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Barriers to Overcome: Women in Information Technology

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Abstract

Women are under-represented in information technology (IT) disciplines, similar to physical sciences and engineering. With the rapid growth of IT and its profound impact on productivity and national economy, tremendous career opportunities in IT have emerged over the last few years. Furthermore, there is a shortage of IT workers, with the U.S. depending upon foreign workers to address the growing workforce needs. The gender equity in IT is critical not only for women, but also for the American society increasingly dependent on IT. In this paper, I examine the reasons for under-representation of women in IT-related disciplines in institutions of higher education.

1. Introduction

The use of IT has been having a profound impact on the productivity, globalization, and growth of the U.S. economy. Since 1995, IT appears to have contributed between 33% and 50% of the acceleration of productivity[12]. IT is also viewed as having contributed to the country's structural shift to a service economy[19]. IT has led to growth in demand for labor as well as overall skill upgrading in the workplace[2]. The Bureau of Labor Statistics[7] has projected that between 1998 and 2008, the number of IT related jobs will grow over 100%, exceeding an overall job growth of 14%. Jobs for computer scientists and engineers are expected to increase from 914,000 in 1998 to 1,858,000 in 2008, while employment for computer system analysts is expected to grow from 617,000 to almost 1.2 million jobs for the same time period[27].

Employers are making it a priority to hire more women to fill IT vacancies in their organizations. However, meeting their goals for hiring women has generally proven difficult. A common complaint among recruiters is inability to find sufficient numbers of women to fill IT positions in their organizations. While women have made great strides in attaining college and university degrees and moving into professions once dominated almost entirely by men (e.g., medicine, law, and business), their participation rates in IT still lag far behind those of males. For instance, women account for more than half of social scientists and almost 40% of biological scientists, but only 28% of computer and information scientists[27].

Moreover, IT pipeline statistics indicate that the number of female computer scientists and engineers will not be much larger in the foreseeable future unless concerted efforts are made to attract and retain women in IT education. Trends in S&E degrees show the number of earned degrees by women has been increasing in the social and biological sciences, but decreasing in IT fields. For instance, women's share of baccalaureates in computer science peaked at 15,126 in 1986, and then declined to 6,772 in 1996[27]. Considering women constitute 51% of the population and 46% of the U.S. labor force, it is important to understand why their number is low in IT.

There are many reasons why women should find IT attractive. With the information revolution, IT has grown rapidly in the recent past, and is likely to do so in the near future. IT knowledge is used in all sectors of the U.S. economy and is not limited to IT industry. Similarly, IT work occurs throughout the United States, not just in Silicon valley or Route 128. Unlike some professions, the work in IT is increasingly office-based and IT graduates receive high starting salaries. There is no reason why careers in IT should not be at least as attractive to women as other fields such as medicine, law, and business, where representation of women is much larger in comparison to IT. Women do use computers for word processing, information, and communication, but they do not use computers to solve mathematical problems, programming, system design, or invent technology[10].

In this paper, I address: What barriers and obstacles must be overcome to attract more women to IT education? Much of the scholarly work related to the gender gap in IT has been based on a broader issue of the under-representation of women in science and engineering. Most point a finger to gender socialization of childhood, bias in schooling, lack of proficiency in mathematics, male-identified image of science and engineering, problems resulting from working in a predominantly male environment, and absence of the women role models—all of which discourage women to pursue a career in science and engineering. I take a more in-depth look into the specific disciplines of IT and show how the wide gender disparities in IT education come about, and are maintained.

2. Information Technology

First, I provide some understanding of IT since the term is used in different ways at different times. IT has been found difficult to define mainly because it does not represent a single technology, but a system of interactive technologies used for information processing such as tools to access information, telecommunications linkages, information processing hardware and software, and storage media[17]. IT occupations are not located solely in the IT industry; instead, they are distributed throughout the U.S. economy including industry, government, and non-profit organizations. Also, many occupations are considered IT work even though they vary enormously in the technical requirements, ranging from data entry personnel to computer scientists. There are many IT-related academic fields such as computer science, network engineering, hardware design, information science, artificial intelligence, graphics/art design, multi-media design, and system administration that study various aspects of IT.

