INCREASING THE PARTICIPATION AND ACHIEVEMENT OF GIRLS AND WOMEN IN MATHEMATICS, SCIENCE, AND ENGINEERING

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Substantial progress has been made in the last fifteen years for women in mathematics, science, and engineering. The proportion of women earning doctorates in science and engineering, for example, has risen from 7% in 1965 to 25% in 1980 (National Research Council, 1980). As Figure 1 shows, however, most of this increase is attributable to large proportions of women in the social and life sciences; women are still at or below 12% in mathematics, physical sciences, and engineering. At the undergraduate level, the proportion of women planning majors in science and engineering also has been increasing (Astin et al., 1974-1982). The greatest percentage increase has been in the field of engineering, in which there were 358 women who earned bachelor's degrees in 1970, representing 0.8% of the graduating class, and 5,680 women in 1980 representing 9.7% of the graduating class. With a projection for 1984 of 14%, it is clear that there have been impressive inroads in the area of engineering. Yet, at this rate of 1% per year, it will be 2020 before there are equal numbers of women and men earning engineering degrees!

A similarly mixed picture appears when the employment of women scientists and engineers is surveyed. Female degree holders have higher unemployment rates than male degree holders, are less likely to be employed in science and engineering jobs, and are paid less. In academic settings, for example, 62.5% of the men with doctorates had tenure while only 35.2% of the women with doctorates had tenure in 1979 (Vetter, 1981).

Examination of participation and achievement of young women in mathematics and science, relative to young men, indicates that the message is also inconsistent. Some national enrollment surveys have found parity in election of mathematics courses in high school (Armstrong, 1982), except at the highest level of calculus, though investigation from state to state shows that there are still substantial differences at the intermediate level of Algebra II (California Basic Educational Data System, 1981). Some researchers are not finding sex-related differences in achievement in areas in which they used to find them consistently (e.g. spatial visualization, see discussion below). On the other hand, the National Assessment of Educational Progress continues to find sex-related differences in science and mathematics achievement that increase from age 9 to age 13 to age 17 (Fennema & Carpenter, 1981).

The progress of women in science is, of course, due to a number of factors. In this chapter, however, we will concentrate on the roles of educational research and of educational program development, and their interrelationship, as major contributors to this progress. It is our contention that the close relationship between research and development activities related to women's participation in math-related fields is an important catalyst for advancement in both research and development.. A good example is the research of the Berkeley sociologist, Lucy Sells, who investigated the persistence of women and minorities in different doctoral fields (Sells, 1975). She found that mathematics training in secondary schools was a "critical filter" for these groups, keeping many students from studying various scientific fields as undergraduate or graduate students. Her personal enthusiasm prompted the founding of the Math/Science Network, now a group of 1000 scientists, educators, and community people who work together to promote the participation of women in math-related and non-traditional fields. Several Network programs are described in later sections in this chapter. The popularization of the "critical filter" idea (Ernest, 1976) caused many educators to take an interest in secondary school mathematics course enrollments.

At about the same time, Maccoby and Jacklin (1974) published their landmark review of the published and unpublished literature on psychological sex differences. While they cast serious doubt on many longheld myths, they allowed to stand as "fairly well established," "that boys excel in mathematical ability" (p. 352). They noted that males and females are similar in mathematical skills through elementary school, but at about ages 12-13, boys' mathematical skills increase faster than girls'. They also indicated that the rate of improvement was not entirely a function of the number of mathematics courses studied, though that question had not been extensively studied at that time. Shortly thereafter, however, the work of Fennema and Sherman (1977) showed that, among students whose mathematics backgrounds were similar, sex-related differences in mathematics achievement were found inconsistently, were small, and were related to affective factors such as confidence, perceived usefulness of mathematics, and perceptions of significant others.

The emerging emphasis on enrollment in elective mathematics classes led to two parallel movements. The desire to understand the causes of lower enrollment among females prompted the National Institute of Education (NIE) to commission papers to assist them in planning their research agenda for 1978 and 1979 (Fox, Fennema, & Sherman, 1977). A concerted research program was launched, in which researchers with various perspectives and methodologies set out to investigate the participation and achievement of women in mathematics. These studies constitute some of the classics to be reviewed in the following section. (A book is being prepared by Susan Chipman and Donna Wilson of NIE which will present and synthesize this work.) The desire to influence the enrollment of girls and women in mathematics and science courses and programs and to increase their success once enrolled prompted a number of educators to step up their activity in programs for women in science and mathematics education. There have been interaction and cooperation between the researchers and the developers, and many individuals have participated in both types of activity. For purposes of examining the impact of these activities, however, it is helpful to summarize the issues raised by the research first, then to detail the ways in which these issues have been addressed by intervention programs and changes in the educational system. Similarly, the prerequisite nature of mathematical achievement for science and engineering participation dictates a consideration of mathematics ahead of the other sciences.

This literature review identifies and summarizes an extensive literature in the following categories: biological factors (quantitative and spatial skills), socialization factors (modeling, expectations, and experiences), attitudinal factors (confidence, sex-typing, perceived value of math), and affective factors (anxiety).

Issues Identified by the Research on Women in Mathematics

Biological Factors

Some scientists attribute the sex differences in performance and participation in mathematics to innate ability or aptitude differences. Proponents of this theory argue that there are consistent sex differences on tests of both quantitative and spatial skills which account for performance and participation differences. Evidence related to each of these conclusions is reviewed below.

Sex differences on tests of quantitative skills. The following results are fairly consistent across studies using a variety of achievement tests: (a) High school boys perform a little better than high school girls on tests of mathematical reasoning (primarily solving word problems); (b) Boys and girls perform similarly on tests of algebra and basic mathematical knowledge; and (c) Girls occasionally outperform boys on tests of computational skills (Armstrong, 1980; Burnett, Lane, & Dratt, 1979; Connor & Serbin, 1980; E.T.S., 1979; Fennema, in press; Fennema & Sherman, 1977, 1978; Hyde, 1981; Schratz, 1978;

Sherman, 1980, 1981; Starr, 1979; Steel & Wise, 1979: Wittig & Petersen, 1979). Among normal populations achievement differences favoring boys do not emerge with any consistency prior to the 10th grade, are typically not very large and are not universally found even in advanced high school populations. There is some recent evidence, however, that the general pattern of sex differences may emerge somewhat earlier among gifted and talented students (Benbow & Stanley, 1980; E.T.S. 1979).

Sex differences in spatial skills. The findings regarding sex differences in spatial skills are also fairly consistent, though not universal, and do not emerge prior to about the 10th grade. Among these older adolescents, boys outperform girls on some measures of spatial skills but the magnitude of the sex difference varies depending on body type (Petersen, 1979), on personality characteristics associated with masculinity and femininity (Nash, 1979), on previous experience with spatial activities (Burnett & Lane, 1980; Connor, Serbin, & Schackman, 1977; Connor, Schackman, & Serbin, 1978), on ethnic background, parental styles, and socioeconomic status (Fennema & Sherman, 1977; Nash, 1979; Schratz, 1978), on maturational rate (Waber, 1979), and on the particular test given (Connor & Serbin, 1980). In fact, in a recent national survey study of 3240 junior and senior high school students, 13-year-old girls did better on a test of spatial skill than 13-year-old boys; 12th grade boys and girls did equally well (Armstrong, 1980). Thus as Connor and Serbin (1980, p. 36) conclude, "junior and senior high school males...perform better than females on some visual-spatial measures, some of the time."

