WOMEN IN SCIENCE: PAST AND FUTURE TRENDS

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1. RESEARCH FINDINGS

Policies affecting the recruitment, education, and employment of women in science and engineering do not arise in a vacuum. Shifts in economic conditions, demographic patterns, and national R&D (research and development) goals stimulate the formulation of human resource policies and the selection of program goals. The United States now faces a critical period in setting its technological and scientific priorities—with particular attention being given to the expansion of the present pool of scientific and technical talent. It should come as no surprise then that many policies affecting the role of women in science and engineering take as their starting point trends in the U.S. demography.

1.1. Demographic Issues

The Bureau of Labor Statistics has predicted that the need for science and engineering personnel will increase, by 36 percent between the years 1986 and 2000, because of high-technology industrial growth and the increasing use of high-technology goods and services. A question of much importance is "How will we meet these increased human-resource needs?" Research reveals that only about 5.2 percent of high school sophomores are likely to pursue studies in the natural sciences and engineering culminating in receipt of bachelor's degrees in those disciplines; and of those receiving baccalaureates in 1984, only 4.7 percent will have earned Ph.D.s in science and engineering by this year. In addition, the 18- to 24-year-old cohort that comprises our undergraduate population—traditionally, whites, both males and females—is expected to continue to decline until 1995. These figures lead some to conclude that the probability of passage through the education pipeline may be too small to meet the projected demands. Planning must be undertaken now to provide the nation with the trained personnel that will ensure the maximum utilization of available human resources for the development of new technologies and new knowledge.

1.2. Education Issues

The education system is the most effective way to attract people into a career. However, data from the National Center for Education Statistics' Earned Degrees Conferred series for the period 1972–1989, show that, after expressing an initial interest in science or engineering studies, individuals often switch to nonscience or nonengineering fields.

Undergraduate: Many undergraduate S&E (science and engineering) majors of both sexes switch to education, law, business, or medicine and other health-related fields for graduate study. Recent statistics highlight this attrition by women. For example, of those female freshmen enrolling in engineering programs in 1985, 35.6 percent dropped out of engineering during their sophomore year, compared to approximately 16 percent of the male first-year engineering majors.[1] In 1989, women earned 53 percent of the bachelor's degrees conferred in the United States. However, they earned only 47 percent of the bachelor's degrees conferred in science (excluding social sciences and psychology) and only 15 percent of the engineering bachelor's degrees awarded. Within science, the percentage of degrees awarded to women varied by field. While women earned 46 percent of bachelor's degrees in mathematics and 45 percent of those in life sciences, they earned less than a third of the degrees awarded in physical science (31 percent), computer science (31 percent), and environmental science (25 percent).

These numbers should not be viewed as milestones on an upward swing of science and engineering degrees awarded to women. Rather, the number of both U.S. citizen women and men earning degrees in science and engineering fields is on the decline. The number of degrees awarded to women in physical sciences peaked in 1987 at 4,837. Women's degrees peaked in environmental science in 1984, in life sciences in 1980, and in engineering in 1987.

Graduate: Since 1980, women have represented about one-third of graduate enrollment in science and engineering disciplines, although this varies by field.[2] Women's graduate enrollment in S&E tends to be concentrated in one of three fields—psychology, social sciences, and life sciences—while men tend to concentrate in engineering. In 1990, women earned 42 percent of all master's degrees conferred in science (excluding social science and psychology), but only 13 percent of master's degrees awarded in engineering.

The percentages of doctoral degrees awarded to women have increased significantly, particularly in certain S&E disciplines. For example, in 1950 only 4 percent of doctoral degrees in chemistry, 6 percent of those in mathematics, and 5 percent of those in physics were awarded to women. In 1990, those percentages were 24 percent, 18 percent, and 11 percent, respectively. Women earning S&E doctoral degrees tend to be clustered in the life sciences and receive fewer Ph.D.s than men in all fields except psychology. Whereas women are likely to complete advanced degrees in the life sciences and social sciences, they are much less likely to do so in the physical sciences, computer and information sciences, and mathematics.