Considering such difficulties, Freeman and Aspray[11] use the term 'IT worker' for those who add more than half the value to work with his or her IT knowledge; for less than half the value added to the work with IT, they use the term IT-enabled worker. IT workers include software engineers, system analysts, programmers, chip designers, and so forth. IT-enabled workers include bank teller, business project managers, product developers, marketing managers, and so forth. I focus on reasons women are detached from pursuing education necessary to join the IT workforce; I do not consider the IT-enabled workforce.

In identifying IT educational fields, I limit along two dimensions—the nature of IT work and education needed for such work. The Computing Research Association (CRA), a nonprofit educational organization to promote research and advanced education in computing, has categorized IT jobs into four classes: (1) conceptualizers, those who conceive of and sketch out the basic nature of a computer system artifact; (2) developers, those who work on specifying, designing, constructing, and testing an IT artifact, (3) modifiers, those who modify or add on to an IT artifact, and (4) supporters, those who deliver, install, operate, maintain, or repair an IT artifact[11]. These classes are based on what the workers actually do. The CRA finds that conceptualizer category is commonly filled with recipients of master's or doctoral degrees, developer and modifier with bachelor or master degrees, and supporter with bachelor or associate degrees.

The vast majority of IT jobs are in the conceptualizer and developer categories. Over the period 1988 to 1996, jobs for computer systems analysts and scientists have grown much faster (158%) than for computer programmers (9.8%). An increase in computer programmers in 1997 was mostly due to the temporary demand created by the Y2K problem[11]. Thus, future women IT workers must have technical knowledge about IT. Only with technical skills, women are likely to use more than half of their IT knowledge in performing the jobs. Furthermore, IT changes rapidly, which means women must have technical knowledge to continuously update their skills. Traditionally, students pick up such technical skills in computer science and computer engineering curricula. It is very difficult to distinguish between computer science and computer engineering because of considerable overlap in these related disciplines. Broadly, computer science can be viewed as having to do with the science of computing and computation, whereas computer engineering with engineering of computer systems and networks (especially hardware related). I, therefore, focus on both fields—computer science and computer engineering.

3. Why So Few?

Until the 20th century, only a few privileged women were allowed in scientific and engineering academics. As recently as 1970, only 358 bachelor's degrees in engineering (less than 1% of the total) were awarded to women[26]. Since 1975, there has been a tremendous growth in the number of science and engineering degrees granted to women. It is because of the encouragement from women's movement for women to participate in science and engineering, and the growing needs of high-tech industries. Still, the numbers remain small in many science and engineering fields including IT. Why so few? The literature is replete with extensive analyses as to why women are under-represented in science and engineering. Recently, some scholars have studied the gender gap in IT disciplines. I draw upon studies on the gender gap in science and engineering to examine how they might extrapolate to IT, and some recent work on the lack of women participation in IT related disciplines.

3.1 Biology as Destiny

There is a long history of scholars pointing to biological differences between men and women as an explanation for the differences in their behavior, which lead eventually to inequality (and inferiority) in general, and in science and engineering in particular. Biological determinists present women as naturally incapable of engaging in scientific activities. Some have tried to account for sex differences in intelligence by measuring the skull to show that the larger male skull held a more powerful brain. Others have asserted that because of a different hormonal makeup, men are more aggressive than women, and this aggression leads to greater achievement in science and engineering professions[13].

Undoubtedly, there are significant biological differences between men and women; but there is no conclusive evidence whether these differences can explain gender inequalities and inferiority in science and engineering. Biologists such as Gould[13], Bleier[5], and Birke[4] have separated unscientific from scientific elements of biological determinism. They show that biology does not set broad limits on what humans can achieve. They do not find any scientific evidence that achievement differences between men and women or blacks and whites are a result of biological factors. They further demonstrate the importance of environmental and institutional factors to show that natural differences between male and female are not absolute.

Since biological determinism does not help to attract more women and under-represented minorities to IT, I do not pursue biological differences between men and women as a possible barrier in IT.

