math and science courses offer students opportunities for in-depth learning in these subjects and consequently high performance (Oakes 1990; Peng, Wright, and Hill 1995). Intensive curricula and high expectations compel students of all backgrounds to learn, whereas inferior curricula and poor instruction often disadvantage underrepresented minority students to a greater extent than they do other students, perhaps because underrepresented minorities have less access to out-of-school learning opportunities as compared to white peers (Ware and Lee 1988; Smith and Walker 1988; Catsambis 1994).

Teachers and counselors may influence students' choices among college programs. Women were less likely to major in science if they were attending a 4-year college and were influenced by high school teachers or guidance counselors in making college plans. However, men were more likely to major in science if they were attending a 4-year college and their choice was not related to high school personnel influence (Ware and Lee 1988). The quality of math and science teachers has also been found to be an important predictor of student learning in those subjects and perhaps later college S&E attendance. For instance, teacher interaction with girls may be different from their interaction with boys; it may be characterized by low expectation, passive feedback (Jones and Wheatley 1990), and attributing failure to students' lack of ability (Fennema 1980). The small numbers of women and minorities who are willing to teach S&E at elementary and secondary levels make it difficult for girls and minority students to find role models. Additionally, the fact that math and science courses at the secondary school level are increasingly taught by education majors rather than by math and science majors may have worsened the quality of instruction (see Seymour and Hewitt 1997).

Learning opportunities—as a broad construct—have frequently been used in examining gender and race/ethnicity differences in academic performance, including math and science learning (e.g., Catsambis 1994; Oakes 1990; Norman 1988). In some high schools, these learning opportunities—as indicated by curriculum provision—are organized by ability grouping or tracking. Commonly, students are grouped in three curricular tracks: academic or college preparation, vocational and technology, and general programs (Oakes 1990). Such tracking systems in math and science have been criticized as much to the disadvantage of girls and underrepresented minorities because, more often than not, these groups have a lesser chance to be in academic programs than white boys (Ware and Lee 1988; Oakes 1990). Thus, some researchers say that schools that provide curriculum via ability grouping tend to compromise the equity of student learning, including learning in math and science (e.g., Coleman and Hoffer 1987; Lee and Bryk 1988).

Postsecondary Institutions

Under the general rubric of institutional environment for S&E equity, prior research has specified a number of factors that are theoretically and empirically relevant to explaining gender and race/ethnicity gaps in the S&E pipeline.

Institutional structure and commitment to equitable S&E education are key factors leading to varying S&E pipeline outcomes *vis-à-vis* underrepresented groups. Compared to large universities, small liberal arts colleges, community colleges, and historically black colleges and universities are believed to have contributed strongly to narrowing the gaps related to gender or race/ethnicity in major selection and graduation (e.g., U.S. Congress 1992). In this perspective, small liberal arts colleges, with an apprenticeship model of education facilitating close interaction between faculty and students, are better able to provide *all* students adequate opportunities for math and science careers (U.S. Congress 1992). The nationwide community college system has been functioning well in expanding minorities' postsecondary education opportunities in general, and enrollment in science and technology in particular (Brazziel and Brazziel 1994; U.S. Congress 1992; Quimbita 1991).

Prior research has also examined the student racial composition of postsecondary institutions as a predictor of campus racial relations, which further relates to minority students' condition in college. Some earlier reports revealed that on campuses with highly diverse student bodies (relatively high rates of minority students), racial tension tended to be high (e.g., Evans and Giles 1986; Longshore 1981). Recent studies have provided further insights on the issue. Seymour and Hewitt (1997) use ethnographic data to suggest that in S&E institutions with relatively high proportions of minorities, resentment and hostility among white students are more obvious regarding minority admission, performance, graduation, and other related issues. Interestingly, minorities on these campuses seem to respond to such conditions with fairly positive perceptions. Hurtado and colleagues synthesized research on campus racial climate in a recent report (Hurtado, Milem, Clayton-Pedersen, and Allen 1998) to provide a conceptual model for examining the institutional history of racial inclusion, current diversity of race/ethnicity, campus psychological climate (attitudes, perceptions held by different groups), and intergroup relationships.

Academic and social climates of the institution are difficult to measure but may have a substantial influence on underrepresented students' persistence and success in S&E studies, as the researchers mentioned below demonstrate. Some observers contend that the contents and the approach of S&E education are inherently disadvantageous to women and underrepresented minorities (Seymour and Hewitt 1997; Tate 1995; Hurtado and Carter 1997). Some argue that the S&E establishment is rooted in a culture in conflict with the intellectual and cultural orientation of underrepresented groups (Tate 1995; Anderson 1990; Seymour and Hewitt 1997). For example, in S&E institutions, personal success is highly regarded; however, women and underrepresented minorities commonly place primary value on people and groups. Grades as a main source for measuring a person's value and social status force many women and minority students to leave the fields (Seymour and Hewitt 1997).