<u>Relation of spatial skills to mathematics achievement</u>. Several studies have demonstrated a strong positive correlation between spatial skills and a variety of mathematical achievement test scores (Armstrong, 1980; Burnett et al., 1979; Connor & Serbin, 1980; Fennema & Sherman, 1977, 1978; Sherman, 1980a,b; Steel & Wise, 1979). But verbal abilities also correlate quite highly with mathematical performance; not all measures of spatial skills correlate significantly with all measures of mathematical achievement; and the patterns of these relations varies across grade level, sex, and study (Armstrong, 1980; Burnett et al., 1979; Connor & Serbin, 1980; Fennema & Sherman, 1977, 1978; Hyde, Geiringer, & Yen, 1975; Sherman, 1980; Steel & Wise, 1979). Further, in a recent factor analytic study, Connor and Serbin (1980) found that the tests of spatial skills factor together and independent of measures of mathematical achievement. Thus the relation between spatial skills and mathematical achievement is not clear. Furthermore, whether or not the sex difference in spatial skills is contributing to the sex difference in mathematical achievement is even less clear. While some findings are consistent with this hypothesis (e.g. Burnett et al., 1979; Fennema & Sherman, 1977; and Hyde et al., 1975); others are not (e.g., Connor & Serbin, 1980; Steel & Wise, 1979).

Whether the sex differences in either mathematical ability or spatial skills contribute to the sex differences in course participation rates is even more debatable. The pattern of results is quite mixed. For example, in Sherman (1981) spatial skills predicted girls' but not boys' participation. In contrast, in Steel and Wise's study (1979) spatial skills predicted for boys only. Participation is also predicted by scores on vocabulary tests (Sherman, 1981), by past math achievements (Armstrong, 1980; Dunteman Wisenbaker, & Taylor, 1979; Fennema, in press; Parsons et al., in press-a; Steel & Wise, 1979), by interest in mathematics and career plans (e.g., Fennema, in press; Parsons Adler, Futtelman, Goff, Kaczala, Meece, & Midgley, 1983 in press-a; Steel & Wise, 1979), and by a variety of attitudinal and social factors which will be reviewed in the next section.

In addition, it must be noted that spatial visualization skills can be trained (Burnett & Lane, 1980; Connor et al., 1977, 1978; Goldstein & Chance, 1965). Thus the magnitude of the contribution of biological factors, the inevitability of their effects, and the exact nature of these effects are still to be determined.

Socialization Factors

Modeling effects. Several studies have found that adult females are both less likely to be engaged in math activities and more likely to express doubts about their math abilities than are adult males. For example, after sixth grade, fathers are more likely to help their children with their math homework than are mothers (Ernest, 1976); advanced math courses are more likely to be taught be men (Fox, 1977); female student teachers have lower estimates of their math ability and openly admit they are less comfortable teaching math than their male peers (Aiken, 1970); and finally, mothers hold a more negative view of their math abilities and interest than do fathers (Parsons ~~et al.~~ Adler & Kaczala, 1982). This under-representation of appropriate female role-models could discourage some girls from engaging in activities involving mathematics during the high school years. The success of several recent intervention programs designed to increase female math participation through exposure to female models supports this line of reasoning (e.g., Brody & Fox, 1980; Tobin & Fox, 1980).

Socializers' expectations and related behaviors. The expectations parents and teachers hold for children are another possible source of influence on children's math involvement. Several studies indicate that parents and teachers have higher educational expectancies for high school and college age males than for comparable females (Good, Sikes, & Brophy, 1973; Hilton & Berglund, 1974; Sears, Maccoby, & Levin, 1957). Only a few studies have directly measured the expectancies that parents and teachers hold for math achievement. While these studies have yielded a mixed pattern of results, when differences emerge, they favor boys. For example, in some studies both parents and teachers believe boys are better at math than girls (Casserly, 1975; Ernest, 1976; Haven, 1971; Luchins, 1976). Similarly, parents rate math as more difficult for daughters than for sons and feel that girls have to work harder than boys in order to do well in math courses (Parsons et al., 1982). Other studies, however, yield either inconsistent or non-significant sex effects (e.g. Ernest, 1976, Parsons, et al., 1982a,b). For example, in the Parsons, et al., (1982) study, neither parents nor teachers had lower expectations for their girls' math performance than for their boys'. Thus, it appears that the sex stereotypes held by parents and teachers are small but favor boys when they are present.

But do these stereotypes affect students' attitudes and if so how? Parents, teachers, and counselors have all been found to provide boys more explicit rewards, encouragement, and reinforcements for learning math and for considering math related careers than girls (Astin, 1974; Haven, 1971; Casserly, 1975; Luchins, 1976; Parsons et al., 1982b). In one study the counselors openly admitted discouraging girls from taking these courses, citing reasons that reflected their stereotyped views of appropriate adult roles and math abilities. In addition, based on extensive observations in classrooms, several investigators have concluded that the quantity and type of teacher instruction sometimes varies according to the sex of the student and the subject matter being taught. Some, but not all, teachers interact more with, provide more praise to, and provide more formal instruction to boys than girls, especially in mathematics and science classes (Bean, 1976; Becker, 1981; Brophy & Good, 1974; Fennema, 1982; Leinhardt, Seewald, & Engel, 1979; Parsons et al., 1982; Stallings, 1979). These differences in teacher behavior, when found, are most extreme among high math ability students.

While the pattern of results associated with differential treatment is fairly consistent, studies which have attempted to assess the causal influence of these differences on course enrollment or career aspirations have yielded a much less definitive picture. Both Heller and Parsons (1981) and Parsons et al. (1982) tested the relation of student-teacher interaction patterns to both students' attitudes toward math and their plans to continue taking math. While both studies found a significant relation between teachers' expectations for a student (as provided by the teacher on a written questionnaire) and student attitudes even after the effects of the students' past grades in mathematics had been partialed out, both studies found very few significant relations between actual teacher behaviors and student attitudes. And those which did emerge were quite small. Other studies, focusing more on the impact of a single, salient teacher, suggest that teachers can have a big impact on girls' attitudes. But the teachers must provide <u>active</u> encouragement to the girls in the form of (a) exposure to role models, (b) sincere praise for high ability and high performance, and (c) explicit advice regarding the value of math and its potential utility for high paying, prestigious jobs (Casserly, 1975, 1979).

Studies demonstrating the causal influence of parents in shaping sex differences in math participation are virtually nonexistent. For example, Parsons and her colleagues have demonstrated that parents' sex stereotyped beliefs are related to girls' more negative attitudes toward math. It is not clear, however, whether the parents' stereotyping fostered the daughters' negative attitudes or the daughters' negative attitudes fostered the parents' stereotyping (Parsons et al., 1982).

Differential experiences. In addition to the more direct socialization effects discussed thus far, parents and teachers also influence children's achievement behaviors and values through the experiences they provide or encourage. Exposure to different toys and recreational activities has been linked to the sex differences in both spatial skill and attitudes toward math and science (Astin, 1974; Connor et al., 1978; Hilton & Berglund, 1974).

Early independence training has also been suggested as a cause of sex differences in math involvement (Ferguson & Maccoby, 1966) and since girls may get less independence training than boys, the sex difference in math involvement may result from these differential socialization practices. This hypothesis has yet to be tested directly.