3.2 Bias in Socialization

Most of the research points to differences in the socialization of women as one of the primary reasons they have not been attracted to science and engineering including IT-related disciplines. Scholars show how gender socialization in the family and schools results in a low degree of commitment to the scientific and engineering activities[16,3]. As children grow, they start distinguishing occupations as “male” or “female”, and shape their career expectations accordingly. While girls grow up to fulfill their feminine roles, boys learn the importance of scientific, technical, and mathematical skills. The close identification of scientific and engineering work with masculinity generates a contradiction for girls to pursue it. The dominant view that science, technology, mathematics, and computers are for males shapes the expectations of parents, teachers, and students themselves. Both males and females end up believing that males are better at computers[9]. Most girls are growing up with computers, yet computer games are designed with boys’ interests in mind[8]. Young boys playing with video games end up feeling comfortable with computers later on. Television shows like “Bill Nye the Science Guy” or “Mr. Wizard” transmit the message to girls about their place with science and technology. Several studies have shown that mathematics and science teachers make more eye contact with boys and pay more attention to them than they do to girls in their classes. When boys give wrong answers in class, teachers challenge them to find the correct answer, where as girls get sympathy[26]. Furthermore, teachers seldom intervene when boys are clustered around computers and girls around art in the classroom.

Gender socialization plays a key role in the choice of a profession even though it is difficult to measure the real effect of early socialization. Consequently, many actions need to be initiated to reduce the gender imbalance in IT. Environmental factors such as family values, social expectations, teachers' roles, media portrayal, and computer game content simply have to change so girls can become interested in science and technology in general, and IT in particular. Parents and teachers need to serve as role models to steer girls toward the field of computing. Girls need to see their mothers and other women not refraining from using computers. Since parents might have a mindset, teachers are the best source for encouraging girls. Other than overcoming gender inequality in the classrooms, teachers need to teach computing classes. Because IT related fields are relatively new, most students applying to colleges and universities seldom have parents as computer scientists or computer engineers. In such situations, explorer mentality and risk taking can help students to select new IT-related disciplines. Parents and teachers, therefore, need to let girls explore rather than telling them what to do. With a shift away from Mattel's Barbie, computer game manufacturers are likely to target girls as potential consumers.

However, one cannot solely limit oneself to gender socialization. Whether women actually become scientists or engineers could also be due to educational resources and the structure of opportunities available to them. Despite traditional socialization patterns, women appear to have taken advantage of opportunities available in IT. Consequently, many educational policies can be initiated later on to reduce the gender imbalance in IT, which I discuss later in the paper.

3.3 Masculinity of Science, Engineering, and IT

Instead of blaming women's socialization for not pursuing science and engineering, feminist scholars find the gender-based distortions in the norms of science itself. For instance, Keller[18] and Harding[14] argue that modern science has embedded a series of dualism: reason versus feeling, fact versus value, rationality versus belief, objective versus subjective, power versus love, and autonomy versus intimacy. Reason, fact, rationality, objective, power, and autonomy have been defined as discourse of scientific knowledge; they are viewed as directly opposite of feminine values such as feeling, value, belief, subjective, love, and intimacy. Similarly, feminist scholars find that the content of engineering education and practice conveys "sex-stratified systems in which men are dominant", rarely mentioned in other disciplines[15]. What distinguishes engineering from other masculine professions is machismo; it is for strong men who wish to have a close encounter with heavy, oily machinery[24]. Feminist scholars argue that such nature of science and engineering deters women from being scientists or engineers.

Computers as powerful machinery are viewed to be for strong men. Tobias[33] has called the computer science field the "boy wonder icon", the association of male traits with success in computer field. The prevalence of "geek mythology", a common male pattern of desires, interests, and attachments to computing, has been noted[22]. An outsider gets the impression that to be successful in IT, one needs to be a nerd-hacker or geek, and must have considerable programming experience as well as will have to sleep/eat near a computer for most of the time. Further, the male model of computer assumes that students develop a fascination with the machine quite early on in life; in contrast, female students have been found to develop interest in computing gradually[31,22]. Such images tend to discourage women students from opting for a major in IT-related disciplines especially computer science and computer engineering. It has been suggested that women are entering other information science programs in greater percentages that computer science and computer engineering programs because the former is perceived as more people-oriented[23,30]. Similarly, medicine and law appeal to women because they are perceived to be socially rewarding.

