Chapter 5

Demographics and Equality of Opportunity

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Demographics and Equality of Opportunity

The principle of equality of opportunity in scientific and engineering careers is embodied in the Equality of Opportunities in Science and Technology Act of 1981:[1]

> The Congress declares it is the policy of the United States to encourage men and women, equally, of all ethnic, racial and economic backgrounds to acquire skills in science and mathematics, to have equal opportunity in education, training, and employment in scientific and technical fields, and thereby to promote scientific literacy and the full use of the human resources of the Nation in science and technology. To this end, the Congress declares that the highest quality science over the long-term requires substantial support, from currently available research and educational funds, for increased participation in science and technology by women and minorities.

The Act sets out three reasons for promoting equality of opportunity: equity, the need for general scientific literacy, and the desire to fully utilize all human resources that could be applied to science and technology. It also explicitly calls for the commitment of Federal resources, within the overall scientific research and training budget, to programs which promote increased participation by minorities and women in science and technology. This commitment has not been completely carried out.

The changing college student demographics of the coming decade have several important implications for national policy regarding equality of opportunity. If the number of college graduates declines substantially, as predicted, the principal of utilization of all potential human resources to the fullest extent possible will become especially important. Although, as argued in chapter 1, it cannot be proven conclusively that the Nation requires the current level of 300,000 new science and engineering bachelor's degree recipients per year, it would not appear prudent, in an era when science and technology are expected by many to play an increasing role in improving our economic competitiveness and national security, to allow the number to decline appreciably. Therefore, from a "utilization of resources" point of view, programs to promote participation of historically disadvantaged groups take on greater significance.

The increasing fraction of college students who are likely to be drawn from the black and Hispanic populations, that have historically participated in science and engineering education and employment at far lower rates than the white population, imply that programs directed at these two minority groups may be needed to keep the supply of scientists and engineers from declining.

In order to understand what will be required, it is important first to have a clear picture of the factors leading to reduced participation by women and certain minority groups in science and engineering. These factors are complex, interrelated, and span the full developmental cycle from early childhood socialization to experiences in the work force. They include:

- the continuing legacy of decades of discrimination and discouragement from scientific and engineering careers,
- differential treatment of women and minorities in the science and engineering work force,
- lack of early educational opportunities due to social class and cultural factors among minorities,
- female socialization patterns that discourage young women from perceived "masculine" careers,
- expectations that women will continue to assume the major role in housekeeping and childrearing and sacrifice their professional interests to those of their husband,
- lack of financial support and institutional biases in the higher education system, and
- lack of role models and early exposure to

[1] National Science Foundation Authorization Act of 1981: Public Law ~6-516, Section 32(b),

science and engineering as worthwhile and accessible careers.

The sections that follow will review, briefly, the participation rates in science and engineering education and employment for both women and minorities, and discuss in some detail the principal causes, as currently understood, of those low participation rates. The limited evidence on the effectiveness of intervention programs that have been initiated to increase participation in science and engineering among these groups will be presented. Finally, a set of policy and research issues related to increasing the participation of women and minorities in science and engineering will be given. These issues have been identified by a review of the literature, an OTA workshop, and a questionnaire to practitioners in the field.

WOMEN

The increasing participation of women in scientific and engineering education and employment is a well-documented phenomenon. The trend is most dramatic in higher education, where women's share of total science and engineering baccalaureates increased from 28 to 36 percent; of master's degrees from 18 to 28 percent; and of doctorates from 15.5 to 29.4 percent between 1972 and 1982. Figure 5-1[2] illustrates that increasing participation by field and degree. In employment the trend is less dramatic but still significant. Women constituted 8 percent of the Nation's scientific and engineering work force in 1973; a decade later they were 13.1 percent. The most impressive gains were in computer specialists, engineers, and life scientists, where the numbers of women increased by factors of 4, 3, and 2 respectively between 1976 and 1983.[3]

Two issues link women's increasing participation in science and engineering to the demographic trends which are the subject of this technical memorandum:

1. the degree to which the increasing participation of women in science and engineering is likely to continue over the next two decades, and
2. the implications of overall demographic trends for policies and programs to promote equality of opportunity for women in science and engineering.

[2]Betty M. Vetter and Eleanor L. Babco, *Professional Women and Minorities*, 5th ed. (Washington, DC: Scientific Manpower Commission, August 1984), p. 37.

[3]*Science and Engineering Personnel: A National Overview*, NSF 85-302 (Washington, DC: National Science Foundation, 1985), pp. 53-54.

To understand these issues better, it is necessary to examine the factors that influence women's decisions to enter and remain in science and engineering careers.

The Science and Engineering "Pipeline"

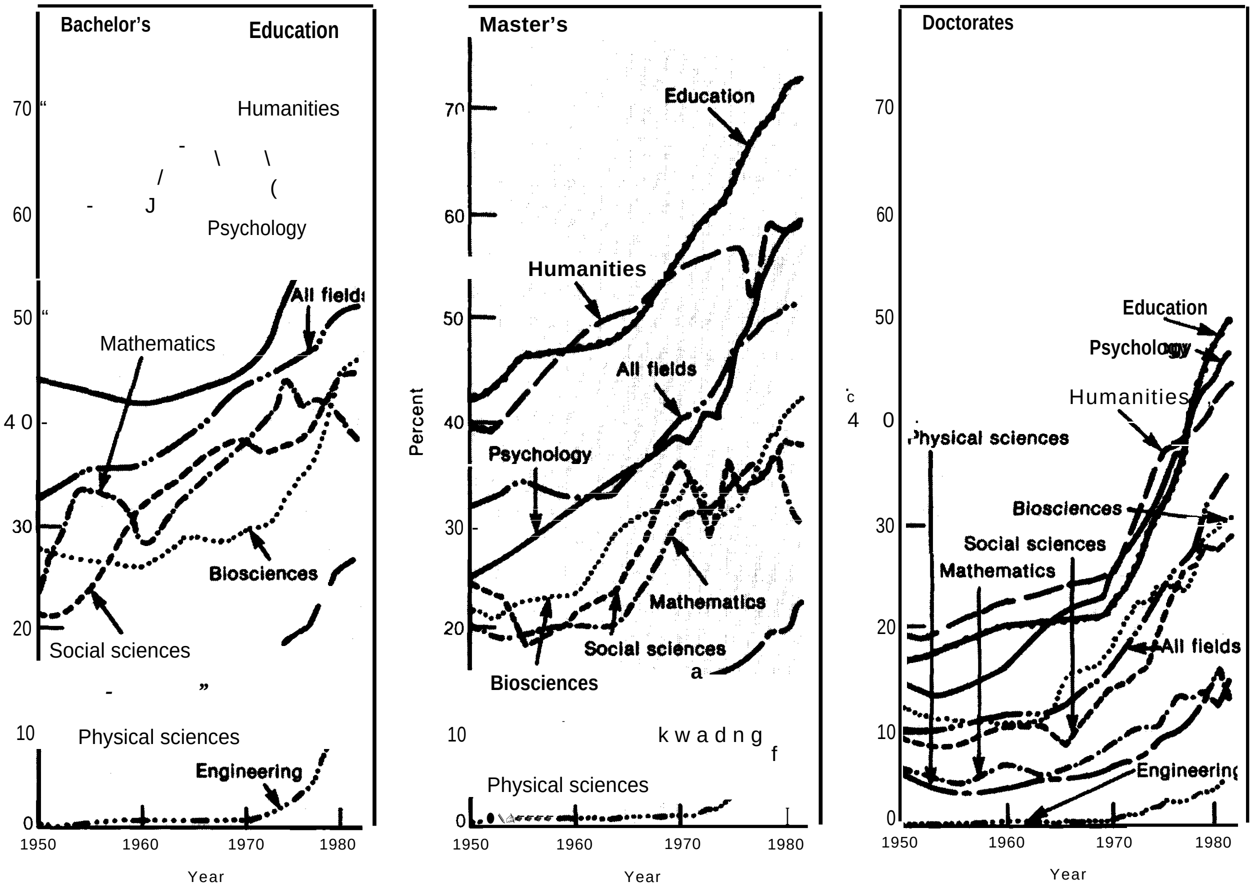
According to Sue Berryman, the pool of talent from which the Nation's scientists and engineers is drawn is largely formed in high school. Interest in science and mathematics first appears in elementary school, develops most intensely prior to 9th grade, and basically is completed by the 12th grade. After high school, migration is almost entirely out of, not into, the pool. As a consequence:

> those who obtain quantitative doctorates or have mathematically-oriented careers a decade after high school come overwhelmingly from the group in grade 12 who had scientific and mathematical career interests and high mathematical achievement scores . . . . By grade 12, these achievement scores clearly differentiate those who plan [to attend] college from those who do not and those who plan quantitative college majors from those who plan non-quantitative ones.[4]

If we follow a group of 4,0OO seventh graders —half boys and half girls—through the sequence of steps from age 12 through 32 that ultimately select those who will become scientists and engineers in quantitative fields (the physical sciences, mathematical and computer sciences, biological sciences, economics and engineering), we find the

[4]Sue E. Berryman, *Who Will Do Science* (New York: The Rockefeller Foundation, November 1983), pp. 66-77.

Figure 5-l.— Percent of Degrees Granted to Women 1950-82



SOURCE Scientific Manpower Commission, *Professional Women and Minorities* (Washington, DC 1984), p 36

following interesting patterns.’ About half each of the boys and girls will have taken and understood enough mathematics by age 12 to be capable of pursuing sufficient advanced work in high school to prepare for a quantitative major in college. (At age 12 the mathematical abilities of boys and girls are almost identical.) Of this group of 1,000 boys and an equal number of girls, only 280 boys and 220 girls will actually take enough high school mathematics to major in a quantitative field in college. This difference in numbers of students taking advanced mathematics courses is one of the factors leading to the observed differences between young men and young women in college SAT mathematics scores.

Of the original 2,000 young potential scientists and engineers, only 140 of the boys and 45 of the girls will actually enter college with plans to major in science or engineering. Forty-five of those young men will emerge from college with a quantitative baccalaureate degree; 20 of the women will do likewise. At the Ph.D. level, five men and one woman, of the original science and engineering pool of 2,000, will actually receive a doctorate in a quantitative field.

We can see from the above statistics just where women's participation in quantitative fields drops off most sharply. Between the age of 12 and the selection of a potential major in college at age 18, young women's persistence in the science and

[5]Betty M. Vetter, "The Science and Engineering Talent Pool" in Scientific Manpower Commission, *Proceedings of the 1984 Joint Meeting of the Scientific Manpower Commission and the Engineering Manpower Commission* (Washington, DC: National Academy of Sciences, May 1984), pp. 3 and 5.

engineering "talent pool" falls off three times as rapidly as that of young men. After college, 1 out of every 20 women, as opposed to 1 out of every 9 men, who receive quantitative B.A. s goes on to complete a quantitative Ph.D. Thus, it is at the pre-college and postgraduate levels that we should look for factors that discourage women from pursuing science and engineering careers.

The factors that lead college freshmen women to pursue science and engineering majors less frequently than men are best illustrated by a comparison of major field preferences among college freshmen. The 1984 study of The *American Freshman* by the Higher Education Research Institute[6] shows exactly where the two sexes differ most in their preferences. Twenty percent of the men, but only 3 percent of the women, report an intention to major in engineering. Three and one-third percent of the men, but only 2 percent of the women report an intention to major in a physical science. By contrast, women show significantly *greater* preference for the social and the biological sciences; 8.4 to 5.1 percent in the social sciences; 4.5 to 4.1 percent in the biological sciences.

These differences are often explained as consequences of young women's lack of exposure to, or poorer performance in high school mathematics, However, *The American Freshman* survey and the records of earned baccalaureates cast considerable doubt on this explanation. According to the survey, 0.9 percent of the freshmen women and 0.8 percent of the freshmen men surveyed in 1984 intended to major in mathematics. More than 7 percent of the women and only 5.7' percent of the men intended to specialize in accounting, Twenty-five percent of the men and 23 percent of the women intended to major in a business field other than "secretarial studies. " According to the Scientific Manpower Commission,[7] more than 40 percent of the bachelor's degrees in mathematics have been received by women every year since 1974. Close to 40 percent of the business and management degrees and close to 35 percent of the computer science degrees were awarded to women in 1982. Thus, it does not appear that women are avoiding quantitative fields in general due to perceived inadequacies in their mathematical capabilities. Rather, it appears that women are avoiding engineering in particular—despite significant increases in their enrollment in that field in recent years—and, to a lesser degree, physics.

To understand why women tend to select engineering as a college major so much less frequently than men do, it is useful to examine those fields which women tend to choose *far n-tore often* than men. The fields with the largest differentials in favor of women in *The American Freshman* are: education (9.6 percent of the women, 2.8 percent of the men); nursing (7.6 percent of the women, 0.3 percent of the men); and therapy (3.4 percent of the women, 0.8 percent of the men). Those three fields account for 20.6 percent of the women and 3.9 percent of the men in the survey, a mirror image of the ratio in engineering (3. o percent of the women, 20. I percent of the men).

Education, nursing, and therapy are all traditional "women's fields," while engineering is traditionally a "man's field. " Education, nursing, and therapy are all considered to be "helping" and "people-oriented" professions, whereas engineering is associated with building things and controlling the physical universe. Freshmen women's tendency to select the first three fields over engineering may simply indicate that traditional sex-role stereotypes and career patterns have not yet worked their way out of the system.

This should hardly be surprising from a historical point of view. It is less than a decade and a half since the women's movement forced open the doors to the traditionally male professions. All of the parents and most of the teachers of the current crop of freshmen were raised in the pro-feminist era. There are significant groups and leaders in the country who are not fully committed to the ideals of equality between the sexes in the work force. Thus, the influential adults who help to shape teenagers' ideas about the world and their place in it are not uniformly aligned in favor of efforts to break with traditional sex roles and occupational choices. The persistence of a sizable fraction of college freshmen who remain true

[6] Alexander W. Astin, et al., ***The American Freshman: National Norms for Fall** 1984* (Los Angeles, CA: The Cooperative Institutional Research Institute, University of California at Los Angeles, December 1984), pp. 16-18, 32-34.

[7] Vetter and Babco, op. cit., p. 37.

to earlier stereotypes of "women's" and "men's" work in these circumstances is hardly surprising.

Recent research by Gail Thomas tends to confirm the persistence of traditional sex-role stereotypes. Thomas found, from an extended study of "Determinants and Motivations Underlying the College Major Choice of Race and Sex Groups, " that the "choice of a college major entails a fairly predictable process that is largely formalized prior to college" and is "characterized by distinct (and to a great extent traditional) male and female interests, values, and aspirations held during childhood. " These findings, according to Thomas, "imply the importance of traditional sex socialization. . . ."[8]

Sue Berryman finds an additional career-related factor helping to explain young women's decisions to avoid quantitative majors in college. The greater a woman's expectation to assume the major child rearing responsibilities of her children, the less likely she is to choose quantitative occupations that require major educational and labor force commitments. The more she expects continuous labor force participation during adulthood, the more her occupational goals approximate those of young men. Berry man notes that "studies show that male single parents make occupational and labor force adaptations to parenting that are similar to the plans of young women who expect dual family and work responsibilities. "[9]

Berry man sees young women's career expectations interacting with their decision to take advanced mathematics courses to produce the pattern of underrepresentation of women in quantitative fields. "Gender differences in grade 12 mathematics achievement are primarily attributable to differences in boys' and girls' participation in elective mathematics during the 4 years in senior high school, " according to Berryman. Prior to grade 9, boys and girls do not differ significantly in average mathematical achievement. The individual's confidence in his or her mathematics ability, and perception of the utility mathematics will play in achieving educational and career goals, are factors contributing to the participation in the high school mathematics sequence. The stronger the two factors are, the greater the likelihood of partipation. Since career goals seem to determine educational investments, gender differences in occupational expectations become key to understanding gender differences in high school mathematics participation. Berry man sums up by stating: **"the key for women seems to be their career choices, their investment in the junior and senior high school mathematics and science sequences being related to these choices"** (emphasis added).[10]

Although Berryman sees mathematics ability and achievement as crucial to success in a quantitative career ("high mathematical achievement at grade 12 predicts realization of grade 12 quantitative career plans by age 29"), she sees such achievement as strongly related to, and influenced by, career choices already being formed in high school.