Conceptual difficulties, faculty nonresponsiveness, the poor teaching quality associated with extensive use of teaching assistants, and lack of collaboration have been cited as major problems facing women and underrepresented minorities who participated in S&E programs (Seymour and Hewitt 1997).

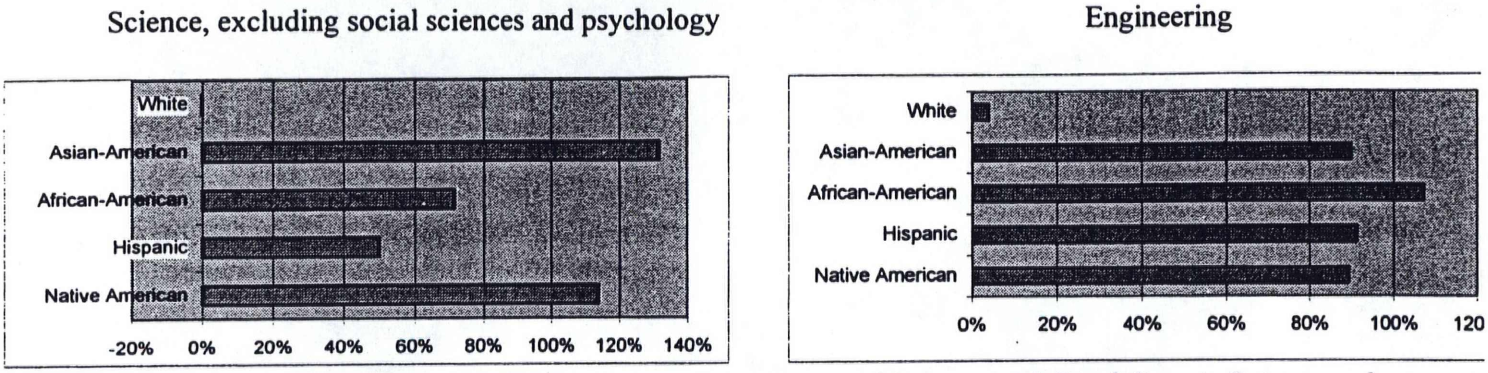
Special programs in recruitment, retention, and financial aid are available in many universities to support S&E participation by women and minorities. The *availability* of such programs, however, can be an overly simplistic predictor of the pipeline outcome. Instead, *program organization* and operation are important in determining the outcomes. For example, S&E enrollment of women and minorities may increase as a result of strong recruitment programs, but their persistence in and completion of these programs also often require assistance (Friedman and Kay 1990). Unless S&E institutions make equally effective assistance efforts, their strong recruitment programs can be counterproductive if disadvantaged students are overwhelmed by difficulties in S&E programs (Seymour and Hewitt 1977).

Research also suggests that S&E specific assistance programs available to students of all backgrounds are particularly useful to women and underrepresented minority students (Seymour and Hewitt 1997). Contrary to *remedial* programs provided only to specific groups, *enrichment* programs offered to *all* students work better for underrepresented minorities and women because such programs are not subject to stigmatization. Such programs run by S&E departments (as opposed to by the university) with S&E field related material (as opposed to general calculus, for example) are effective (Seymour and Hewitt 1997; Bonsangue and Drew 1995). Some universities have collaborated with high schools to support underrepresented students' learning of S&E subjects by offering learning and research opportunities to these students. Some of these programs are reported to have been quite successful in raising the rates of girls and underrepresented minorities who intended to study in S&E fields at college (Anderson 1992; New Mexico Commission on Higher Education 1987; Hamburg 1984; Thomson 1984; U.S. Congress 1992).

Lack of financial support has been repeatedly cited as a main reason for underrepresented minority students' low enrollment in and dropout from S&E programs (e.g., Porter 1990; Rotberg 1990; Seymour and Hewitt 1997). Institutions that provide strong financial aid to promising underrepresented minority students who need support are said to be better able to recruit and retain these students in the programs (Swail 1995; National Action Council for Minorities in Engineering 1994).

A Snapshot of Racial/Ethnic Underrepresentation in 1996

Figure 1.—Percentage change in S&E graduate enrollment, by field and race/ethnicity of U.S. citizens and permanent residents: 1985–1995



SOURCE: National Science Foundation (1999), *Women, Minorities, and Persons with Disabilities in Science and Engineering: 1998* (NSF 99–338), figure 4–7 and appendix tables 4–15 through 4–20.