Even if we assume that the whole science and engineering enterprises including IT are dominated by a unified masculinity, these fields have contradictions, which give space and provide opportunities, however few and difficult to exploit, for women to succeed in them. The task, therefore, is not to stereotype the male with rationality and clear thinking, and the female with intuition and emotional thinking, but to focus on how women can pursue and succeed in science-related professions and how to remove obstacles they face.

Many steps need to be taken to deal with the masculine image problem. IT professionals need to be educated about the types of attributes that create the stereotypes about IT (e.g. emphasis on powerful hardware). Departments need to reach high school women graduates and expose them that IT works to help society and is rewarding, along with career opportunities in IT. At college level, an introductory course needs to show the human dimension of computing, the role of computers for the betterment of people, application of IT to a wide range of problems including business and management, and computer literacy being similar to English and mathematics. There should be a way so both high school and college level students can observe IT professionals in an actual work setting; this way women could learn about computers in a purposeful context. At Carnegie Mellon, introduction of such courses is one of the main reasons to increase women's enrollment in computer science from 8% in 1995 to 37% in 1999[29]. Yet, it is not clear whether "girls only" classes will be an effective strategy to recruit and retain women to IT education; such classes are likely to reinforce masculinity of IT.

3.4 Loss of Confidence in Science, Mathematics, and IT

Many scholars have focused on the specific requirements such as background in science, mathematics, and computing which propels students towards science and engineering paths. They see lack of preparation and proficiency in mathematics and science as the single most important barrier precluding women from science and engineering fields including IT[20,35,36]. They cite academic achievement tests such as the National Assessment of Educational Progress (NAEP), which identifies trends in academic progress, and the Scholastic Aptitude Test (SAT), which measures the mathematics and verbal skills of high achieving students, to show male students scoring higher than females in mathematics and science proficiency. They also find females to be under-represented among the highest scores in the NAEP and SAT. These tests provide an incomplete picture of students' knowledge and skills, but are considered a primary indicator of the state of mathematics and science education.

The importance of a solid background in mathematics and science to pursue education in IT can not be denied. However, recent NAEP and SAT tests show little difference between male and female students' score in mathematics and science proficiency[25,27,32]. Results of the 1996 NAEP show that the gender gap in mathematics has disappeared and males only scored slightly higher than females in science (152 for males versus 148 for females). The slight gender difference in the SAT scores is due to a higher proportion of female, as opposed to male, test takers are from low-income families; socio-economic status accounts for a substantial amount of the differences in mathematics and science achievement[25]. Some difference, however, remains in the percentage performing at the proficient level of achievement. A higher percentage of males than females continues to score at the advanced level.

Access to computer technology in the classroom also influences instructions and exposure to IT. Students differ in their access to computer technology and in their use of computers. Females are slightly more likely than males to have experience in word processing and to use a computer in their language or social science courses. Females are less likely than males to have experience in computer literacy, using computers to solve mathematical problems and taking courses in computer programming[10].

The most striking difference between boys and girls is not in achievement or in opportunities to learn, but in the confidence in science, mathematics, and computing. Even when girls have similar exposure to courses and similar achievement level, they are less confidant of their ability, feel less prepared, and lack interest in science, engineering, and IT education[21,28,31]. Both men and women believe that men are better than women in mathematics and computing[34]. A study of undergraduates at Carnegie Mellon found that the actual performance of women students in computer science courses was far better than their perceived abilities[22]. It further noted that men who face difficulties with computer course work do not struggle under the additional burden of the presumption that they are inferior by virtue of their gender; nor do they have the pressure of feeling they are representative of their gender.