Once in college, it appears that young women have significantly less trouble than young men completing a quantitative baccalaureate. Forty-two percent of the women, as opposed to 30 percent of the men, who begin college with a quantitative major emerge after 4 years with a quantitative B.A. In graduate school, however, further attrition occurs. Women receive less than one-third as may quantitative master's degrees and one-fifth as many Ph. D.s. As a fraction of quantitative B.A.s women's attainment of quantitative M.A.s and Ph. D.s is less than half that of men.

The causes of women's attrition from the science and engineering "talent pool" in graduate school are not well documented. The problem does not appear to be with initial enrollment. The percentage of science and engineering graduate students who are women is almost identical to the percentage of science and engineering B.A. s awarded to women. There are some differences from field to field, with a considerable underrepresentation of women in mathematics and a significant overrepresentation in life science graduate programs,

[8] Gail E. Thomas, *Determinants and Motivations Underling the College Major Choice of Race and Sex Groups* (Baltimore, MD: Center for Social Organizations of Schools, Johns Hopkins University, March 1983), p. 40.

[9] Sue E. Berryman, "Minorities and Women in Mathematics and Science: Who Chooses These Fields and Why?" presented at the 1985 annual meetings of the American Association for the Advancement of Science in Los Angeles, CA, May 1985, p. 14.

[10] Ibid., pp. 13-14.

but overall the numbers are quite close, as can be seen below:[11]

Field	Percent B. A., women, 1980-82	Percent grad. enroll., women, 1982
Total, S/E.	36.6%	35.3 %
Physical sciences	24.5	21.0
Engineering	11.0	10.9
Mathematical sciences	36.9	27.1
Life sciences	40.0	52.4
social sciences	51.8	47.0

The problem appears to be with persistence in graduate school, with women's participation decreasing "at each successive degree level. "[12] Shirley Malcom cites one possible cause of this decline—lack of financial support:[13]

> In the 1981 *Summary Report of Doctorate Recipients,* a discussion of differences in financial support of doctoral training is a cause for serious concern. Women were more likely to report "self" sources of support. This was the primary source of support for 45 percent of the women but only 30 percent of the men. On the other hand, research assistantships were reported as the primary source of support for the doctorate by over twice as many men *(22* percent) as women (10 percent).

Since research assistantships facilitate entry into a research career, by providing access to equipment, mentors, conferences, and publications, the differential access to research assistant support appears to be an especially important problem.

A second factor, however, is undoubtedly women graduate students' increasingly negative perceptions of the actual benefits their advanced degree training will bring them. Once in graduate school, women can often see in the behaviors of their professors the forms of discrimination they will face in the workplace, reducing considerably the return on their investment in higher education.

[11] Vetter and Babco, op. cit., pp. 27-37.

[12] Shirley M. Malcom, ***Women in Science and Engineering: An Overview,*** prepared for the National Academy of Sciences (Washington, DC: American Association for the Advancement of Science, September 1983), pp. 27 and 37.

[13] Ibid., p. 8.

Differential Treatment of Women in the Science and Engineering Work Force

It would be nice to report that once a woman has gone through the time and trouble to receive training in a science or engineering field, especially to the Ph.D. level, she is safely ensconced in the technical work force with as great a likelihood of remaining there and receiving the full benefits of her education as her male counterpart. Unfortunately that is not the case. Sue Berry man finds that "labor force attrition rates differ far more by gender than by race" with female attrition rates "more than so percent higher than those of men. " In 1982, almost 25 percent of the women trained as scientists and engineers, compared to 16 percent of the men, were not using their training in the scientific and engineering labor force. One-third of the women who were out of the labor force in 1982 had left for reasons of family responsibilities.[14]

Lilli Hornig, in an article entitled "Women in Science and Engineering: Why So Few?" speaks of a "gender gap in jobs" for women Ph. D.s in the science and engineering work force. With the exception of engineering, male scientists are able to realize their plans for either employment or postdoctoral fellowships sooner than women. In academia, men are "far more likely than women to be hired to tenure-track positions, to be promoted to tenure and to achieve full professorships. " Women, on the other hand, "hold assistant professorships and nonfaculty positions more than twice as often as men. In industrial research, women Ph. D.s are underrepresented by about so percent. " Those who do obtain employment are only about half as likely as men to advance to management positions.[15]

The salary differential between women and men in comparable scientific positions is quite pronounced. Data from the National Science Foundation (NSF) show that women earn less than men in almost every field of science, in every employ-

[14] Berryman, 1985, op. cit., p. 7.

[15] Lilli S. Hornig, "Women in Science and Engineering: Why So Few?" ***Technology Review,*** November-December 1984, p. 40.

ment sector, and at every level of experience.[16] In 1982 the median annual salary of women scientists and engineers was 75 percent of that of their *male* counterparts: $26,300 v. $35,000. The percentage was highest among the computer specialists at 86 percent, and lowest among the life scientists, social scientists, and physical scientists at 74 percent. (See table 5-l.) Employed female scientists and engineers with less than 5 years' experience earned on the average 90 percent as much as their male counterparts; those with 31 to 35 years experience earned less than 78 percent.

Aline Quester, in an exhaustive study of "The Utilization of Men and Women in Science and Engineering Occupations: Task and Earning Comparability" finds that:[17]

> Male scientists and engineers earn substantially more than female scientists and engineers. While one-fourth to one-third of the male earnings premium is accounted for by differences in income-producing characteristics between males and females (primarily different subfield concentrations), the other portion of the differential is unexplained; the men simply earn more than the women.

No observable variables have yet been isolated which would account for the systematic earnings differential. If no such variables emerge in the face of repeated investigation, the presumption grows stronger that the earnings differential rests on covert discrimination.

Unemployment

In 1974, NSF reported unemployment rates [among all scientists and engineers] of 1.6 percent for men and 4.1 percent for women. By 1982, unemployment rates had climbed to 1.9 percent for men and 4.5 percent for women. Unemployment rates for **doctoral** men and women scientists and engineers were 0.9 and 3.9 percent, respectively, in 1973, and 0.8 and 2.6 percent in 1983.

NSF found the smallest unemployment rate differential between women and men among computer specialists, while the greatest difference was

[16] *The 1982 Postcensal Survey of Scientists and Engineers,* NSF 84-330 (Washington, DC: National Science Foundation, 1984), tables B-32 and B-33, pp. 144-151; and *Science and Engineering Personnel: A National Overview,* op. cit., table B-17, pp. 128-129. These two publications are the sources for all the numbers in this paragraph. They are not quite consistent with one another.