Summary. The studies reviewed in this section provide strong support for the hypothesis that socializers treat boys and girls differently in a variety of ways that might be linked to math achievement and course selection. But only a few studies have assessed the causal impact of these socialization experiences on students' math attitudes, math achievement, and course selection. The results of these few studies suggest that sex differences in math behaviors and course selection may result from the differential treatment accorded girls and boys. For example, encouragement from parents has emerged in several studies as an important factor in girls' decisions to elect advanced mathematics courses in high school (e.g., Armstrong, 1980; Fennema & Sherman, 1977, 1978; Haven, 1971; Luchins, 1976; Parsons et al., in press-b; Sherman & Fennema, 1977). The effects hold up longitudinally and are significant even when the effects of the children's past performance in mathematics are partialed out (Parsons et al., in press-a). Thus it seems likely that parents and teachers are having a negative impact on girls' math course-taking.

Attitudinal Factors

Confidence in one's math ability. The pattern of findings regarding confidence in one's math ability and related attitudes are quite consistent. While sex differences are typically not present among elementary school children, by junior high school boys are more confident of their math abilities than girls (e.g., Armstrong & Kahl, 1980; Brush, 1980; Ernest, 1976; Fennema & Sherman, 1977; Fennema, in press; Fox, Brody, & Tobin, 1980; Kaminski, Erickson, Ross, & Bradfield, 1976; Parsons et al., in press-a; Sherman, 1980). This sex difference, however, is not reflected in students' expectations for their performance in the courses in which they are currently enrolled (Heller & Parsons, in press; Parsons et al., in press-a). Rather the sex difference emerges on measures reflecting students' more general rating of confidence in their math abilities and their expectations for future courses.

Although sex differences in confidence have been established, only a few studies have tested the link between confidence in one's math ability and course selection. These studies have yielded a consistent pattern of positive relation between confidence and enrollment patterns (Armstrong, 1980; Kaminski et al., 1976; Parsons et al., ~~in press-a~~ 1983; Sherman, 1980; Sherman & Fennema, 1977). More studies, however, are needed to clarify the causal significance of this relationship.

<u>Sex typing of mathematics</u>. While numerous studies have shown that when high school students sex-type mathematics they classify it as a male achievement domain (Armstrong & Kahl, 1980; Ernest, 1976; Fennema & Sherman, 1977; Parsons et al., ~~in press-a~~ 1983; Stein & Smithells, 1969), the implication of this fact for math enrollment is not clear for several reasons. First, math is neither always stereotyped as masculine (e.g., Fennema & Sherman, 1977; Parsons et al., ~~in press-a~~ 1983; Stein & Smithells, 1969), nor is it even one of the most likely subject areas to be stereotyped; mechanical arts courses and athletics are both more likely to be classified as masculine (Stein & Smithells, 1969). Second, boys are more likely to stereotype math as masculine than are girls (e.g., Brush, 1980; Fennema & Sherman, 1977; Parsons et al., ~~in press-a~~ 1983; Sherman, 1980). Third, studies which have attempted to assess the relation of sex-typing, of math to actual math achievement, and course plans have yielded mixed results. Furthermore, the variations in results do not follow a consistent pattern (Boswell, 1979; Dwyer, 1974; Fennema & Sherman, 1977; Nash, 1975, 1979; Parsons et al., ~~1982~~ 1983; Sherman, 1980). Thus the

relation between the sex-typing of mathematics and students' achievements and course plans in mathematics is not clear at present.

<u>Perceived Value of Math</u>.

Ratings of the utility value of math also vary by sex. Several studies indicate that boys, as early as 7th and 8th grades, rate math as more useful than girls (Brush, 1980; Fennema & Sherman, 1977: Fox, Tobin, & Brody, 1979; Haven, 1971; Hilton & Berglund, 1974; Parsons et al., ~~in press-a~~ 1983; Wise, Steel & MacDonald, 1979). These results, however, are not entirely consistent across age groups and schools (Fennema & Sherman, 1977; Sherman, 1980).

Perceived value of math and math-related career plans emerge as significant predictors of both achievement and course plans in most studies (e.g., Armstrong, 1980; Brush, 1980; Fennema, in press; Fennema & Sherman, 1977; Fox et al., 1980; Fox & Denham, 1974; Lantz & Smith, 1982; Parsons et al., ~~in press-a~~ 1983; Wise et al., 1979). Furthermore, while Brush (1980) found that the perceived usefulness of math was a relatively weak predictor of course participation in comparison to other predictors such as ability level, socioeconomic status, and general feelings toward math, other investigators have found that interest in math and perceived utility value are two of the most important mediators of the sex differences in math involvement.

Affective Factors

In recent years math anxiety has emerged as yet another explanation for the sex difference in math involvement (Lazarus, 1974; Tobias, 1978; Tobias & Weissbrod, 1980). Although there are only a few empirical studies which test for sex differences in "math anxiety" and these are not entirely consistent, there is some support for the hypothesis that in high school and beyond girls have more negative affective response to math than boys (Brush, 1976, 1980; Dreger & Aiken, 1957; Meece, 1981; Suinn & Richardson, 1972). These studies, however, have not controlled for the possibility that boys may be less willing to admit to feelings of anxiety, especially since they regard mathematics as a male domain.

The few studies that have tested for the causal impact of anxiety on course taking suggest that anxiety does not have a large direct effect on course plans. Instead it appears to have its most important effect on other variables related to students' course selection such as how much they expect to like the course and how well they expect to do (Brush, 1980; Meece, 1981; Parsons, 1982). In two of these studies, girls' attitudes were affected more by their anxiety levels than boys. Thus, it is likely that anxiety is having a more negative effect on girls' math involvement than on boys'.

Summary of Past Research

We have reviewed several explanations for the sex difference in math involvement. Not surprisingly, no one cause has emerged with unequivocal support. Because aptitude differences appear to be quite small and difficult to assess and because the majority of the researchers have been interested in identifying modifiable determinants of the sex differences in participation, much of the recent research has focused on social and experiential factors. Evidence from these studies suggests that socializers have a powerful influence on students' academic choices. There is also fairly strong evidence suggesting that students themselves, through their attitudes, self-perceptions, and feelings about mathematics are a major source of the sex differences in both math achievement and course enrollment patterns. Of these variables, confidence ability and the perceived value of math appear to play the most critical role. Finally, there is some support for the possibility that biological factors may be involved, but the exact nature of these factors and their susceptibility to training are still unknown.

Relationship of the Women in Science and Engineering Research to that in Mathematics.

The research on women in science and engineering begins with the prerequisite abilities in mathematics, but the differences in mathematical ability and achievement described above cannot completely account for the differences in achievement and participation in science and engineering. This section considers the extent to which the research issues above are also relevant for science, and considers the additional factors in science and engineering.

The quantitative and spatial skills associated with high achievement in mathematics are also associated with high achievement in science, though the importance of spatial ability for science achievement is also uncertain in science. There is some evidence that spatial ability may be more important for some areas of science, particularly physical sciences and engineering, than it is for others, namely the life sciences (Kelly, 1975). Again, because of the confound of differential experience with spatial activities, most science educators believe that the spatial ability deficit, if it exists, is modifiable through educational experiences.

The socialization factors discussed above are also involved for science. Some factors, such as modeling, may be magnified with respect to science because there are fewer women to serve as role models, especially in engineering and physics. It has even been suggested that the most effective strategy for addressing the low participation of women in science is to recoup the women who have science training and are not currently active as scientists. This would enlarge the proportion of active women scientists and alleviate the lack of role models and the sense of isolation that many female scientists feel (Lantz, 19). The sex-typing of science as masculine has been found as early as first and second grade, but recent research indicates that this stereotyping may be limited now to the physical sciences (Vockell & Lebonc, 1981). Similarly, analyzing the National Assessment of Educational Progress survey information on students' science experiences, investigators found that females were somewhat more likely than males to report experience with living plants and animals, substantially less likely to report experience with magnets and electricity (Kahle & Lakes, 1982). These experiential differences increase with age, as do achievement differences in science.