It is not clear why women end up underestimating their abilities in mathematics, science, and computing, compared to men. One can assume various social, cultural, psychological, and educational factors contributing to women losing self-confidence. The result of a loss in self-confidence appears to begin around the 7th grade and continues through high school. Females begin taking fewer courses in mathematics, science, and computing than their male schoolmates, and start disliking them[27]. Attitudes toward science, mathematics, and computing reflect as well as reinforce achievement in these fields. Those who do well tend to like science, mathematics, and computing; those who like these subjects tend to have higher levels of achievement in them. Women who enter college often do not have a clear view of what they want from their education in IT. Their ability to do rigorous course work in IT fields tends to be dependent on the judgments of others. They do not know how to assess the adequacy of their performance. They start questioning whether they belong in IT, and as a result end up losing faith and interest in IT. It was found that women in the computer science program at Carnegie Mellon were transferring to other majors at more than twice the rate of male students[22]. Furthermore, they were placing more of the blame for leaving the field on themselves.

The problem of self-confidence is rooted in the pattern of socialization that does not encourage an independent self-image, self-reliance, and assertiveness in getting education needs met. Since girls start losing confidence while entering high schools, teachers need to be educated to support girls' perception to succeed in science, mathematics, and computing. This way girls will choose IT education for reasons of field or career interest instead of being drawn through the influence of others. College departments in IT related fields should clarify that science and mathematics are necessary but not sufficient factor for IT education. They should adapt to widely varying levels of experience among students. The relationship with faculty and mentoring can convey that female students do not have to measure themselves against male performance. While holding high standards for IT programs, departments should create instructional programs whereby students have an opportunity to meet those standards. Ultimately, by getting good grades, female students will be able to maintain confidence against more experienced students.

3.5 Lacking Role Models

The number of women faculty in IT and other engineering disciplines is still quite low. This seems to reinforce the image that these disciplines are not meant for females. This is a kind of chicken-and-egg problem. Unlike in some other fields, women face many cultural barriers to acceptance in computer science and computer engineering melieu[6]. They end up taking longer than men take to achieve promotions. In four-year colleges and universities, women in IT-related disciplines hold fewer high-ranked positions than men. Women are less likely than men to be full professors and more likely than men to be assistant professors. Women are also less likely than men to be tenured[27]. Such differences in institutions of higher education influence the type of work performed and salaries. It is commonly believed that a presence of 15% is necessary to achieve critical mass in the education process. When women in IT-related disciplines achieve the critical level, their performance in the classroom tends to become indistinguishable from their male colleagues; however, when the number is below the critical level, their retention rate decreases relative to men, as does their average performance[25].

Without female faculty members, many female students in IT-related disciplines feel isolated. Presence of role models, mentoring, active advising, and parental/family encouragement as factors in persuading female students to select science and engineering majors including IT has been noted[1]. Studies have found that women are more likely to enter science and engineering fields if some family members, especially their fathers, were scientists or engineers[24]. The fact that there are few women computer scientists or computer engineers with whom female students can talk to about the fields, and to whom they can look to as possible role models, does not help. Seymour and Hewitt[31] find that attitudes and practices of the faculty and the experience of undergraduate women have a significant impact on whether women stay in the field or switch to other majors. Women have been found to dislike large classes because they are too impersonal and one does not get to know the faculty. They consider good teachers to be approachable, friendly, patient, and caring.

Many policies can be initiated to improve the experience of undergraduates in IT-related fields. Department chair, advisor, and teachers should make sure that female students feel valued by them for their potential in IT. Departments should take actions to open channels of communication between women students with one another and with the department chair and faculty through meetings, informal get together or other departmental events. There should be programs to engage students as role models for each other as well as peer tutors. An effort should be made to recruit additional women faculty members. It is important to have at least more than one senior woman IT faculty member.

4. Conclusion

The U.S. is entering the 21st century with an increasing demand for IT workers but shortage of supply. The under-representation of women in the IT pipeline poses a challenge for the economy and for the equity of women. This paper has identified a number of barriers which women face as well as some strategies to overcome these barriers. However, research in this area is just beginning, mostly with the initiative taken by the National Science Foundation. There is a need to investigate the under-representation problems from many aspects such as socialization, cultural factors, educational resources, school environment, characteristics of IT field, faculty-student relationship, role models, pre-college experience, exposure to IT technology, parental guidance, and media. Only then one can mitigate factors that contribute to the under-representation of women in IT.

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