FACTORS IN THE UNDERREPRESENTATION OF WOMEN IN SCIENCE AND ENGINEERING: A REVIEW OF THE LITERATURE

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Abstract

A review of the empirical literature concerning the underrepresentation of women in science and engineering is presented. Since factors involved in this underrepresentation are sensitive to societal changes, only research conducted in the past decade has been included. Factors including mathematical ability, early childhood socialization, education, self-efficacy, perceptions of engineering, career choice and persistence are included.

Introduction

Despite the fact that previously male-dominated occupations including law, medicine, dentistry and business have increased the participation of women by 1200% in recent years[1], there remains an underrepresentation of women in science and engineering. In January, 1994, only 2.9% of all women entering college planned to major in engineering[2]. In May, 1991 there were 74,783 engineers; only 3.1% of whom were female[3]. One study found that women's interest in the sciences actually *declined* by more than two-fifths during the past 20 years[4].

While researchers have been interested in the phenomenon of women and men clustering into different occupations since the late 1960s[5], the factors involved in the continuing underrepresentation of women in certain fields remains somewhat a mystery. This paper will review the empirical literature concerning the factors in the underrepresenation of women in science and engineering. However, since changes in the conventional wisdom regarding women in the workplace affect these factors, only research conducted in the past decade has been included.

Mathematical Ability: Genetic or Environmental?

Some researchers have speculated that the reason for the underrepresentation of women in quantitative fields is genetic. In fact, "math and science achievement are linked to innate abilities more than achievement in any other discipline"[6]. However, innate sex differences fail to explain the underrepresentation of women in science and engineering[7]. Recent studies have refuted the idea that males have genetically superior math ability[8].

The average sex difference in mathematical ability is very small, but like differences in spatial abilities, it is decreasing over time, supporting the argument that these differences are environmentally determined, since genetic differences do not change that fast[9]. There are some differences, however. Girls outperform boys in computation during elementary and middle school while boys outperform girls in problem solving during high school and college[10]. However, using typically "feminine" terms and examples in math and logic problems increase correct responses for girls and decrease correct responses for boys[11]. Males outperform females on the GRE quantitative measure but not on the analytical measure. There do not appear to be any sex differences on SAT Math scores[12], but girls obtain higher grades in high school math courses. Indeed, SAT scores have been found to under predict women's academic performance in college[13]. Finally, boys score higher than girls on spatial ability tasks[14].

While some research does suggest that males possess genetically superior spatial abilities[11, 15, 16], cross-cultural research indicates that child-rearing practices and societal gender roles effect gender differences in spatial ability[11]. Also, while boys' play gives them practice with spatial skills, girls' play typically does not. Since school curriculums do not address spatial abilities at all, girls are at a disadvantage[16]. However, there has been some debate as to whether spatial ability has any impact on math ability[7, 15, 16].

Attitude toward math, thinking and feeling decision-making styles, and the perception of how much engineers deal with people differentiates women who will enter math careers, teach math, or enter a career not related to math[17]. Math anxiety, and the perception that math is more difficult for girls than for boys (even when her math ability is approximately equal to the boys'), is a hurdle many girls must overcome in school[9, 12, 18]. Math anxiety is an important predictor of math grades and course-taking plans for girls[9]. What a mother believes about the difficulty of math for her children is directly related to math anxiety[9]. Math anxiety does not appear to be caused by previous math performance, but does affect future math performance[9].

There is also a tendency for girls to see math as less useful than boys do[18, 19]. Boys view math and science as relevant to their adult life[18], and plan to study more of it than the girls do as early as the seventh grade[9]. This may related to the fact that both boys and girls perceive math to be masculine[12, 14, 20]. However those girls planning to pursue engineering or the physical sciences value and enjoy math more than girls who plan to enter law, social science, humanities, or education[21]. Math background and scholastic ability is highly correlated with a woman's choice to enter engineering[22]. Women in engineering majors have taken more science courses in high school and have higher self-ratings for their math and science abilities than even women choosing other quantitative fields of study[23]. Furthermore, research has found that gender differences in math ability does not appear among students with strong math and science coursework backgrounds[24].

Early Childhood Socialization

Women engineers are typically from families of high socioeconomic standing[25]. Their fathers are usually employed in science or engineering[26], but if not, fathers are still likely to be well educated[27, 28]. Interestingly, while chances are good that her mother works, her mother is *less* likely to work than the mother of a girl who will pursue a traditionally feminine career[27]. However, her parents are more likely to have college degrees and be employed in a professional positions than the parents of a male engineer[29]. Birth order does not appear to affect a girl's chances of becoming a scientist or engineer[26], nor does it matter what gender her siblings are[26].