[17] Aline O. Quester, *Utilization of Men and Women in Science and Engineering Occupations. Task and Earning Comparability* (Alexandria, VA: The Public Research Institute, July 1984),

Table 5-1. –Average Annual Salaries of Scientists and Engineers by Field and Sex/Race/Ethnic Group, 1982

Field	Total	Men	Women	White	Black	Asian	Native American	Hispanic
Total, all fields	$34,000	$35,000	$26,300	$34,100	$29,900	$34,200	$34,000	$31,400
Total scientists	31,700	33,400	25,800	31,800	28,500	32,400	32,600	27,600
Physical scientists	34,700	35,500	26,400	34,900	30,100	32,500	42,500	33,600
Chemists	33,600	34,600	25,500	33,900	29,500	30,400	42,300	29,800
Physicists/astronomers	37,900	38,100	32,600	37,900	34,600	40,500	43,500	40,500
Other physical scientists	35,000	35,700	26,300	34,900	33,400	37,100	42,100	39,800
Mathematical scientists	34,800	37,500	29,100	35,000	31,600	34,500	31,200	25,400
Mathematicians	35,400	37,700	29,500	35,600	31,800	36,200	31,200	30,000
Statisticians	32,800	36,700	28,100	33,000	30,900	28,600	(1)	17,200
Computer specialists	32,200	33,500	28,800	32,300	31,100	32,000	33,000	30,600
Environmental scientists	36,800	38,000	29,900	36,700	30,700	37,200	46,600	38,500
Earth scientists	37,600	39,000	30,300	37,500	31,200	38,100	42,200	39,800
Oceanographers	34,600	36,500	22,300	33,400	28,200	30,000	56,400	22,400
Atmospheric scientists	32,700	33,100	28,500	32,600	29,400	33,600	(1)	31,400
Life scientists	28,900	30,400	22,500	29,000	27,700	28,100	30,800	25,600
Biological scientists	28,200	29,500	22,500	28,300	28,000	27,400	25,800	24,100
Agricultural scientists	27,500	28,800	17,900	27,400	26,300	28,100	35,700	27,600
Medical scientists	38,900	42,600	28,200	39,300	27,100	32,000	34,500	30,700
Psychologists	28,800	31,700	23,900	29,000	25,900	28,400	23,300	20,400
Social scientists	30,600	33,000	24,300	30,700	26,400	34,300	29,000	24,100
Economists	34,700	35,900	29,600	34,700	31,100	37,200	28,700	31,000
Sociologists/anthropologists	24,900	27,000	21,600	24,900	23,800	26,700	28,500	18,100
Total engineers	$35,800	$36,000	$29,000	$35900	$31,700	$35,100	$35,000	$33,700

SOURCE National Science Foundation *Science and Engineering* Personnel *A National Overview* NSF 85302, p 138 noted among social scientists. After controlling for field, the unemployment rate for women remained twice that for men. For recent (1980 and 1981) science and engineering graduates at the bachelor's level, 7.7 percent of the women and 5.1 percent of the men were unemployed. Among recent master's degree graduates, 7.3 percent of the women and 2.3 percent of the men were also unemployed.[18]

Underemployment

The term "underemployment" is used by NSF to describe the combined effect of involuntary employment outside of science and engineering and involuntary part-time employment where full-time employment is sought. The "underemployment" rate for women scientists and engineers in 1982 was 5 percent; for men it was 1 percent. Part of this difference was due to the greater concentration of men in engineering, where full-time employment is more the rule. But when only scientists are compared, women are still twice as likely as men to be "underemployed. " NSF reports that underemployment rates for women are higher in every field of science except for computer specialists, where the rates are essentially equal. This is true also at the doctoral level, where underemployment rates for women are above those for men in all major fields of science and engineering.[19]

Rank and Tenure

According to Betty Vetter:[20]

> Among all academically employed doctoral scientists and engineers in 1983, 65.6 percent of the men, but only 39.2 percent of the women, were tenured. An additional 14 percent of men and 21 percent of women were on the tenure track, while 8.4 percent of men and 19.9 percent of women were neither tenured nor in tenure-track positions. . . .

The National Research Council (NRC), in 1981, reported on the results of a survey of *Career Outcomes in a Matched Sample of Men and Women Ph. Ds.* It found that for men and women with degrees in the same field, in the same year, from equally prestigious universities, significant gender differences could be found in employment, rank and promotion, and salary. Specifically, NRC found that:[21]

> Among the academically employed Ph.D.s who were surveyed 20 or more years past the doctorate, 87 percent of the men were full professors compared with 64 percent of the women.
>
> For a given pair of one woman and one man with matched characteristics [10-19 years past the Ph.D.], the man is 50 percent more likely than the woman to have been promoted to full professor.
>
> Among 1970-1974 Ph. D,s one-third of the women, but one-half of the men held senior faculty posts. In every field, the distribution by rank was less favorable for women than men, based on their greater concentration among assistant professors and nonfaculty appointees.
>
> Female salaries at major research universities are significantly below the estimated salaries for men with similar characteristics.
>
> Salary differences between young male and female Ph. D.s in academe still exist, even after controlling for type and quality of doctoral training.

Lilli Hornig reports that only 79 out of approximately 4,200 faculty positions in the 171 Ph. D.-granting physics departments in the United States are held by women. Women hold only 188 of the 4,4oo faculty positions in chemistry departments that grant the doctorate.[22] This situation exists despite the fact that, according to NRC, there are more than 3,600 women doctoral chemists in the U.S. labor force. " Vivian Gornick, in her book on *Women in Science* likens the situation of women in chemistry to that of "Jews in Czarist Russia. "[24] She reports the following statement from an anonymous woman chemist at a "great research university '':[25]

[18] *Women and Minorities in Science and Engineering* (Washington, DC: National Science Foundation, January 1984), pp. 18-21.

[19] Ibid.

[20] Betty M, Vetter, "Women in Science and Engineering, " typescript, p. 10.

[21] Nancy C. Ahern and Elizabeth L, Scott, *Career Outcomes in a Matched Sample of Men and Women Ph. D.s—An Analytical Report* (Washington, DC: National Academy Press, 1981), pp. xvii, xviii.

[22] Hornig, op. cit., p. 41.

[23] Betty D. Maxfield and Mary Belisle, *Science, Engineering, and Humanities Doctorates in the United States: 1983 Profile* (Washington, DC: National Academy Press, 1985), p. 28.

[24] Vivian Gornick, *Women in Science* (New York: Simon & Schuster, 1981), p. 98.

[25] Ibid., pp. 102-103.

The chemistry department here doesn't advertise. It's illegal now, but they still do it that way. Somehow they consider it a "shame" to advertise. They write to their friends. And of course their friends are men who have only male graduate students. But even so, some awfully good young women get through the system and come up here for interviews. It's always the same. They look at these excellent young women and they say, "She's very good but she lacks seasoning. Let her go off somewhere else for the year and then we'll consider her again. " Of the young men just like her they say, "We'd better grab him before someone else does. "

Implications for Women's Participation in Science and Engineering

Of the many factors that reduce the participation of women in science and engineering education and employment, the discriminatory practices discussed in the preceding section are perceived by many to be the most serious impediments to the goal of equality of opportunity. Those practices are thought to violate the equity principle most directly, because they affect people who have established, by virtue of obtaining an advanced degree, the right to pursue a scientific career based solely on the quality of their work, Their effect on women who have made the long and arduous investment in training for a scientific career can be devastating. Vivian Gornick describes discrimination against women in science as:

. . . the kind of experience that becomes lodged in the psyche: both the individual one and the collective one. It may go unrecorded in the intellect but it is being registered in the nerve and in the spirit. **It means sustaining a faint but continuous humiliation that, like low-grade infection, is cumulative in its power and disintegrating in its ultimate effect** [emphasis added].[26]

The differential treatment of women in the science and engineering work force is believed to have a significant effect on female students in the educational "pipeline. " A woman student in a physics or chemistry department where no women have achieved tenure, or, perhaps, even been hired to a tenure-track position, is not likely to form a positive picture of her likely future employment prospects. Nor will she experience the kind of role model which the literature on equality of opportunity suggests is desirable to assist a young woman in identifying herself with her future profession. These two factors will considerably decrease the motivation for such a student to make the sacrifices required to stay in graduate school and complete her Ph.D.