Additional research has been done in science education that goes beyond the factors identified for mathematics. It has focused primarily on career development issues and has been hampered in two important ways. First, theories and literature in career development, especially in the sciences, are models that have been developed on male samples. A good example of this is a longitudinal study, using the Project TALENT data bank, in which the prediction equation for factors in high school that predicted subsequent scientific careers had to be based on the male sample because too few women in the sample of 23,700 1960 high school students became scientists by 1975 (Gilmartin, McLaughlin, Wise, & Rossi, 1976). Second, and closely related to the first point, retrospective studies of women who have succeeded in scientific careers have found that they are extremely capable individuals who probably could have succeeded in almost any field, so that their lives do not yield particular insights into women in science _per se_ (e.g., Kundsin, 1974). More extensive treatment of women's career development is given in the career education chapter of this book.

Intervention Programs Designed to Increase Girls' and Women's Participation and Achievement in Mathematics, Science, and Engineering

Two years ago, the American Association for the Advancement of Science (AAAS) prepared an inventory of programs for women and girls in mathematics, science, and engineering (Aldrich & Hall, 1980). It covered projects started in the United States since 1966 and ended data collection in 1978. While such an inventory can never be complete, it included 315 projects. Observing that only half of the directors of NSF-funded career days for college women had completed the requested summaries, one of the authors has estimated that there may easily have been twice as many programs in all of the categories (Aldrich, 1982). Realizing that it is impossible to do justice to as many as 600 programs, in this section, we will summarize the characteristics of programs in the directory first, then turn to descriptions of model programs. Model programs were selected by virtue of the availability of program descriptions and evaluation data, and judgments about the likelihood of replication and impact elsewhere. The presentation of the model programs will be organized by educational strategy (curriculum, conferences, etc.) rather than by the problem that they set out to solve, because most of the programs had a number of complementary goals.

Of the 315 projects in the AAAS directory, more than a third covered six or more fields of science, nearly all of which included mathematics. Of those projects that covered five or fewer fields, engineering was the most popular, being a focus of half. Approximately one fifth of the programs concentrated exclusively on mathematics. The projects were distributed throughout the educational system in almost a normal curve with respect to age--i.e. a few at elementary, more at junior high and high school, the largest number at the undergraduate level, and tapering off at graduate and faculty development levels. The projects were also distributed widely around the country, and nearly all of them (84%) were university-based. There was variability in the participation of boys and men, and no project director reported the exclusion of men from participation. The participation of minority and disabled women was requested from the project directors, but many did not have accurate data on their presence.

Special Classes for Women

Schools and colleges for women were founded initially to offer women an education comparable to that offered to men in institutions that did not admit women. Now, of course, women are admitted to all of the prestigious colleges and universities in the United States. Comparison of the female graduates of coeducational colleges and universities with graduates of women's colleges has shown that graduates of women's colleges are more likely to obtain Ph.D.'s, not only in the humanities, but in the

the physical, life, and social sciences (Tidball & Kistiakowsy, 1976). High selectivity and student interest in attending a women's college make it impossible to attribute the finding to the experience of attending a women's college perse, but there is some sentiment that achievement for women is easier in an all female environment. With respect to a traditionally male-dominated field like science, the sense of being out of place is alleviated by the presence of other women.

With the advent of Title IX, it became more difficult to conduct sex-segregated classes in public institutions. In private institutions that receive public funding, the picture is less clear. There have been several projects which have experimented with all-female environments that indicate that there may be some advantage to female students from spending some of their instructional time in single-sex settings. All of the projects described below, however, used several strategies in conjunction with the exclusion of males, so that they cannot be said to test a single-sex setting perse.

Math for Girls. In 1973, the Lawrence Hall of Science, which offers after-school classes in mathematics, computer science, and the sciences, found that fewer than 25% of the participants were girls. To attract girls to the Hall and to inform them and their parents that mathematics is an appropriate topic for girls to study, a "Math for Girls" course was established. The course, which aims to increase positive attitudes towards mathematics and to increase problem solving skills, has four problem solving strands: (1) logic, strategies, and patterns; (2) breaking set; (3) creative thinking, estimating, and observing; and (4) spatial visualization. The eight 1 1/2 - 2 hour sessions are taught by a young women who uses mathematics in her studies (often a University of California science major) or in her career, who establishes a cooperative, recreational atmosphere.

The course is supported by tuition and has not had the the resources to conduct a formal evaluation. The original goal, to increase young women's participation in Hall course offerings, has been met in part, as female enrollment in other courses has increased from 25% to 40%. The role of the Math for Girls course in influencing this progress cannot be disentangled from several other Lawrence Hall of Science outreach efforts, however. The course does remain popular, though, and a handbook that gives a detailed curriculum guide for the course, has sold ____ copies (Downie, Slesnick, & Stenmark, 1981).

<u>An Acceleration Program for Mathematically Gifted Girls</u>. The Johns Hopkins University Study of Mathematically Precocious Youth (SMPY was established in 1971 to identify mathematically precocious youth and to encourage their talent by tailoring educational experiences to their needs. After identifying mathematically talented students by superior performance on the Scholastic Aptitude Test, SMPY conducted a fast-paced mathematics class for students as young as ten years old to learn high school mathematics. The program was far more successful in identifying and accelerating the progress of boys than of girls (Fox, 1976),

so that an experimental program was started just for girls.

The program and its evaluation are described in Fox (1976) and Brody and Fox (1980). Designed to counter the formal, competitive, and theoretical conditions that observation and interviews indicated as factors diminishing the girls' success in the coeducational class, the girls' class was taught in an informal, cooperative style by three women. The relevance of mathematics for social problems was stressed through rewritten mathematics problems and career speakers who described interesting fields, such as operations research, in which mathematics is used to solve social problems. Female role models also discussed their combination of interesting mathematics-related careers with raising families.

The all-girls class was more successful in attracting girls to the accelerated class than the coeducational class had been, and the completion rate was similar to the coeducational classes. Eighteen of the 27 girls completed the experimental class, meaning that they had learned Algebra I over a three month summer period, meeting about four hours a week. Their performance on a ninth grade normed Algebra I test was at the 89th percentile, significantly higher than control boys and girls who had been matched from the SMPY sample for SAT scores.

Attempts to place these girls in Algebra II when they were eighth graders met administrative barriers, so that only 11 girls were able to accelerate. Follow-up studies were conducted annually and they revealed that the control boys had accelerated in mathematics on their own while few of the control girls had done so. By the end of the 1976-77 school year, 42% of the experimental girls, 46% of the control boys, and 8% of the control girls had accelerated.

An Experiment at the College Level. A special section of a mathematics course for women has also been tried successfully at the college level. In 1974-75, the University of Missour-Kansas City conducted an NSF-funded project that offered a special section of the introductory mathematics sequence (MacDonald, 1980). This section enrolled 33 students in the first semester and 22 in the second semester, compared with 55-60 students in the regular sections. Taught by a female professor and a female advanced graduate student, the class was preceded by a one-hour optional tutoring session in which students worked in small groups in a social, informal atmosphere. Other supplemental activities included discussions of the socialization of women, services available to students on campus, social and cultural issues, and personal experiences. Students were given take-home review tests and had the chance to take each test a second time, counting the second score if better or the average if not. A comparison of participants in the special course with women in the regular sections showed that they had higher grades and a better completion rate. While the retaking of tests may have contributed to higher grades, the women in the special section had been selected because of weaker backgrounds. Women in the special section also reported greater satisfaction with the course than those in the regular sections, and they reported that they had spent more time studying mathematics. It is not possible to determine which of the many differences contributed to success, but 56% of the participants went on to enroll in another mathematics course, compared with 17% of the women in other sections.