Some of the factors leading to women's under-representation among graduate degree recipients are similar to those for the undergraduate level. First, the transition between undergraduate and graduate school is critical, yet women do not make the transition as often as do men to earn master's degrees.[2] Women do not receive the same kinds and levels of financial aid as their male counterparts in science and engineering, and this may inhibit their entry. OSEP (Office of Scientific and Engineering Personnel) data on graduate support patterns show that women graduate students in general are more likely than men to have to be self-supporting and less likely to be funded as either teaching assistants (TAs) or research assistants (RAs). Thus, relative to men, women overall are more likely to be deprived of research time and important opportunities for interaction with peers and faculty. Finally, the alienation that prevents full participation of women at the undergraduate level is even stronger at the graduate level. Examples range from simply being "left out" of the intellectual process to disparaging remarks

about women and blatant sexual harassment.[3] With the critical role played in the life and future success of graduate students by the departmental faculty (in particular the major adviser), the impact of even minimal alienation can be tremendous.

Interventions: The S&E education infrastructure has both formal and informal mechanisms for attracting and retaining talented and qualified individuals into careers in the sciences and engineering. Forming the backbone of the formal S&E education infrastructure are (1) the institutions providing the education to potential scientists and engineers and (2) the policies and programs providing the financial assistance essential for acquisition of that education. Informal aspects of the education infrastructure include the media, parents, and role models and mentors.

Among formal mechanisms, the most common is the availability of financial support, a very important factor in recruiting and retaining able women in science and engineering. At the undergraduate level, scholarships to women for studies in the physical sciences and engineering often reinforce recruitment efforts.[2,4] Similarly, undergraduate women are encouraged to pursue studies in the sciences and engineering because of the knowledge that financial support will be available for continued studies at the graduate level: research indicates that women who are offered financial aid at the beginning of their undergraduate education are more likely to continue their studies in the sciences and engineering. Furthermore, variations in Ph.D. attainment rates by S&E field may be quite large and are highly correlated with the availability of financial support.

There are also numerous informal mechanisms by which women are recruited to and retained in science and engineering. These informal interventions typically: address the negative image that the public has of scientists and engineers and of science and engineering; encourage interest of young women in S&E majors and careers; develop support or networking groups—both informal gatherings and the more structured meetings of student chapters of professional organizations, such as the Society of Women Engineers—to reduce feelings of isolation and alienation for women in traditionally masculine fields; as in formal programs, provide opportunities for female students to interact with scientists and engineers in academe, industry, and government; and cultivate "climates" (atmospheres and environments) that encourage academic achievement among women.

Research on retention of both men and women in S&E programs indicates that effective ones include the following: career seminars, educational and career counseling, research opportunities, role models and mentors, involvement of the media, other opportunities to interact with members of professional organizations, and recognition awards and events. Furthermore, both formal and informal interventions are often necessary to maintain one's interest in pursuing study and careers in science and engineering. This is true because, in addition to formal barriers and overt discrimination, women in traditionally masculine fields often encounter very subtle forms of discrimination called "micro-inequities."[5,6] The sum of the macro- and micro-inequities typically found on a particular campus contributes to an unsupportive "campus climate." While on an incident by incident basis, micro-inequities appear to be insignificant, collectively they comprise an important and significant difference in the collegiate experience of men and women. For example, women who try to participate in classroom discussion are much more frequently ignored or interrupted than men by both faculty and male students; their questions are more often treated as trivial by faculty, and they are frequent targets of "good-natured" derogatory humor. But, many academic institutions

are unaware of the successful activities by other institutions to create a supportive campus climate. These include data collection and analysis from each department on the participation and advancement of women at the undergraduate, graduate, and faculty levels. The campus climate for women is also enhanced by on-campus branches of professional societies—such as the Society of Physics Students, Chicanos in the Health Sciences, and the Society of Women Engineers—which promote interactions between S&E professionals and students and which shepherd women students into professional careers.

1.3. Employment Issues

The National Science Foundation[2] cites six major areas of difference between male and female scientists and engineers in the United States:

1. Numbers: Women are under-represented in science and engineering compared to their participation in the U.S. work force (45 percent). In 1988 women comprised 16 percent of all employed scientists and engineers—30 percent of scientists; 4 percent of engineers.
2. Unemployment: Since 1986, the unemployment rates for women and men scientists and engineers has been fairly constant, at 2.7 percent and 1.3 percent, respectively. However, while women and men holding bachelor's degrees have similar unemployment rates (3.5 and 3.3 percent, respectively), women holding advanced degrees in science and engineering, in general, experience greater unemployment than do their male peers: at the master's level, 2.7 versus 1.5 percent; and 1.7 and 0.6 percent for Ph.D.s.
3. Underemployment: "Women scientists and engineers were three times as likely as men to report being underemployed in 1986: 6.3 percent versus 1.9 percent." In this case, NSF defines an underemployed person as one seeking an S&E position (who currently has a non-S&E job) or seeking a full-time rather than their current part-time S&E job.
4. Salaries: Women's yearly earnings are approximately three-fourths those of men's. "Their yearly earnings were also below those for men within individual S&E fields and—with few exceptions—at all levels of professional experience."
5. Years of Experience: Due to the recent increase of women entering S&E fields, women "on average, are younger and have fewer years of professional experience than their male colleagues." Nearly two-thirds of women in science and engineering versus only a quarter of men had less than 10 years of professional experience in 1986.
6. Underutilization: Across fields, women are underutilized very unequally. They are especially well-utilized, for instance, in electrical/electronics engineering and computer science, which are large employment fields, but less utilized in aeronautical/astronautical, chemical, civil, and mechanical engineering and in the mathematical, environmental, life, and social sciences. In general, the positions occupied by female scientists and engineers are not those of power and prestige or those that permit them to engage in policymaking or consulting, the activities that give the individual the greatest visibility outside his or her own institution and provide the greatest incentives.

Some feel that these difference between men and women in science and engineering are attributable to a "glass ceiling," defined by the U.S. Department of Labor[7] as "those artificial barriers based on attitudinal or organizational bias that prevent qualified individuals from advancing upward in their organizations into management level positions." The Labor Department[7] identified three such attitudinal and organizational barriers:

Recruitment practices involving reliance on word-of-mouth and employee referral networking; the use of executive search and referral firms in which affirmative action/EEO requirements were not made known.

Developmental practices and credential building experiences, including advanced education, as well as career enhancing assignments such as corporate committees, task forces, and special projects—which are traditional precursors to advancement—were often not as available to minorities and women.

Accountability for Equal Employment Opportunity responsibilities did not reach to senior level executives and corporate decision makers.

Interventions: The problem is "not with getting women in [science and engineering], but with helping women move up in their careers."[8] The annual employment growth rate for scientists and engineers has been greater for women than for men since 1978. Some have attributed this growth to interventions put into place by employers. While interventions targeting women faculty are few in number, women faculty at some institutions have been able to effect change by such means as establishing their own informal network, as happened at the University of Michigan-Ann Arbor.[9] For a time, companies cautiously implemented programs to attract and retain women scientists and engineers. In addition to offering women S&E graduates starting salaries comparable to, and sometimes higher than, those offered to men, the private sector responded to the fact that in recent years the previously separate worlds of work and family have become increasingly interconnected due to demographic changes in the work force and changing notions of work and careers.[10]

Policies implemented to promote a better balance between career and family responsibilities include: Job-sharing, in which either spouse may share a job outside the home with another employee, perhaps even his or her spouse; Assistance in locating, obtaining, and improving the quality of child care; Elder care, "providing some type of assistance with the daily living activities for an elderly relative who is chronically frail, ill, or disabled"[11]; Parental leave; and Alternative work schedules, not restricted by an 8-hour day, 5 days each week, for full-time employees.

As labor supplies decrease, the current employment situation for women may change, particularly if effective intervention programs are widely disseminated. For both campus and company, it is useful to sensitize men to situations of inequity by discussion, films, etc. For instance, Hewlett-Packard has created a program to increase the sensitivity of managers to teach "them about their own gender biases and about different cultures and races and to inform them about the company's needs in terms of employee training and development."[12] Also, at the professional level, mentoring is important for enhancing the performance of employees, especially women employees: in some companies, each new woman employee is able to choose a mentor from a list of suitable volunteers supplied by her manager or department head. Another approach that has been found helpful in some companies—*e.g.,* Corning, Inc.—is building in accountability by basing some fraction of the performance appraisal of the manager

on affirmative action performance—specifically, hiring, promotion, and development of the potential of female employees.[13,14] Such accountability approaches might also have applicability to colleges and universities.