Finally, the discrimination, higher attrition rates, greater unemployment, and underemployment experienced by women as compared to men in science and engineering are seen by many to be a serious waste of human resources that have been cultivated and prepared at considerable expense to the individual and the Nation.

The two avenues for dealing with this problem appear to be strict enforcement of existing affirmative action laws, and leadership from within the scientific community. As Lilli Hornig writes :[27]

Despite the widespread nonenforcement of "affirmative action, " laws against explicit bias have opened up much broader access to education and careers for women. Universities discourage most of the more obvious forms of discrimination against woman and point with pride to equal access and success for women students . . . . The most effective way to deal with [less explicit disparities] is probably not by external intervention but through the leadership of administrators and senior faculty. MIT took this approach more than a decade ago and has had considerable success in recruiting women as both students and faculty, even in fields that have traditionally "had no women. "

The National Academy of Engineering, in its report on *Engineering Education and Practice in the United States,*[28] has taken such a leadership role. It finds "anecdotal" evidence that "female engineering professors are not obtaining tenure at the same rate as their male counterparts" and "a perception of discrimination against female faculty members in assignment of teaching responsibilities and in selection for research teams. " It recommends that college administrators "make a candid assessment of the negative aspects of campus life for women faculty members" and, where these are found, "take firm steps to *eliminate* them. "

[26] Ibid., p. 74.

[27] Hornig, op. cit, p. 41.

[28] National Research Council, *Engineering Education and Practice in the United States—Foundations of" Our Techno-Economic Future* (Washington, DC: National Academy Press, 1985], p. 94.

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MINORITIES

Minorities represented 9.7 percent of the science and engineering work force in 1982, up from about 5.5 percent in 1976, but substantially less than their 18.0 percent representation in the general working population. Blacks constituted 2.6 percent of the Nation's scientists and engineers, as compared to 10.4 percent of the general labor force. Hispanics represented 2.2 percent of the scientific and engineering work force, as opposed to 5.5 percent of the total labor force. On the other side of the coin, Asian-Americans' 4.5-percent share of the scientific work force was nearly triple their 1.6-percent share of the working population in the United States.[29]

In the educational "pipeline," minorities' differential experience in science and engineering from that of white males is also quite dramatic. As table 5-2[30] shows, blacks, Hispanics, and American Indians receive degrees in quantitative fields at less than half the rate of whites, while the rates for Asian-Americans are more than double that of the white population. The numbers in the table represent the ratio of the percent of quantitative degrees awarded to the particular group to its percentage representation in the age-relevant population. For example, blacks received 4.1 percent of the quantitative B.A.s in 1978-79, but were 12.9 percent of the age 22 population, leading to a ratio of 0.32 in the table.

The very low ratios for blacks, Hispanics, and American Indians are, in fact, the product of two factors: the tendency of these groups to receive higher education degrees at far lower rates than whites, and their tendency, as well, to major in nonquantitative fields. These two factors are displayed in tables 5-3 and 5-4.[31] Blacks, Hispanics, and American Indians are 50 to 62 percent as likely as whites to obtain a baccalaureate, and 30 to 66 percent as likely to receive a Ph.D. Among those who do obtain the two degrees, the three minority groups under discussion are 62 to 88 percent as likely as whites to have majored in a quantitative field at the undergraduate level, and 39

[29] Vetter and Babco, op. cit., p. 96. See also *Statistical Abstract of the United States, 1985 (Washington*, DC: U.S. Department of Commerce, Bureau of the Census, 1985), pp. 391-392.

[30] Berryman, 1983, op. cit., p. 21.

[31] Ibid., pp. 18 and 20.

Table 5-2.—1978/79 Representation in Quantitatively Based Fields[a] Relative to Representation in Age-Relevant Population by Degree Level and Racial and Ethnic Group

	Degree level			
Racial and ethnic group	B.A.	M.A.	Ph.D.	Professional degrees
Whites	1.13	1.12	1.12	1.12
Blacks	0.32	0.21	0.16	0.35
Hispanics	0.55	0.29	0.21	0.47
American Indians	0.43	0.50	0.33	0.50
Asian-Americans	1.93	2.79	2.71	1.58

[a] Quantitatively based fields for the B.A M A , and Ph D. are defined to include the physical sciences, mathematics, computer sciences, biological sciences, engineering, and economics For professional degrees the fields are biologically or physically based and defined to Include medicine, dent! stry, optometry, osteopathy, podiatry veterinary medicine, and pharmacy

SOURCE Sue Berryman, *Who Will Do* Science (New York The Rockefeller Foundation, 1983), p 21

Table 5-3.—1978/79 Representation Relative to Representation in the Age-Relevant Population by Degree Level and Racial and Ethnic Group

	Degree level				
Racial and ethnic group	Associate degree	B.A.	MA.	Ph, D,	Professional degree
Whites	1.04	—1.11	1.10	1 11	1 14
Blacks	0.70	0.51	0 5 8	0 . 4 1	0.35
Hispanics	0.86	0.62	0.36	0.31	0.45
American Indians	0.86	0,57	0.66	0.66	0.50
Asian-Americans	1.27	1.13	1,05	1 3 3	0.95

SOURCE Sue Berryman, *Who Will Do Science* (New York The Rockefeller Foundation, 1983), p 21

Table 5-4.—1978/79 Representation in Quantitatively Based Fields[a] Relative to Representation in Total Degrees by Degree Level and Racial and Ethnic Group

	Degree level			
Racial and ethnic group	B.A.	M.A.	Ph.D.	Professional degrees
Whites	1.02	1.02	1.01	0.99
Blacks	0.62	0.36	0.39	0.98
Hispanics	0.88	0.80	0.69	1.04
American Indians	0.75	0.75	0.50	1.00
Asian-Americans	1.71	2.65	2.04	1.67

[a] Quantitatively based fields for the B A , M A , and Ph D are defined to include the physical sciences, mathematics, computer sciences, biological sciences. engineering, and economics For professional degrees the fields are biologically or physically based and defined to include medicine, dentistry, optometry, osteopathy, podiatry, veterinary medicine, and pharmacy

SOURCE Sue Berryman, *Who Will Do Science* (New York The Rockefeller Foundation, 1983), p 21 to 69 percent as likely to have majored in a quantitative field on the graduate level. The ratios in table 5-2 are the product of the ratios in tables 5-3 and 5-4 for each racial and ethnic group and each degree level.

Asian-Americans are about equal to whites in their likelihood of obtaining higher education degrees. However, they are more than twice as likely to select quantitative majors in college and graduate school. This picture for Asian-Americans may, however, be deceiving. Robert Suzuki claims that 85 to 90 percent of the Asian American scientists and engineers are non-U. S. citizens, or naturalized citizens who immigrated to this country to pursue their college education. This indicates, according to Dr. Suzuki, that:[32]

> American-born Asian/Pacific Americans of second, third and even fourth generation who bear the legacy of **130** years of racial oppression and who generally trace their ancestry to poor immigrant peasants are probably not over-represented in science and engineering and, indeed they may still be underrepresented, although I know of no definitive studies on this subject.
>
> On the other hand, most of the foreign-born Asian/Pacific Americans in science and engineering come from the more affluent classes in their countries of origin and represent perhaps the top one-hundredth of 1 percent of their country's populations. Consequently, these persons have not suffered the historical discrimination experienced by their American-born counterparts. Moreover, they generally represent an elite class, the cream of the cream, who are likely to do well even as immigrants.