Retention of Women in the Science Disciplines. A program at Purdue University combined intensive counseling, a special course, and special laboratory projects for freshman students in an effort to increase the retention of women in undergraduate science majors, and found that the effects of these interventions were cumulative (Brown, 1976). The counseling was in addition to the usual level offered to freshmen and the special course offered students the opportunity to meet women from various scientific fields and learn about the rewards and hazards of pursuing a scientific career. The component of the program that has special relevance for this section, however, was the finding concerning the special projects, in which students were assigned to small laboratory groups to work on projects directly with professors, an experience not usually given to freshmen. Although no female reported experiencing discrimination in the laboratory situation, it was found that the greatest percentage of female students who completed the project and reported the greatest personal satisfaction were participants in either all female groups or groups in which females were at least half of the group membership. The sex composition of the group did not have a similar effect on the male students. The author pointed out that the small numbers involved (120 women in the entire project) and the voluntary character of the sample (after random selection, participation was not required) limit the reliability and the generalizability of the findings.

Women in Engineering. Another program at Purdue, in its Engineering Department, was designed to meet the special needs of freshmen engineering women, particularly to address their lack of "hands-on", technical experience compared with males' childhood experience gained through hobbies and educational experiences. The course combined laboratory experiences (hand tools, power tools, engines, plumbing, metals, and lectures from a variety of male and female role models. Students were selected randomly from those who had expressed interest, yielding one section that was predominantly female (85% and one section that was balanced. Pretest posttest comparisons showed that male and female participants in the special course gained in technical knowledge and self-confidence when compared with the control groups. The progress of the women in the two sections was similar, such that the gap between the experimental women and men was substantially narrowed during the one semester course (Heckert, LeBold, Butler, Knigga, Smith, Blalock, Hoover, 1978).

Reentry Programs for Women in Science. Surveys have shown that as many as 40% of all women scientists drop out of the labor force at some time (Burks & Connolly, 1977; Vetter, 1978). To reclaim this under-utilized segment of the labor force, reentry programs have been developed to bring these women back into the sciences, updating their competency so that they can be full participants. A successful group of reentry programs was funded by the Women in Science Program of the National Science Foundation (NSF), all of which emphasized a strong academic component though including confidence building, study skills, and other components. The NSF-supported programs concentrated on updating a women's knowledge in an area in which she already had a bachelor's degree, facilitating a change of major (e.g., from mathematics to electrical engineering) or combining these features. The goal of accomplishing this transformation in approximately one academic or calendar year has encouraged creative approaches to curricula. In addition, most programs have included skills for success, counseling, and assistance with child care. Linking the academic program with industry helps students gain internship experiences and assists with placement upon graduation.

One of the most successful of these NSF-sponsored programs is that at the University of Dayton, directed by Carol M. Shaw, which provides a mechanism for career change from science to chemical and electrical engineering. The program offers traditional lecture courses (15 weeks), sequential short courses (7 weeks) and self-paced instruction over an 11 1/2 month period. With an initial group of 71 students, 60% of whom were unemployed or underemployed, 63 students completed the program, 61 of whom are employed and one of whom is in graduate school. The students received an average of three job offers each (Shaw, 19).

Special Classes to Address Problems Faced by Women

A thin line separates the courses described above, which were explicitly designed to attract women and in some cases are restricted to female enrollment, and the courses that will be described in this section, which were designed to address the issues in mathematics and science instruction that have been identified as particularly important for women. As indicated above, Title IX restricts schools from providing educational opportunities on the basis of sex, so that caution must be exercised in creating courses that would segregate students by sex. In addition, it can be argued that special courses for girls and women reinforce the idea that females have deficiencies that need to be remedied, and therefore contribute to the problem they are trying to solve.

The "Math Anxiety"/"Math without Fear Continuum. In the mid-70's, a number of people in institutions of high education became aware that existing mathematics curricula did not meet the needs of students who were unprepared to take calculus. As women undergraduates particularly were seeking fields of study and work that required quantitative skills, they found that there were not appropriate courses to address their lack of confidence and/or competence in mathematics. There were a number of factors in these students' elementary and secondary education that were identified as probable causes of this situation, clustering around the idea that mathematics is often taught in such a way that it creates strong negative feelings in students that are increasingly hard to overcome. Two major approaches have been used in higher education settings to assist students who lack confidence in their mathematical ability and skills--attempts to decrease math anxiety and attempts to teach mathematics in an environment that will increase confidence. While these approaches are usually combined in most interventions, they will be described first separately for purposes of discussion.

The "math anxiety" approach was popularized by Sheila Tobias (1978), who coined the phrase that captured the frustration and difficulty faced by many students when confronted with failure in mathematics. Working with professional psychologists, she set up the Math Anxiety Clinic at Wesleyan University, where she was Associate Provost, and provided counseling for students to assist them in overcoming the negative feelings about themselves as learners of mathematics. The success of the clinic in enabling students to conquer their math anxiety so that they could take courses and graduate school entrance examinations that had been precluded before led to considerable replication of this approach. Tobias has catalogued the programs and resources available regarding math anxiety from an Institute for the Study of Anxiety in Learning that she established in Washington, D. C. (Tobias, 19).

Investigations of the math anxiety construct have found that anxiety can be broken down into two components--math test anxiety and numerical anxiety (Hendel, 1981). This finding points out one of the subtleties in research and program development in this area--that the anxiety that is observed comes from more than one source. While some of the negative feelings are associated with the subject matter _per se_, another source of negative feelings is the typical environment of mathematics courses, which includes more frequent assessment than other courses and a more prevalent message that there is just one right answer (Brush, 1980).

An alternative approach to conquering math anxiety, then, has been to change the classroom environment in which mathematics is taught so as to reduce the feelings of insecurity that are present in traditional classes. One example of this approach is the "Math without Fear" course established by Diane Resek at San Francisco State University in 1975 (Resek & Rupley, 19). Resek's premise is that a great deal of the discomfort that many students experience in mathematics courses comes from the strategy they have used to learn mathematics. Having tried to memorize a set of rules or procedures for solving problems rather than understanding mathematical concepts, they have no fallback strategy when their memories fail them. The course tries to convert these "rule-oriented" students to a conceptual approach to mathematics that will enable them to solve problems for which they have no set algorithm to follow. Techniques of guessing, using physical materials to build abstract concepts, using visual representations to solve problems, small group and recreational activities, and explicit recognition of difficulties are used to increase students' problem solving capabilities. The "Math without Fear" course has been successful in moving 70% to 80% of its students to a concept-orientation in one semester. A Center for Mathematics Literacy has been established at San Francisco State that has added "Statistics without Fear" and "Computers without Fear" courses to increase access to these quantitative fields for the students, primarily women and minorities, who arrive at the university without adequate preparation for the standard, entry level courses.

A sister course to the one at San Francisco State was started by Ruth Afflack at California State University, Long Beach. It was more formally evaluated by external evaluators (Davis & Stage, 1980), who found that students' attitudes towards mathematics and problem solving were improved, that their mathematics skills improved, and that their performance in subsequent mathematics courses exceeded their performance in courses they had attempted prior to taking "Math without Fear."

Combined Approach. As indicated above, most programs for adults with low mathematics confidence combine anxiety reduction with mathematics instruction. Some have criticized the "math anxiety" approach as an example of "blaming the victim" since it identifies the problem as a pathology of the student rather than the educational and social systems which influenced her. Not all math anxiety programs teach mathematics, but many do (Tobias & Weissbrod, 1980). Conversely, not all building math confidence programs deal explicitly with the psychological barriers to success in mathematics (Davis & Stage, 1980), but most of them do. There are, however, courses that have explicitly adopted components of both models, one of which is offered at Humboldt State

University.