Table 5.—Racial/ethnic groups as a percentage of S&E graduate enrollment and master's and doctor's degree recipients, by field, in 1989 and 1996

	Graduate enrollment		Master's degree		Doctor's degree	
	1989	1996	1989	1996	1989	1996
Science, excluding social sciences and psychology						
White	81.2	86.0	72.6	69.4	68.7	60.5
Asian-American	6.0	5.6	7.3	10.0	5.1	16.0
African-American	2.9	2.5	2.2	3.9	1.2	1.8
Hispanic	2.8	2.0	2.0	2.8	1.8	2.3
Native American	0.2	0.2	0.4	0.3	0.3	0.3
Unknown	5.1	2.8	6.5	5.3	1.8	1.2
Engineering						
White	74.3	69.9	67.6	65.4	40.9	42.0
Asian-American	8.7	12.0	10.5	12.6	8.6	16.6
African-American	2.3	4.1	1.9	3.2	0.8	1.4
Hispanic	2.5	4.2	2.4	3.6	1.1	1.8
Native American	0.2	0.3	0.2	0.3	0.2	0.3
Unknown	9.2	6.5	6.9	5.3	1.3	0.8

SOURCE: Burrelli (1998), *Graduate Students and Postdoctorates in Science and Engineering: Fall 1996* (NSF 98–307), table 12. Hill (1999b), *Science and Engineering Degrees, by Race/Ethnicity of Recipients: 1989–96* (NSF 99–332), tables 7, and 10.

Table 4.—Percentage of U.S. resident population and percentage of S&E participation, by race/ethnicity, 1995–96

Race and ethnicity, U.S. citizens and permanent residents	U.S. resident pop.[1] 18–29 age group	U.S. resident pop.[1] 18–64 age group	Associate's degrees: S&E, excluding social sciences/psych.[2]	Bachelor's degrees[2] Total	Bachelor's degrees[2] S&E, including social sciences/ psychology	Bachelor's degrees[2] S&E, excluding social sciences/ psychology
White	75.4	79.5	74.6	77.4	75.4	74.9
Asian-American	1.4	1.3	4.2	5.5	7.9	10.6
Underrepresented minorities, total	22.9	18.9	17.3	14.7	14.1	12.2
African-American	14.3	12.2	9.1	7.8	7.4	6.2
Hispanic	8.1	6.1	7.2	6.2	6.1	5.5
Native American	0.5	0.5	1.0	0.6	0.6	0.5
Unknown	0.4	0.2	2.0	2.4	2.5	2.3

Race and ethnicity, U.S. citizens and permanent residents	Graduate school enrollment[3]: S&E, excluding soc. sci./psych.	Master's degrees[2]: S&E, excluding soc. sci./ psych.	Doctor's degrees[2]: S&E, excluding soc. sci./ psych.	U.S. labor force[1] 18–29 age group	U.S. labor force[1] 18–64 age group	S&E workforce[1,4] 18–29 age group	S&E workforce[1,4] 18–64 age group
White	72.1	74.1	71.7	78.9	81.6	83.0	87.8
Asian-American	14.2	12.3	21.4	1.5	1.4	4.0	2.3
Underrepresented Minorities, total	7.7	7.7	5.5	19.3	16.8	12.8	9.7
African-American	3.8	3.9	2.2	11.8	10.8	7.7	6.2
Hispanic	3.6	3.5	2.8	7.1	5.5	4.9	3.3
Native American	0.3	0.3	0.4	0.4	0.4	0.2	0.2
Unknown	6.0	5.8	1.4	0.3	0.2	0.2	0.2

NOTE: Columns may not add to 100 percent due to rounding.

[1] October 1995 Current Population Survey, public-use data file.

[2] The associate's, bachelor's, and master's degree data were collected by the National Center for Education Statistics (NCES) from all accredited institutions of higher education. The data on doctor's degrees are from the Survey of Earned Doctorates, a universe survey of individual doctorate recipients, sponsored by the National Science Foundation (NSF) and four other federal agencies. These data cover earned degrees conferred in the aggregate United States, which comprises the 50 states, the District of Columbia, and the U.S. Territories and Outlying Areas. Degree data are compiled for a 12-month period, July through June of the following year.

[3] The data on graduate enrollment are derived from the National Science Foundation/National Institutes of Health (NSF/NIH) Survey of Graduate Students and Postdoctorates in Science and Engineering (graduate student survey), Fall 1996. These data represent estimates of total enrollment in S&E programs in approximately 11,592 graduate departments at 603 institutions in the United States and outlying areas.