Dr. Suzuki is undoubtedly overstating the case. However, because the high participation rate among Asian-Americans in science and engineering education and employment does not constitute a problem in equality of opportunity, we will use the term "minorities" to refer exclusively to blacks, Hispanics, and Native Americans in this chapter. Asian-Americans will be discussed separately, where appropriate.

Due to limitations of time and space, differences between blacks, Hispanics, and American Indians, between men and women in each minority group and between the different Hispanic subgroups cannot be discussed in this technical memorandum. The omission of a discussion of these differences is not meant to imply that they are insignificant.

The quality of academic preparedness in secondary school is cited by many experts as the greatest factor affecting minorities' academic performance and baccalaureate attainment in college. The greater attrition levels in the sciences of minority groups correlates very highly with measures of academic preparedness, such as high school grades, aptitude test scores, quality of study habits, rigor of the high school curriculum, and perceived need for tutoring. Of those factors, Alexander Astin found that grade average and class rank were more important predictors of undergraduate grades and persistence than were standardized test scores .33

Unlike some other disciplines, it is essential to begin the science course sequence at an early stage in the high school curriculum. Fields such as chemistry, physics, and engineering require extensive preparatory coursework. Students in private high schools who have greater access to college preparatory curricula, including advanced mathematics and science courses, than do students in public high schools, tend to choose mathematics and science majors in larger proportions. The poor quality of mathematics and science curricula in many inner-city high schools has been found to be a contributing factor to the low rate of selection of science and mathematics majors among minorities. It has been found that a higher percentage of black students from predominantly white high schools choose mathematics-based majors than blacks from predominantly black high schools.[34] In a study of 474 juniors and seniors at Wayne State University, where one-fifth of the students are black, it was found that:[35]

> Over 70 percent of the white science majors felt their high school training was adequate while less

[32] U.S. Congress, House Committee on Science and Technology, Subcommittee on Science, *Symposium on Minorities and Women in Science and Technology* (Washington, DC: U.S. Government Printing Office, July 1982), p. 12.

[33] Alexander W. Astin, *Minorities in American Higher Education: Recent Trends, Current Prospects & Recommendations* (San Francisco, CA: Jossey-Bass, Inc., 1982), p. 180.

[34] Thomas, op. cit., p. 8.

[35] Maureen A. Sic, et al., "Minority Groups and Science Careers," *Integrate Education, vol. 16*, May-June 1978, pp. 44-45: quoted in Meyer Weinberg, *The Search for Quality Integrated Education: Policy and Research on Minority Students in School and College* (Westport, CT: Greenwood Press, 1983), p. 288.

than 50 percent of the black science majors did. Sie and her colleagues found that a number of black students had taken advantage of special opportunities in secondary school: Of the twenty-four black science majors, thirteen went to Cass Technical High School where science is emphasized.

Because of the high-level of preparation required for the sciences many minorities opt for other fields of study. Astin's study revealed that with the possible exception of Puerto Ricans, during their senior year in high school minority students already show a strong preference for an education major and a tendency to avoid majors in the physical sciences and mathematics and in engineering. This was attributed in part to the students relatively poor academic preparation at the secondary school level.[36] Sue Chipman and Veronica Thomas report that "a survey of high school students who were seniors in 1980 indicated that black, Hispanic, and Native American students were only about half as likely to have taken advanced math courses as white students, whereas Asian-American students were about twice as likely to have done so."[37]

The educational level of the minority student's parents plays an important role in determining whether the student will be enrolled in an engineering or science curriculum. Students whose parents have obtained college or graduate degrees are more often enrolled in quantitative majors than are students who have less well-educated parents. Sue Berryman found that "being second generation college not only increases, *but also equalizes,* the choices of quantitative majors across white, black, American Indian, Chicano and Puerto Rican college freshmen."[38] (Asian-American students select quantitative majors at much higher rates than any other group whether their parents have a college education or not.) College-educated parents apparently tend to assume their children will also attend college, and therefore encourage them to enroll in the required preparatory courses. College-educated parents also appear to be better informed about the importance of pre-college training, and expose their children to a greater variety of career options.

The financial resources available to the minority college student play an important role in determining academic success and attrition rates. Minority students typically experience difficulty in financing undergraduate study. They must rely more on scholarship, work-study, and loan programs in contrast to nonminority students, who receive greater family support. In 1975, black and Hispanic college-bound high school seniors estimated that their parents would contribute about $200 a year toward college expenses, while the median figure for whites was over $1,100. That same year minority students comprised one-third of the persons assisted through the major U.S. Office of Education aid programs. Upon graduation from college, immediate employment opportunities may appear more rewarding than advanced study in view of the prospect of further financial difficulties, the academic risk of graduate study (about half of all doctoral candidates fail to complete Ph.D. degrees), and labor market uncertainties.[39] Associated with these financial difficulties are the problems of the working student in general. If a student must hold down a full-time job while in college he or she is less likely to complete his or her baccalaureate.[40]

Factors such as poor academic preparedness and inadequate financial support provide a surface-level explanation of why minorities tend to participate at lower rates in higher education in general, and science and engineering in particular. Underlying these factors are the deeper issues of culture and social class. Sue Berryman describes the importance of these factors as follows:[41]

> Racial and ethnic differences in mathematical achievement that we observe at grade 9 appear

[36] Astin, op. cit., pp. 73-74.

[37] Susan F. Chipman and Veronica G. Thomas, "The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields," commissioned by the Committee on Research in Mathematics, Science, and Technology Education of the National Research Council Commission on Behavioral and Social Sciences and Education, September 1984, p. 49.

[38] Berryman, 1985, op. cit., p. 17.

[39] "National Board on Graduate Education, *Minority Group Participation in Graduate Education* (Washington, DC: National Academy of Sciences, 1976), p. 8.

[40] Astin, op. cit., p. 109.

[41] Berryman, 1985, op. cit., pp. 14-17, the studies cited by Berryman to support her conclusions are the following:

- J. D. Coleman, et al., *Equality of Educational Opportunity* (Washington, DC: U.S. Department of Health, Education, and Welfare, 1966).
- R. H. Dave, "The Identification and Measurement of Environmental Process Variables That Are Related to Educational

at grade 1, [with] blacks, Chicanos, and Puerto Ricans starting school with mean scores on verbal and non-verbal tests of achievement below the national white average.

Two momentous factors contribute to the relationship between ethnicity and mathematical performance at each educational stage: culture and social class. Both affect family behavior patterns which in turn powerfully affect children's school performances.

A study of verbal, reasoning, numeric and spatial achievements among Puerto Rican, Jewish, Chinese, and black children at grade 1 shows clear racial and ethnic differences in the *patterns* of these abilities and subsequent studies suggest that ethnic differences in ability patterns at grade 1 persist through elementary and secondary school. More important, although social class has important effects on the level of abilities of each group, it does not alter the basic *pattern* of abilities associated with each group.

At the same time, the study shows that middle-class children from the various ethnic groups resemble each other to a greater extent than scores of the lower-class children from the different groups . . . . Social class has a particularly profound effect on the performance of black children, lower class status depressing performance more for these children than for children from the lower classes of other ethnic groups.

Social class seems to be a proxy for *family characteristics* that affect school achievement. For example, an American study showed that characteristics such as the family's press for achievement, language models in the home, academic guidance provided by the home, indoor and outdoor activities of the family, intellectuality in the home—as represented by the nature and quality of toys, games and hobbies available to the child, and work habits in the family together correlated at *0.80* with children's achievement scores.

An analysis of 1972 data on blacks' choice of and persistence in a science major found that family socioeconomic status affects blacks' choice of a science major. Higher family socioeconomic status increased the rate of choosing science majors, the effect operating by increasing the mother's educational aspirations for the student and the student's high school mathematical achievement. **When white and black students were equated on the intervening variables, blacks had a higher probability of choosing a science major than whites** [emphasis in the original].