The "Building Math Confidence in Women" course at Humboldt (which was open to men, as well) is a two-quarter sequence described by Gale, Frances, Friel, and Gruber (1978). The first quarter prepares the student psychologically for a regular college mathematics course and provides intensive tutoring in basic math skills. The second quarter provides psychological and mathematics tutoring support while the student is enrolled in a regular college mathematics course at the level of algebra or higher. The psychology instruction includes relaxation training, anxiety control, acquiring a positive self-image, and acquiring assertiveness in the mathematics classroom. The mathematics instruction emphasizes logical thinking. Evaluation showed significant gains in arithmetic skills and improvement on the Math Anxiety Rating Scale and acceptable performance in regular mathematics courses.

Curricula Designed to Address Special Needs of Women

A thin line also separates the special courses described above from the curriculum development efforts that have tried to increase females' achievement and interest in mathematics and science. As with the courses, some curricula have focused on a particular issue, such as the usefulness of mathematics for future careers, while others have taken a more global approach and tried to influence many areas. In this section one general program and two specifically targeted approaches will be described.

Solving Problems of Access to Careers in Engineering and Science (SPACES). The SPACES project at the Lawrence Hall of Science took a broad mandate, to develop a set of 30 enrichment activities for grades three to ten that would provide career awareness and certain mathematical skills that are important for problem solving. The career awareness activities emphasize the variety of employment options available to people with good mathematics background, including non-traditional areas for women such as construction and the trades in addition to the sciences and engineering. The mathematical skills that are emphasized are problem solving, particularly the gathering and organizing of data, and spatial visualization.

Trial versions of the activities were used in 100 classrooms in 1980-81, and evaluated by pre-and posttesting students on six major objectives. Significant improvement was found, above the improvement observed in the comparison group, in five of the six areas tested. While attitudes towards mathematics did not change, the SPACES students improved in career awareness (career interest, career knowledge, and identification of tools) and in mathematical skills (word problem solving and spatial visualization). The program was developed to assist girls in areas in which they have traditionally not been strong, but it was effective for boys and girls who used the materials, which are available from the Lawrence Hall of Science (Fraser, 1982).

Career Oriented Modules to Explore Topics in Science

(COMETS). The COMETS project at the University of Kansas is a parallel in science to SPACES in math, but it has focused on the particular strategy of using role models to encourage science career interest. Each of the 24 modules describes science activities which role models, called community resource people, can use to arouse interest in a science concept that is being studied by the students and is used in the person's career. Following an introductory activity, such as conducting a perc test with a geologist, the geologist can go on to describe his/her own testing of soils for various characteristics. The resource person is then asked to talk about the career and how she or he prepared for it and how it relates with other parts of her or his life, such as family roles. The materials are produced so that the introductory activities can be conducted by the classroom teacher in preparation for the resource person's visit; they provide teachers with additional information about women's contributions to science, including biographical and language arts materials. Following field testing and evaluation, a revised set of materials are available at cost for national trial from the developer, Walter S. Smith, University of Kansas (Smith, 1982).

Multiplying Options and Subtracting Bias. This set of videotapes focuses on the decision to take elective mathematics courses by addressing issues and concerns of four specific groups: junior and senior high students, mathematics and science teachers, parents, and counselors. The program aims to increase knowledge about sex-related differences in mathematics and to improve attitudes of females, their male peers, and the adults who influence them, about females as mathematics students. The tapes provide specific information about the amount of mathematics required for various careers and discuss stereotyping and differential treatment of males and females with regard to mathematics and counseling. A facilitator's guide accompanies the tapes to provide an outline for each workshop, including information and points for discussion to be held in conjunction with viewing the tapes. It is recommended by the authors (Fennema, Becker, Wolleat, and Pedro, 1980) that the tapes be used in a full intervention, i.e. with each of the target groups in a school or school system, since the attitudes of young women are influenced by these other groups and, in some cases, are less in need of intervention than these significant others.

An evaluation of the videotapes alone (i.e. without the workshops) in nine high schools in Minnesota and Wisconsin (Fennema, Wolleat, Pedro, & Becker, 1981) using a pretest/posttest, control group design, found that the tapes were more successful with students than with the adults. Although males' increase in high school mathematics plans was not as great as females' increase, experimental males and females made similar gains in after high school plans and in their knowledge of sex-related differences in mathematics. Few changes were observed in teachers and counselors.

Teacher Education Programs

As indicated above, the attitudes and knowledge of teachers are important influences on students' attitudes and achievement, and several programs have been developed to address the particular issues of concern in mathematics. With regard to elementary teachers, the observation has been made that their own avoidance of mathematics may be perpetuated in their subsequent teaching, so that elementary programs have tried to improve the attitudes and skills of the teachers themselves to begin to break the cycle. Two such programs, one concentrating on attitudes and one emphasizing spatial visualization, will be described below. Then, an inservice program that works to change the school and classroom climate will be detailed.

Teacher Education and Mathematics (TEAM). The TEAM program was designed to help prospective teachers at Queens College to develop positive attitudes towards and deal effectively with mathematics (Chapline & Derker, 1981). Four mathematics content modules and four attitudinal modules constitute a course to be taken prior to the math methods course, or can be used as supplementary materials in other preservice courses. Comparison of post-course measures of attitudes, math anxiety, and mathematical concepts indicated that TEAM students benefited from the program. In addition, they were able to suggest ways to counteract sex role bias in mathematics education and more of them volunteered to teach mathematics than did a comparison group of student teachers.

Improving Teachers' Ability to Visualize Mathematics. A course was developed at the University of Washington by Nancy Cook and Betty Kersh that had three goals: to improve elementary teachers' spatial skills, problem solving skills, and attitudes towards mathematics. The 30 hour course focused on three aspects of spatial ability: visual imagery, mental rotation, and mental transformation. The course was sequenced in terms of the spatial tasks, the materials used, and the strategy of instruction. The tasks proceeded from those requiring no movement of the image, to movement of the complete image, to movement of different parts of the image; from two dimensions to three dimensions; and from concrete representations to pictures. The instructional strategies moved from free exploration to structured analysis. All work was done in pairs and students were encouraged to discuss their ideas so that they would become aware of their own thinking and of individual differences in frames of reference. Significant improvement was found in three classes of teachers on three spatial tests, a college level algebra word problem solving test, and five attitude scales (Cook, 1980).

EQUALS. The EQUALS program is an inservice program for teachers, administrators, and counselors, grades K-12, to assist educators in using materials and activities to promote the participation and achievement of women and minorities in mathematics. Educators attend 10- or 30-hour inservice workshops during the school year. They collect and analyze research findings on sex differences in mathematics participation and career aspirations, explore math-related fields of work and study, participate in activities that promote improved student attitudes and understanding of mathematics, develop problem solving skills, and plan inservice presentations to disseminate EQUALS to other educators.

The evaluation of the EQUALS program has examined its impact on several levels. The most directly affected participants, the educators who attend the workshops, keep journals and report their activities at the subsequent workshops. Most of the activities and teaching strategies are used by most of the teachers, with an average implementation level for each activity of over 70%. A follow-up survey conducted in 1981 of all participants since 1977 found that the majority of them were still using EQUALS materials.