Differential treatment of boys and girls from birth, by their parents and others, has been confirmed by an abundance of studies[17]. Women who have pursued nontraditional fields tend to report high levels of instrumental characteristics, while those in traditional fields report expressive characteristics[30]. Instrumental characteristics include being goal directed, task-oriented, and independent, while expressive characteristics include being concerned with interpersonal relationships, understanding and dealing with emotions, and the ability to keep others content[31]. These characteristics probably emerge when a child develops a sense of gender identity[32], which begins around 18 months of age[33]. Expressive and instrumental characteristics have been found to remain stable from first through twelfth grade, and to affect career choice[34]. Men and women scoring high in instrumentality report greater levels of supervisory and technical responsibility, salary, involvement in professional activities, and satisfaction [35].

Female engineers typically either have masculine perception of themvelves[36], or value stereotypically masculine characteristics[17]. Masculinity later in life tends to be associated with childhood masculine interests and activities[37]. However, women engineers score significantly higher on feminine and androgynous scales and lower on masculine scales than male engineers. Female engineers also have different gender-oriented childhood play experiences than male engineers[38].

Women scoring high on masculinity scales tend to employ problem-solving rather than emotion-focused coping, and have higher self-efficacy, defined below, than low-masculine women[39]. Women who score high on masculinity scales also tend to have better spatial and mathematical performances than other women[40].

Women in nontraditional majors typically have more egalitarian sex role attitudes[41], and believe that women have a right to compete for jobs traditionally held by men[27].

Education

There is substantial evidence to suggest that teachers interact more often with male students than with female students, even when girls indicate similar levels of confidence in their abilities. This interaction differential increases from seventh to eighth grade[16]. Research suggests girls don't receive as much "wait-time" as male classmates after a question has been asked, a factor that increases the likelihood of correct responses[16].

Sadker and Sadker, who have done a multitude of research in this area, report that "the more precise, the more valuable, and the more evaluative the teacher comments, the more likely they were to be directed at male students (p. 301)" [16]. While teachers give detailed instructions to boys, they simply do things for the girls, resulting in "learned helplessness" [42]. Evidence suggests that girls become less assertive over time, volunteering answers less often, and having fewer experiences with instruments, materials and techniques of science[16].

Parents and teachers influence career choice more often for male *and* female students choosing careers in engineering and science[24], however women in engineering majors often blame a lack of encouragement from teachers and counselors in high school for the underrepresentation of women in engineering[43, 44]. Science majors typically report a strong positive influence from a high school teacher[26].

However, it isn't just the teachers that have an effect on girls during school years. Girls' groups stress different values than boys' groups (being popular, cute and sweet vs. being strong, a good student and a good athlete)[45]. Girls are dissuaded from taking advanced math courses and skipping grades for fear they won't be accepted[16]. In fact, girls in one study reported that 76% of the girls they knew had "played dumb" to be accepted[46].

Exposing students to the performances of competent females may be an effective method for changing biased attitudes about gender roles[47]. When students read about a female involved in a "masculine" activity, they were more likely to think that females could and should participate in that activity[16]. However, science texts have few illustrations of women[16] and only 1/4 of all high school physics teachers are women. Of these, many complain they are being forced to teach a subject they are ill-prepared to teach and don't really like[48].

Self-efficacy

Research suggests that the socialization of women provides them with less access to the sources of information necessary for them to develop career self-efficacy. Self-efficacy is the belief about one's ability to successfully perform a given task or behavior. The sources of information that are important for self-efficacy development include performance accomplishments, modeling, and support for achievement-related behaviors[49]. Low self-efficacy may be a major factor in the restriction of women's career options[50].

Women with high self-efficacy are more likely to select a science-based college major[51]. Math self-efficacy has been negatively correlated with math anxiety, and positively correlated with degree of self-reported masculinity[51]. It is unclear whether there are gender differences in math self-efficacy[52, 53]. In fact, even Hackett and Betz[54], who originated this area of research, found that women's math self-efficacy was not *unrealistically* lower than men's, although there was a tendency for men to be overconfident and for women to be underconfident about their mathematical abilities. There is evidence that other types of self-efficacy do play a role in career choice, however.