Some programs authorized by the U.S. Office of Personnel Management (OPM) for application throughout the civil service might aid in the retention of women scientists and engineers. OPM[15] believes that the "government's generous leave program," health benefits, flexible and compressed work schedules, leave for parental and family responsibilities, part-time employment, job sharing, and leave transfer program are enticements for continued employment within the federal sector. However, many of these benefits are not accessible to scientists and engineers, male or female, whose major work activities are primarily research and development (R&D, 24.8%), design (8.9%), data collection and processing (7.9%), natural resource operations (7.9%), and management (5.9%).[16]

2. SUMMARY

To summarize, education and employment prospects for women in science and engineering in the United States have not been as good as those for men. Women's position in the labor market, when measured by earnings, is relatively disadvantaged compared to men's. However, current and projected levels of female labor force participation indicate that women will continue to make up a significant portion of the U.S. work force. The increase in women's economic activity over recent decades, concomitant changes in household and family structure, and women's continued unequal status in the S&E labor force raise crucial questions about many of the assumptions that underlie prevailing employment policies and related policies in such areas as the family and education. Meanwhile, among the measures that have been found helpful to advancing the careers of women scientists and engineer are (1) the availability of female role models and mentors among the more senior S&E work force and (2) access to support networks.

3. ROLE OF THE NATIONAL RESEARCH COUNCIL

From time to time, it is necessary to alert the research and policy communities to opportunities for action in areas of mutual concern. The National Research Council (NRC) has a long and distinguished history of providing the federal government with information to develop effective policies for recruiting and retaining individuals in scientific and engineering (S&E) careers. In recent years, the Office of Scientific and Engineering Personnel (OSEP) has served as the focal point in the Council for providing information and advice on the health of the human resource base. It is no surprise, therefore, that to strengthen and clarify policies affecting the preparation and recruitment of women for careers in this area, the Governing Board of the National Research Council established in 1990 a continuing Committee on Women in Science and Engineering (CWSE). As a standing committee of the National Research Council, the Committee includes in its growing portfolio four sets of activities:

1. Collecting and disseminating current data about the participation of women in science and engineering to broad constituencies in academe, government, industry, and professional societies;

2. Monitoring the progress of efforts to increase the participation of women in scientific and engineering careers;
3. Conducting symposia, workshops, and other meetings of experts to explore the policy environment and to stimulate and encourage initiatives in program development for women in science and engineering and to evaluate their effectiveness on a regular basis; and
4. Proposing research and conducting special studies on issues particularly relevant to women scientists and engineers in order to develop reports that will document evidence and articulate NRC recommendations for action.

Specifically, the Committee on Women in Science and Engineering focuses on the postsecondary segments of the education/employment pipeline—undergraduate, graduate, postdoctoral, and career segments—while keeping abreast of developments in precollege science education designed to recruit females into scientific and engineering careers. In developing its strategic plan, CWSE began its work by surveying the global policy environment, including policies affecting the employment and education of women in science and engineering. The plan itself explores the capacity of the education infrastructure to prepare women for careers in science and engineering and the factors that determine how a skilled female scientist or engineer pursues a career. It focuses on formal and informal mechanisms in the postsecondary S&E education infrastructure, career patterns, and intervention models, undergraduate through employment.

The Committee is mandated to hold annual conferences and conduct studies illuminating the status of women in science and engineering and recommending ways to increase their participation in all postsecondary education and employment.

3.1. Conferences

Annual conferences are planned for the NAS/NAE Beckman Center, Irvine, California. The first, held on November 4–5, 1991, examined postsecondary interventions, both in education and employment. Because the causes and extent of differences in industrial employment are not clear or so easily obtained, the Committee's second conference—"Women Scientists and Engineers Employed in Industry: Why So Few?"—will be held on January 17–18, 1993. The third conference, tentatively planned for 1994, will examine the environmental issues that attract or deter women from pursuing careers in science and engineering.

3.2. Studies

The Committee's research program is fluid, in that it responds to the global policy environment. In fact, although a program of eight studies was developed in August 1991, it was modified both because of sponsor interest and because of other developments brought to the attention of the Committee. Committee-sponsored studies will begin in 1993. The first research activity is an examination of the career paths of a matched sample of men and women Ph.D.s in science and engineering. The purpose of this study is to provide data that may help measure any reduction of disparity between careers of men and women Ph.D.s during the past decade, examining sex-related barriers to their participation and advancement. Emphasis will be placed on identifying the career barriers that federal policy might help to overcome. The second research

activity, being conducted jointly with the National Research Council's Board on Engineering Education, will examine the status of women engineering faculty and result in two products: (1) a report that presents the findings of four focus group sessions on the situation of women in U.S. engineering departments and (2) a directory of women engineering faculty, showing not only their locations but also their ranks. This study relates to a more comprehensive research activity examining all scientific disciplines. Such studies are particularly important, since inequalities between women and men in career success indicators—such as academic rank, tenure, and salary—may influence young women to seek careers in other professional fields, where they perceive less inequality. The Committee on Women in Science and Engineering—believing that further national progress in increasing the participation of women in science and engineering will depend heavily on making timely and carefully analyzed data about their career status available—will devote much effort to securing and publishing such information.