The effect of the materials on students has been investigated by a pretest/posttest, control group design using a career awareness survey and a mathematics attitude scale, for older students, and pictures of bears in various occupations for younger students. Over the years of evaluation the results have varied, but have indicated modest improvement in attitudes towards mathematics and increased interest in math-related fields. An additional measure of effectiveness has been student enrollment in elective mathematics classes. While there are many factors influencing student enrollment, including availability of qualified teachers and changes in state requirements, there is indication that increased participation of girls has been associated with EQUALS activity by teachers in some schools (Kreinberg, 1981).

In addition to the regular program, which is held at the Lawrence Hall of Science, EQUALS staff members have conducted workshops for school districts throughout California and in 25 other states. Staff development personnel from 12 states have attended training seminars at the Lawrence Hall of Science to enable them to design workshops for their states or districts. Workshops have also been conducted for 300 educational leaders (administrators, school board members, community leaders) to inform them of the efforts of teachers and to assist in their support of the teachers in their areas. A handbook has been produced by the program (Kaseberg, Kreinberg, & Downie, 1980) that has allowed others to conduct EQUALS workshops without direct assistance from the program.

Efforts of School Districts

Many school districts have surveyed their mathematics enrollments and discovered the low participation of females at the higher levels. A number of them have designed programs to increase females' participation, or all students' participation, in mathematics and science courses. In the San Francisco Bay area, several spinoffs from the EQUALS program have evolved, including projects in Emery, Napa, Novato, Santa Cruz, and San Francisco. Their programs, while adapted to local characteristics, are similar to EQUALS in their emphasis on awareness of the importance of mathematics achievement for all students, problem solving and building competence in mathematics, and the relationship between mathematics and career opportunities.

In Minneapolis, the public schools' 1976 finding of only 25% to 35% female enrollment in highest level mathematics courses prompted a major emphasis on increasing female enrollment in college preparatory mathematics courses. The goals was discussed at teacher inservice workshops, department head meetings, and in communications with teachers. Activities included use of the "Multiplying Options and Subtracting Bias" videotapes (discussed above), participation in the Visiting Women in Science Program (discussed below), speakers from local corporations, and workshops on mathematics anxiety for teachers. To inform students about the importance of mathematics to their future educational and career opportunities, a series of six career information brochures called "Don't Knock It, Unlock It With Math," listing careers that demand knowledge of the material in algebra, geometry, trigonometry, advanced algebra, probability & statistics, and math analysis were developed and widely disseminated. The enrollment of females has increased in the advanced courses to 43% to 57%, a substantial improvement in a short period of time (Taylor, 1979). While other factors may have helped these enrollment figures, they are nevertheless encouraging.

Extra Curricular Activities for Women

The preceeding sections have described a variety of programs that have attempted to change the educational experiences that girls and women have in educational institutions, either by making special classes or curricula, or by changing the outlook or behavior of teachers and counselors. A complementary approach to these interventions has been seen in the development of a variety of extra curricular or cocurricular activities that attempt to enhance the effect of the regular school offering, including visiting programs, conferences, and support networks.

The Visiting Women Scientists Program. The idea of inviting a woman scientist or mathematician to speak to a group of secondary students about her career has been tried by a variety of groups for several years. The Women and Mathematics Program of the Mathematical Association of America has arranged for women mathematicians to visit schools since 197 , for example. In 1977, a large scale demonstration program was contracted by NSF to the Research Triangle Institute, to design and implement a pilot Visiting Women Scientists program, the purpose of which was to motivate female high school students to consider careers in science, including engineering, mathematics, social sciences, as well as biological and physical sciences.

The program included visits by 40 women scientists to 110 high schools across the United States. Approximately 40% of a national sample of high schools accepted the offer to participate in the pilot program, and they were randomly assigned to experimental and control groups. The visit of the woman scientist to the participating high schools included some combination of the following: large and small group meetings with female students, meeting with individual (coeducational) classes, and meetings with school staff members. Scientists talked about their jobs, their educational and personal backgrounds, and ways of resolving problems associated with combining a career in science with a full family life.

A major goal of the program was to encourage high school girls to seek more information about scientific careers (Weiss, 19). Students in both experimental and control schools were given postcards to request further information, and the return rate from experimental schools was significantly greater than from control schools (21% vs. 6%). A survey of school staff with career guidance responsibility found that 57% of the experimental schools versus 38% of the control schools reported that more than the usual number of female students had sought information about scientific careers.

A Manual on Program Operations is available from ERIC; a Women Scientists Roster is available from the National Science Teachers Association.

Expanding Your Horizons in Science and Mathematics Conferences. Beginning with two conferences in the San Francisco Bay area in 1976, there were 43 Expanding Your Horizons conferences sponsored by the Math/Science Network in 1982, half of which were outside California and three of which were outside the United States. The Math/Science Network is a group of over 1000 scientists, educators, and community people who work together to increase girls' and women's participation in math-related and non-traditional fields, and their sponsorship of these conferences is one of their most extensive efforts. The purposes of the conferences, which are held in the Spring on college campuses, are to increase students' interest in science and mathematics, to foster awareness of career opportunities in math and science-related fields, and to provide students with an opportunity to meet and form personal contacts with women working in traditionally male fields.

While individual conference committees plan and conduct their own programs, the Network provides guidance and technical assistance (Koltnow, 1979). Features common to the conferences are panel presentations, "hands-on" workshops, and career workshops with women in non-traditional, math- and science-related fields. Evaluation includes surveys on the day of the conference and follow-up surveys six to nine months after the conference. Students increase the number of math, science, and computer classes they plan to take in high school and learn more about these career fields. They actually enroll in as many or more mathematics courses as they plan, and they take a number of actions to further their knowledge of and experience related to these careers. A kit for evaluating interventions like this is currently being prepared under a National Science Foundation grant (Sheila Humphreys, Principal Investigator).

<u>NSF Science Career Workshops</u>. One of the major activities of the NSF Women in Science Program was the support of one- or two-day Science Career Workshops, designed to provide factual information and practical advice regarding careers in science to prospective women scientists and engineers. During the six years of the program, a total of 135 workshops were conducted in 37

states, the District of Columbia, and Puerto Rico by 107 different institutions, the majority of which were universities. From 1976-1979 the workshops were directed at undergraduate and graduate students. In 1980-81 at least a third of the participants were expected to be women with at least a bachelor's degree in science who were unemployed or underemployed in science.

Evaluations of these programs took several forms. Summer interns in the Women in Science Program office analyzed final technical reports in 1978 and 1979, and concluded that the majority of the workshops were extremely effective and valuable, and that personal feelings of enthusiasm and warmth from the conferences translated into increased confidence and motivation of the participants. As evaluation methods were not proscribed by NSF, it is not possible to generalize about effects, but two sample evaluations are presented here as examples. (More information about the conferences and suggestions for conducting them are available in a handbook <u>Ideas for Developing and Conducting a Women in Science Career Workshop</u>, written by Nancy Kreinberg and available without charge from NSF.)

<u>Rutgers' Science Career Workshop</u>. Freshmen and sophomore women were identified by science faculty in two- and four-year colleges in New Jersey and invited to attend a one-day workshop. The first half of the program consisted of twelve scientists speaking about their work and opportunities in their fields, their personal backgrounds, and their attempts to combine scientific careers with families. For the remainder of the program,

these scientists led informal discussions for each of the science disciplines represented. The 161 students who attended the workshop filled out one questionnaire several weeks prior to the workshop, one on the day of the workshop, and one six months later.