Sue Chipman and Veronica Thomas find that "lower educational and career aspirations associated with lower socio-economic status may undermine minority students perception of the utility of mathematics . . . ." She adds that it is "quite possible that minority students, again because of their socio-economic status, have still less knowledge of the relationship between mathematics and particular occupational goals than do students in general. "[42]

Betty Vetter reports on a study carried out by the National Opinion Research Center in 1980 for the Departments of Defense and Labor .43 It identified a nationally representative sample of nearly 12,00016- to 23-year old men and women, and administered to this group the Armed Forces Qualification Test (AFQT), a general measure of trainability and enlistment eligibility for the armed forces. The test showed that youths from higher socioeconomic groups scored higher than those from lower socioeconomic groups; that white youths generally did better than black or Hispanic youths; **but the strongest single predictor of both the AFQT score and reading ability was the mother's educational level.** Later analyses suggested that the measured correlation of mother's education with test performance approximated the

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Achievement, " University of Chicago, unpublished doctoral dissertation, 1963.

- R.L.Flaugher, *Project Access Research Report No. 22—Patterns of Test Performance by High School Students of Four Ethnic Identities,* Research Bulletin RB-71-25 (Princeton, NJ: Educational Testing Service, 1971).
- C.Jencks, et al., *Inequality—A Reassessment of the Effect of Family and Schooling in America* (New York: Basic Books, 1972).
- G.S. Lesser, "Cultural Differences in Learning and Thinking Styles, " *Individuality in Learning,* S. Messick (cd.) (San Francisco, CA: Jossey-Bass, Inc., 1976).
- G.S. Lesser, et al., *Mental Abilities of Children From Different Social-Class and Cultural Groups,* Monographs of Society for Research in Child Development, Serial No. 102, vol. 30, No. 4, 1965.
- K.Marjoribanks, *Ethnic Families and Children Achievements* (Sydney: George Allen & Unwin,1979).
- K.Marjoribanks, *Families and Their Learning Environments* (London: Routledge and Kegan Paul, 1979).

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[42] Chipman and Thomas, op. cit., p. 50.

[43] Betty M. Vetter, "The Emerging Demographics—Effect on National Policy in Education and on a Changing Workforce, " contractor report prepared for the U.S. Congress, Office of Technology Assessment, May-June 1985, p. 50.

combined measured correlation of the four variables usually used to determine socioeconomic status: mother's education, father's education, average family income, and father's occupational status.

The differences were substantial. Youth whose mothers had completed eighth grade or less scored in the 29th percentile on the tests. Those whose mothers had completed high school had an average percentile score of 54. Those whose mothers were college graduates or more averaged 71.

The effect of socioeconomic status or class on minorities' persistence in the science and engineering educational pipeline is a cause for optimism among some, pessimism among others. Sue Berryman paints the optimistic picture :[44]

> In the short run, specially designed interventions can increase minority shares of quantitative degrees by targeting those who have the capacities to respond to these interventions, but who, in their absence, would probably not pursue a quantitative training program and career. In the long run, the trends favor increased minority representation in the quantitative fields. The growing number of second generation black and Hispanic college students will bean important factor in increasing the representation of these groups in the nation's scientific and engineering labor force.

Betty Vetter makes the more pessimistic case. She points out that 44 percent of all black households and 23 percent of Hispanic households are headed by single women. Nearly 72 percent of all black families and 46 percent of Hispanic families with incomes below the poverty level were maintained by single women. Seventy percent of all black children are being brought up in poverty. She concludes that:[45]

> We can anticipate an increasing school dropout rate among Hispanic and black children, growing up with young, single mothers who, because they have too little education themselves, are unlikely to be able to provide the incentives that may be required to keep their children in school and learning . . . . If present trends continue, we can anticipate that more of [the baby boom echo group] will drop out of school or out of math and science classes at earlier stages, and far fewer of them will obtain the educational preparation required for professional participation in quantitative fields.

In reality, both pictures may be true. An increasing number of minority students with middle class, college-educated parents, will undoubtedly enroll in higher education and major in science and engineering. However, an even larger number of black and Hispanic students from poor, single-parent households will find a college education and a science or engineering career difficult to achieve due to poor academic preparedness.

Differential Treatment in the Work Force

As was the case for women, minorities have a somewhat different experience from that of whites in the science and engineering work force. Recent NSF data[46] indicate that unemployment rates among black and Asian-American scientists and engineers were significantly higher than those of whites: 4.6 and 3.3 percent, respectively, versus 2.1 percent for whites. The unemployment rate for Hispanic scientists and engineers, by contrast, was about the same as that of whites, while Native American scientists and engineers had substantially lower unemployment rates. Black, Hispanic, and Native American scientists and engineers were somewhat less likely than whites to be employed in science and engineering (81 to 83 percent versus 87 percent), Asian-American scientists and engineers were somewhat more likely (90 percent) to be so employed.

Blacks and Hispanics reported significantly lower salaries than whites in science and engineering. The average salary for whites in all science and engineering fields was $34,200; that for blacks $30,100; and that for Hispanics $31,500. The salary differentials varied from lows of $500 between white and Hispanic environmental scientists and $900 between white and black computer specialists, to highs of $9,800 between white and Hispanic mathematical scientists, and $7,000 between white and black environmental scientists. Asian and Native American scientists and engineers re-

[44] Berryman, 1985, op. cit., p. 4.
[45] Vetter, 1985, op. cit., p. 7.

[46] *Women and Minorities in Science* ***and Engineering,*** op. cit., pp. viii, ix, 20-24.

ported salaries almost identical to those of their white counterparts.

Despite these differences in salaries and unemployment rates, analysts consulted by OTA did not report strong evidence for discrimination in the work force against minority scientists and engineers.

EFFECTIVENESS OF PROGRAMS TO PROMOTE PARTICIPATION

As shown in the preceding sections, many of the factors that inhibit participation in science and engineering by women and minorities are related to pre-college experience, both academic and nonacademic. These factors include overall poor academic preparedness (for blacks and other minorities); lack of exposure to the needed science and mathematics sequence (for minorities and women); socialization factors that underemphasize the desirability or appropriateness of a scientific or engineering career (especially for women); poverty and inadequate financial resources (especially for minorities); and family characteristics that affect school achievement. To some degree, it appears that these early factors can be overcome, or at least compensated for, by special programs designed to facilitate access to science and engineering education for disadvantaged cultural groups.

In 1983 the Office of Opportunities in Science of the American Association for the Advancement of Science (AAAS) conducted an "assessment of programs that facilitate increased access and achievement of females and minorities in K-12 mathematics and science education" for NSF.[47] The assessment was based on a survey questionnaire to the directors of more than 400 pre-college intervention programs for women and minorities, and site visits to more than 50 exemplary projects in different regions of the United States. Time and budget limitations precluded AAAS from carrying out formal evaluations of the programs it surveyed, but the results of such evaluations, where they had been performed independently, were requested from program directors in the survey.

AAAS found that "the primary feature of successful programs for minorities and females seems to be that they involve the students in the 'doing' of science and mathematics and convey a sense of their utility. " Such "exemplary programs" are "sensitive to the group or groups they are intended to serve and address these audiences' fundamental needs for academic enrichment and career information :48

> Exemplary programs for minorities recognize the deficiencies in performance many students are likely to have and stress rigorous academic preparation in mathematics, science and communications . . . . Projects for females focus heavily on career awareness—on the utility of mathematics and science to whatever they might want to do. Young women are encouraged to take all the courses available to them in high school. They are shown models of science and engineering professionals and students who "are making it" in these fields.