Self-efficacy has been found to predict the choice of a math-related major more significantly than gender, years of high school mathematics, ACT math score, or math anxiety[54, 55]. Academic milestones self-efficacy (confidence in one's ability to negotiate major hurdles in an engineering program) was found to be the strongest predictor of academic performance in one study[53]. Participants in another study reported higher self-efficacy for same-gender-dominated occupations than for cross-gender dominated occupations[25]. Those with high self-efficacy for educational requirements are more likely to achieve higher grades and persist longer in engineering programs than those with low self-efficacy[56]. However, most college-aged women have extremely low self-efficacy for engineering and drafting careers, as well as for most other traditionally masculine careers[57, 58].

A significant negative correlation between age and self-efficacy, with older females having lower self-efficacy for male jobs than younger females (age range = 17-36), has been found[57]. In fact, one study found that younger women were more likely to enroll in college-level math courses than older women (median ages = 25.7, 36.8)[59].

Perceptions of Engineering

Another factor in the underrepresentation of women in science and engineering is how women and society view those fields. Engineering is consistently rated as masculine, even more than physical sciences and math[60]. Research suggests that those occupations rated as more masculine are also rated as more difficult, and the probability of success is rated lower, even when occupations are matched on the basis of training requirements[21, 60].

While many males perceive the occupation of physician as being the most difficult, many females perceive engineering to be the most difficult[49]. In one study, 70 percent of the males, but only 30 percent of females felt they could successfully complete engineering educational requirements[49]. While females perceive engineering to be more difficult than nursing, success at nursing was seen as *more* important than success at engineering[21].

A comparison study found that in 1964 men and women thought that engineering was not feminine. By 1992, men felt that engineering was too demanding for a woman to combine with family responsibilities, while women felt that male engineers resent their women colleagues[61]. Women in nontraditional majors do, indeed, appear to expect more difficulties than women in traditionally feminine programs[41], and their perceptions may be accurate.

Career Choice

Factors involved in choosing a major in science and engineering are different for women and men. For women in one study, having highly educated parents, extremely high SAT Math scores, a strong desire for control, prestige and influence, and a desire for positive interaction with others was important. For men in the same study, having high grades in science courses their freshman year and being certain about the choice of a major the summer before entering college was important[62].

The decision to pursue engineering is influenced by courses and work-related experiences for both men and women in engineering[29], but men may make their career decisions sooner than women do[28].

Enjoying a science course more than other courses during their freshman year is also a significant predictor for declaring a science major for both men and women, however more men than women in one study reported that a science course was the most enjoyable for them[62].

More women than men reported that direct recruitment efforts to enter science and engineering was important in one study[28]. Other important factors are money, fringe benefits[63], and the availability of jobs and salary[26].

Once a woman has entered engineering, she may have a different career path than men. For women in one study, market and sales engineering positions looked interesting, while the men gave priority to construction and field engineering. The women in engineering thought of it as an opportunity to help others and do challenging work[28].

Persistence

At the end of their freshman year, significantly less women than men who had been interested in science entering college will actually declare a major in scientific areas, even though they were equally prepared for a scientific major by way of aptitude and academic backgrounds in science and math[62]. However, once in an engineering program, with the exception of computer science, there is some evidence to suggest that women persist at about the same rate as men[64].

GPA and math ability are generally the most important variables in determining persistence[64]. However, women in engineering programs cite a number of other issues that are problematic to them, and may be deterring other women from entering engineering: a lack of academic advising[43], a lack of contact with women in science[43], gender discrimination[43, 44], a lack of work experience and previous exposure to nontraditional work[63], the competitive atmosphere in technical classes[44], and a lack of encouragement, with Euro-American and Mexican-American men receiving more encouragement than Euro-American or Mexican-American women[53].

Conclusion

It is impossible to include all of the literature conducted in the past decade concerning the underrepresentation of women in science and engineering in six pages. Instead, this paper presents a summary of the findings important to understanding the societal, institutional and familial influences that keep women from entering these fields.

The factors in the underrepresentation of women in science and engineering are not genetic. Girls are steered away from quantitative interests at an early age; even before 18 months. Parents, friends and teachers have great influence on a girl during her school years. Unfortunately, these influences often further dissuade girls from pursuing math and science. Once her attitudes about these subjects are firm, she is not likely to consider a career in science and engineering. If she does, she is faced with further factors that will make her decision a difficult one.

The research included in this paper suggests many means of rectifying this situation. Conventional wisdom regarding women in the work place *has* changed in the past thirty years. The time has come to change society's perception of women in science and engineering.

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