In the six month follow-up (Cohen & Elgart, 1981), students reported that the workshop stimulated their thinking (90%) and that they had become more interested in their chosen fields due to the workshop (42%) or had become interested in a new field of science (33%). They also reported that they had learned that it was possible to combine a science career with a family (75%), and that they had learned useful information about job requirements and salaries (85%). The follow-up also surveyed the science career-related actions taken by the women and the extent to which they were attributed by the participants to their attendance at the workshop. The proportions of actions taken and attributed were: enrolled in a science course (96% took action, 14% of whom attributed it to the workshop); engaged in research (24%, 44%); joined science-related organization (29%, 30%); sought contacts with women scientists (29%, 60%); sought information in books or magazines (71%, 67%); sent for science-career pamphlets (26%, 61%); and watched scientific television program (79%, 28%). Since the participants were recruited for their interest in science to begin with, the high rates of activities are not surprising. On the other hand, the discrimination in their attributions to the workshop--low for actions they were likely to pursue such as coursework, high for actions they learned about at the workshop, such as the willingness of women scientists to speak with them about their careers--gives confidence that the workshop probably did achieve some additional career-related activity on the part of the students.

Women Moving Up Conferences. A total of five conferences were conducted by the Math/Science Network at the University of California, Berkeley, and Mills College, for women with undergraduate degrees in the sciences to gain information and resources to advance their careers. Keynote panel discussions by government, industry, and academic leaders in science were followed by workshop sessions on job advancement, education, company profiles, employment outlooks, and career development strategies. A Women Moving Up Directory gave additional information and career resource lists to participants. Follow-up surveys, six to nine months after the conferences, found that over 75% of the participants had taken some action to advance their careers, and at least a third of them had taken a course in math, science, or computer science. A similar proportion of the participants had interviewed for a new job since the time of the conference.

Summary and Conclusions

The programs reviewed in this chapter share several elements that provide guidance for future efforts to increase women's participation and achievement in mathematics, science, and engineering. Three general features are present in nearly all of the successful programs: strong academic emphases, multiple strategies, and systems approaches.

Strong Academic Emphasis. The causes and mechanisms of the sex-related differences in science and mathematics achievement are not clearly understood, but program planners have acknowledged their existence by designing curricula to address the specific skills identified by research as potential causes. Thus spatial ability, problem solving, and mechanical sophistication are present in many programs. A commitment to extending competence by enrolling in advanced courses and acquiring marketable skills is presented as an essential goal for young women in science. By defining such specific and measurable goals, the programs can evaluate their efforts and demonstrate measurable gains to others. The presence of evaluation and the link to research srengthens both program development and dissemination.

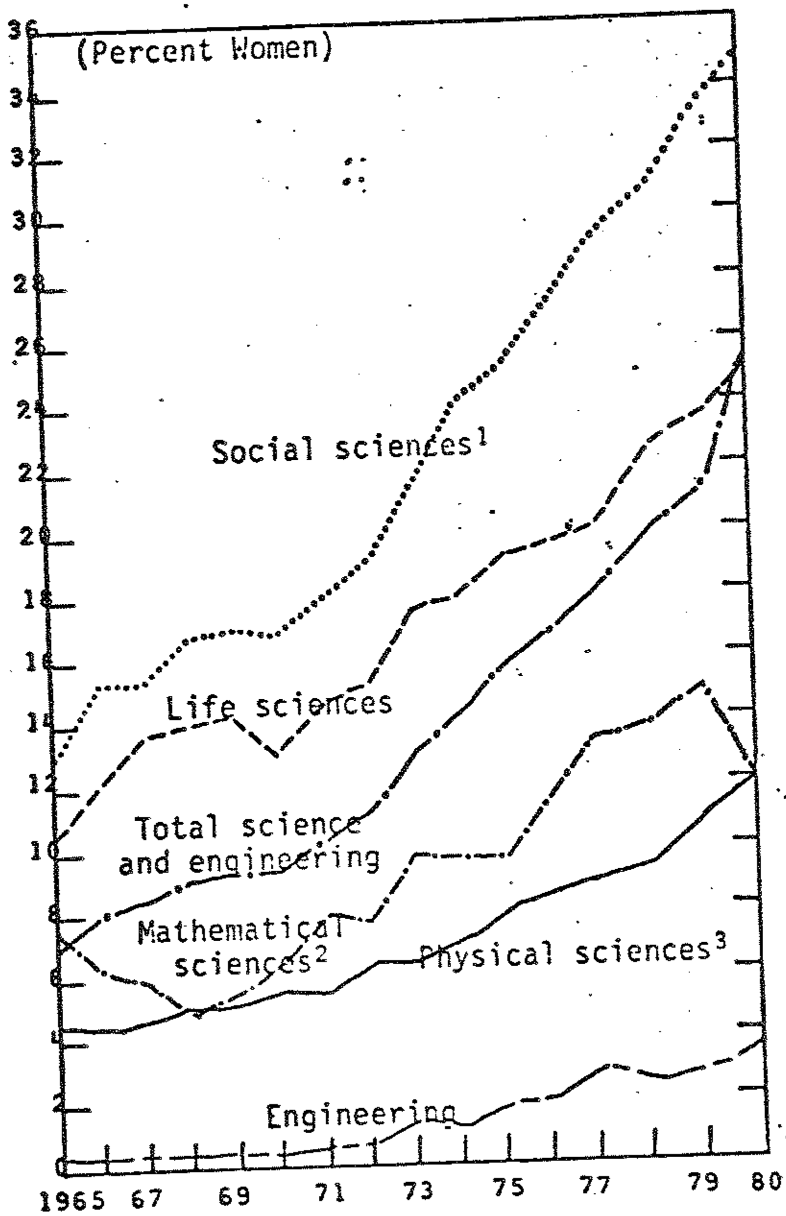
Multiple Strategies. Most successful programs have made use of more than one strategy to address women's participation in science. They have tried to influence the environment in which mathematics and science are taught, to make it accessible to women and to present it as a viable option for women. Role models of women in math-related and science-related fields are highly motivational to students as they also deliver information and strategies for achieving in science activities. Hands-on experiences, particularly in all-female groups, yield confidence as well as skills that can be relied on in subsequent courses. Combined goals of confidence and competence enhance each other, as do the complementary attitudes of enjoyment and usefulness of cuantitative activities. Given the complex origins of the low participation of women in science, it makes sense that multiple strategies are needed to solve the problem; in practice, it is not only sensible, but effective to make use of several strategies.

Systems approach. As indicated more prominently in the research section of this chapter than in the program descriptions, the problems for women in science are not theirs alone. The expectations and sex-stereotyping of parents and teachers, their lack of awareness of the importance of mathematics and science proficiency for all students, and their lack of experience in problem solving and spatial skills which they neglect to develop in females, all contribute to women's difficulties. Some of the programs described above have developed materials for several target groups, notably "Multiplying Options, Subtracting Bias," and others are extending their efforts to include parents, administrators, teachers, and students.

Final Thought. These elements--strong academic emphasis, multiple strategies, and systems approaches--represent the strengths of programs to increase women's participation and achievement in math, science, and engineering, but they also represent sound educational practice. One might argue that girls and women are more susceptible to poor educational practices, such as learning mathematics as a collection of rules or science as a set of formulae. But as long as so few women reach their potential in the sciences, specific strategies that address the reasons for their low participation and achievement must be designed, implemented, and evaluated.

FIGURE 1

WOMEN AS A PERCENT OF TOTAL SCIENCE AND ENGINEERING DOCTORATE RECIPIENTS BY FIELD: 1965-80



[1]Includes psychology.
[2]Includes computer sciences.
[3]Includes environmental sciences (earth sciences, oceanography, and atmospheric sciences).

SOURCE: National Research Council [7]

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