It is important to point out that deeper discussions of all issues delineated above should occur between practicing scientists and engineers, their professional societies, employers, the Office of Science and Technology Policy, the Congress, and the media so as to meet head-on the challenges to be overcome if the United States is to maintain a competitive work force. The Committee does not act alone but, rather, responds to the concerns of its various sponsors and other partners in this effort. It views its role as a catalyst in bringing together these diverse groups in order to address the underparticipation of women in careers in the sciences and engineering. Thus, we can look forward to an increasingly rich program of activities from the Committee in coming years as it establishes itself firmly in the research and policy world.

4. FUTURE DIRECTIONS

Within the current policy environment, current data indicate the need for a concerted effort by the United States' scientific and engineering community to analyze the reasons underlying the decreasing participation of American students in science and engineering and to take corrective action. The declining number of college-aged students expected during the next decades does not necessarily imply that the United States will have a shortage of native-born scientists and engineers. An important strategy to offset the potential adverse effects of these expected demographic factors is to increase the probability that young people go into scientific and engineering careers. Such a strategy should include increasing the participation of groups who in the past have been under-represented in the S&E work force. However, in the face of national scientific and engineering needs, women are under-represented and underutilized in the sciences and engineering.

5. QUESTIONS YET TO BE ANSWERED

Policies affecting the S&E education infrastructure are diverse. Many groups—public and private alike—have placed high priority on developing programs to increase the number and quality of women entering science and engineering careers. However, beyond program development are specific questions that the National Research Council's Committee on Women in Science and Engineering believes should be addressed:

Are current employment policies still appropriate in light of the recent big changes in the number of women working and in light of current family structure?

How will changes taking place in employment policies—for example, employer-sponsored women's support groups and women's councils designed to suggest improvements in working conditions for women, changes in nepotism rules, availability of choice of benefits, changes in maternity and adoption leave policies, employer-provided or -sponsored dependent care, changing tenure and promotion policies to reflect women's extra family responsibilities, and extended possibilities for part-time and flex-time employment—affect the recruitment and retention of women in science and engineering?

What are the barriers to the advancement of women scientists and engineers—the "glass ceiling"—and how should they be addressed?

What are reliable "outcome measures" for assessing the specific contribution of program components to career outcomes for women?

Why, after expressing an initial interest in science and engineering (S&E) studies, do women, more often than men, switch to nonscience or nonengineering fields?

What trends about the career patterns of women scientists and engineers might be revealed if current data were more obtainable, a necessity if policymakers are to effect change so as to increase their participation in the S&E work force?

6. CONCLUSION

Understanding the problems that lead to the under-representation of women in science and engineering is a necessary first step in moving to alleviate that problem, but it is not sufficient. While we need to understand better the particular obstacles that prevent women from entering careers in science and engineering, we also need to continue, at the same time, to develop and implement programs that do something about removing those obstacles and increasing women's participation in science and engineering. A wide spectrum of programs has been introduced to assist women to gain entry into science and engineering through intervention efforts at various stages of education and employment. However, the absence of systematic and reliable information on the effects of these interventions represents a major barrier to the examination of policies and intervention programs fostering careers for women in science and engineering.

The decisions that we make about our scientific/engineering cadre today will have a significant effect on our ability to find solutions to future problems. Our ultimate success depends upon the degree to which we maximize use of all of the nation's human resources. The challenge in the 1990s will be the identification of new opportunities for assuring that women will take their place beside men in building a strong science and technology base in the United States. The poor participation of women in these fields is a matter of record; the understanding that something might be done to bring qualified women into productive careers as researchers, teachers, and practitioners of science and engineering prompted the National Research Council (NRC) in 1990 to establish the Committee on Women in Science and Engineering (CWSE) within the Office of Scientific and Engineering Personnel (OSEP).

ENDNOTES

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