In general, AAAS found that these programs "have demonstrated that there are no inherent barriers to the successful participation of women and minorities in science or mathematics, " if these groups are provided with "early, excellent, and sustained instruction in these academic areas. " AAAS also found that:"

> Successful intervention programs are those that have strong leadership, highly trained and highly committed teachers, parent support and involvement, clearly defined goals, adequate resources, follow-up and evaluation. For the positive effects to be sllstained, these programs must eventually be institutionalized, that is, made part of the educational system . . . .
>
> Scientists and engineers from the affected groups must be involved in the planning as well as in the implementation of projects . . . .

[47] Shirley M. Malcom, et al., *Equity and Excellence: Compatible Goals* (Washington, DC: American Association for the Advancement of Science, December 1984).

[48] Ibid. , pp, vii-viii.

"'Ibid., p. viii.

Intervention programs must begin early and must be long-term in nature; "one-time" or short-term efforts do have a place for motivational, informational, supplemental or transitional purposes.

AAAS reported on a number of specific intervention programs that could document their success. An evaluation of the Mathematics, Engineering, Science Achievement (MESA) Program of the Lawrence Hall of Science in Berkeley, CA, which includes 16 centers, 131 high schools and about 3,4oo students, found that:[50]

Of recent MESA graduates, 90 percent have attended a college or university and approximately 66 percent have pursued a math-based field of study. MESA seniors performed significantly higher than college-bound seniors of similar racial/ethnic backgrounds across the nation. MESA seniors at sampled schools did not differ significantly on SAT performance from the total population of college-bound seniors . . . . despite the fact that the sampled schools were among the lowest-achieving schools in the state.

The Summer Science Enrichment Program at Atlanta University provides summer instruction in mathematics, science, and communication to high school juniors, most of whom are black. All 338 of the students who have participated in this program since its inception in 1979 have gone on to college, and 95 percent of them have majored in a quantitative field. It should be noted that this program selects students with demonstrated interest and performance in science and mathematics.

The Philadelphia Regional Introduction for Minorities to Engineering (PRIME) is a consortium of more than 34 businesses, 14 government and civic organizations, and 7 universities and public schools which has operated in the Philadelphia area for more than 9 years. It is a supplementary program in science and mathematics which begins in seventh grade and takes students through high school. Of the more than 820 high school seniors who have graduated from this program since 1977, more than 60 percent have chosen careers in engineering and/or technology. In addition, the number of minority students in the Philadelphia area enrolled in academic-track high school programs has tripled during the years of operation of the PRIME project, with one-third of those students in the PRIME project.

The Professional Development Program (PDP) of the University of California, Berkeley, is a faculty-sponsored program which recruits sophomores from 45 public and private high schools in eight districts to participate in special summer academic programs and Saturday classes during the school year, Over 60 percent of the students are women, and 75 percent are black or Hispanic. Of the 421 students from 60 local schools that have completed the program, "90 percent have gone on to college and a substantial number are in quantitative fields.''" The average SAT mathematics scores of the 1981-82 PDP senior class was 598.

These projects illustrate the general point made by AAAS that intervention programs at the precollege level can be effective in increasing the participation of women and minorities in science and engineering education. A far more systematic and thorough evaluation would be required to document the extent to which changes observed can be reliably attributed to the effects of the programs themselves. It should be noted that participation in these programs is voluntary, so those affected by the programs tend to be students who are already somewhat motivated toward science and engineering.

[50]1 bid., p. 56.

"Ibid., p. 56.

POLICY IMPLICATIONS

The AAAS report on *Equity and Excellence: Compatible Goals*, cited above, states that "the magnitude and complexity of the problem" of equality of access to scientific and engineering careers requires "a large and continuing effort that specifically targets large sectors of our societv .". . ." The NSF Authorization Act of 1981, Section 35(a), required the President to submit to Congress, by January 29, 1982, a report "proposing a comprehensive national policy and program, including budgetary and legislative recommendations, for the promotion of equal opportunity for women and minorities in science and technology." That report has neither been prepared nor transmitted to Congress. Therefore, there is, at this writing, no national policy or program to promote equal opportunity in science and engineering for women and minorities.

The Director of NSF did submit a report to Congress on December 15, 1981, in conformity with Section 34(b) of the 1981 NSF Authorization Act which required "a report proposing a comprehensive and continuing program at the Foundation to promote the full participation of minorities in science and technology." However the report contained neither budgetary nor legislative recommendations as required by the Act, and contained little more than restatement of existing policies and programs.[52] In fact the report attempted to rationalize budget *cuts* in a number of programs that were created in the 1970s, including the Minority Institutions Science Improvement Program (MISIP), the Resource Centers for Science and Engineering Program (RCSE), the Student Science Training (SST) Program, the Opportunities for Women in Science Program (OWS), and the Visiting Professorships for Women Program (VPW),

In the absence of executive branch leadership in this area, the AAAS study recommended that the following steps be taken by the Federal Government: 53

> Federal support for programs to improve the quality of pre-college education in science, mathematics, and technology should require that proposals specifically address themselves to plans for serving women, minority, and disabled student populations.
>
> Federally supported programs for teacher training and retraining should require that teaching methods and career and equity aspects be included, along with a rigorous focus on improving competence in subject content.
>
> The Federal Government should support dissemination of models previously shown to be effective in improving science and mathematics education for women and minorities, including technical assistance on management and evaluation systems . . . .
>
> . . . . previously supported programs that had a strong positive educational impact on women and minorities should be reexamined for possible reinstitution. Of particular interest in this regard are the RCSE and SST programs.

In order to better understand the policy implications of the problems experienced by women and minorities related to participation in science and engineering education, OTA sponsored a panel discussion among experts[54] in this area on July 2, 1985. The findings of the panel are presented below:

Issue l—Keeping Options Open

1. The self-perception of women and minorities of their inability to succeed in science and mathematics courses is frequently reinforced by the system's perception of their inability to do science and engineering.
2. Opportunities should be provided for this population to experience success in science and mathematics courses prior to grade 9 as weIl as opportunities for them to perceive the variety of career options and lifestyles that are based on these disciplines.
3. The Federal Government should support improvements in the training of junior high school science and mathematics teachers, the development of counseling programs involving teachers and parents and the identification and funding of model programs which enhance the self-perception of students.
4. Tests should be developed that are better indicators of the potential of women and minorities to succeed in science and mathematics careers.

Issue 2—Reducing Attrition

1. The graduate student pipeline should be enlarged by providing long-term support for promising minority and women students who are satisfactorily progressing toward the

"National Science Foundation, "Proposals of the National Science Foundation to Promote the Full Participation of Minorities and Womenin Science and Engineering, " typescript, December 1981·

[53]Malcom, op. cit., p. 30.

[54]The panel consisted of Lloyd Cooke, Michael Crowley, Maria Hardy, Shirley Malcom, Shirley McBay, Denis Paul, Willie Pearson, Luther Williams, Allan Hoffman, and Jerrier Haddad.

Ph.D. degree in science and engineering with identification and support beginning at the junior year in college.

2. The circumstances which lead to the success of women and minority students in science and engineering should be studied, and the knowledge obtained applied to improving the retention of less successful students.
3. Opportunities for early experience in research should be provided for minority and women students beginning at the undergraduate level. Existing efforts at the graduate level should be strengthened.
4. The Federal Government should disseminate and encourage programs and operating conditions which demonstrably facilitate the retention of women and minorities in science and engineering.
5. Federal Government affirmative action guidelines for recipients of Federal funds should be extended to protect against the following:
   - sexual harassment of women students, and
   - bias of some foreign professors whose cultures hold women in low status.

In addition to the above options for increasing the pool size and reducing attrition, it is probable that further gains might be realized if more were known about how different minority subgroups respond to different options. For example, differences may exist:

- for blacks, American Indians, and Hispanics;
- within the various Hispanic subgroups (e. g., Chicanos, Puerto Ricans, and Cubans); and
- for minority and nonminority women.

This suggests the need for support of studies on this issue. Further suggestions are provided in appendix B.