P

Participation of Women in Information Technology

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INTRODUCTION

Our nation's continued global competitiveness is widely believed to depend upon the United States maintaining its leadership in the development and management of new information technologies (Freeman & Aspray, 1999; Malcom, Babco, Teich, Jesse, Campbell, & Bell, 2005; Sargent, 2005). Rapidly changing technologies have pervaded every sector of American society, infusing nearly everyone's work and personal lives. Over the long term, we may face a shortage of highly educated IT workers who are needed to maintain and increase the economic productivity of the United States. Interestingly, according to Freeman and Aspray, if women were represented in the IT workforce in equal proportion to men (assuming the percentage of men in IT vis-à-vis other professions remained constant), this impending shortage and its potentially economically devastating consequences could be prevented.

We identify the pipeline of potential female IT workers as beginning in the middle grades, with the girls who take college-prep algebra by the eighth grade and elect college-bound courses in math, science, and computer science through high school. These girls are then prepared to complete a bachelor of science degree in computer science, computer engineering, or electrical engineering and become creative future IT workers.

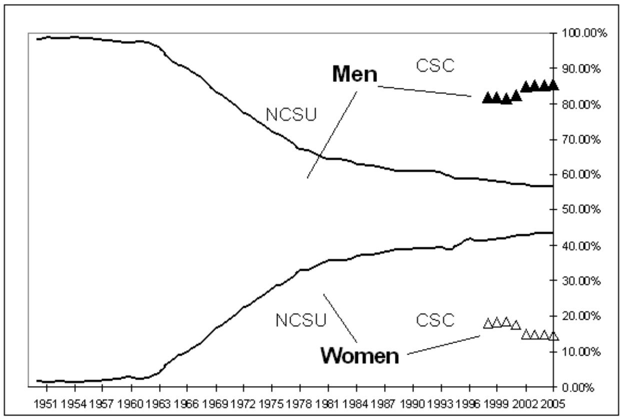
In this article, we examine some of the factors that, as suggested by the literature, influence the low participation of women in IT. We also discuss the open research issues in understanding and modeling the (educational) persistence of young women in IT-related disciplines, and we outline some results from Girls on Track, an intervention program for middle-school girls. We end with some suggestions for making IT more appealing to this currently underrepresented population.

BACKGROUND

While the enrollment of girls in advanced science and mathematics courses in high school continues to increase, their enrollment in high-school computer-science courses is extremely low (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development [CCAWM], 2000). With women's increased participation in advanced high-school mathematics and science, the achievement gap is closing between men and women (National Science Board, 2000). However, our research seems to indicate that these academic gains may not translate into future career gains in IT.

In the later stages of this pipeline, undergraduate women continue to be underrepresented in computer-science, electrical-engineering, and computer-engineering majors (American Association of Undergraduate Women's [AAUW's] Educational Foundation, 2000; Vesgo, 2005). While in recent years, women's representation in the U.S. undergraduate population has risen to more than 50%, their overall numbers in computer-science programs have in fact declined (Freeman & Aspray, 1999; Vesgo, 2005). Figure 1 illustrates this trend using publicly available North Carolina State University (NCSU) data.

Figure 1. Recent gender trends at an engineering school (CSC=computer science)



The National Science Foundation (NSF, 2000) has identified several related issues.

- Women are prevalent in fields such as psychology and biology.
- Women are less likely to choose science and engineering.
- Women are more likely to work part time.
- Women holding doctorates in science or engineering are less likely to be tenured or to hold the rank of full professors at educational institutions.
- Women scientists and engineers tend to receive lower salaries.

Positive developments are that the number of bachelor's degrees earned by women in all major science and engineering fields, except mathematics and computer science, are increasing, and the number of younger women engineers in management positions seems to be increasing as well (NSF, 2000).

On the other hand, the number of undergraduates seeking computer-science degrees is down sharply since 2000, and the percentage of women has also declined (Malcom et al., 2005; Vesgo, 2005; Zweben, 2005).

Hence, we continue to be concerned with the declining numbers of women in computer science, particularly as many researchers have reported that this problem has roots in girls' decisions, dispositions, and experiences as early as elementary school.

We now focus on these trajectories of personal and academic development among college-bound females aged 12 to 20. In this context, the term college bound implies middle-grade students that take algebra by the eighth grade, achieve in the top third of their class, and have a predisposition and preparation to take calculus later in their studies.

Underrepresentation of Females in Information Technology Fields

Women's underrepresentation in science, engineering, mathematics, and technology courses and careers has been studied extensively (e.g., AAUW's Educational Foundation, 2000; Malcom et al., 2005; Vesgo, 2005). While the achievement gap in mathematics and science is closing as more women select advanced courses in high-school science and mathematics (National Science Board, 2000), the enrollment of young women in CSC courses and advanced-placement classes in high school continue to remain low (AAUW's Educational Foundation).

A number of hypotheses have been generated to explain the declining enrollment of women in CSC as a function of girls' experiences from ages 12 to 18. For example, Freeman and Aspray (1999) cited the following issues.

- Lack of appropriate equipment in high school
- Lack of computer experiences
- Nature of computer games
- Lack of career guidance
- Perception of competitive environment
- Gender differences in socialization
- Perception of solitary occupation, requiring long hours in unsafe working environments
- Lack of women role models

We add to this the possibility of a very strong influence of parents of the girls (Berenson, Howe, & Vouk, 2005). These hypotheses are supported by an ethnographic study of 20 female CSC undergraduates that found that prior class experiences, as well as interest in computers and the promise of the field, were primary motivators for majoring in CSC (Margolis & Fisher, 2001).

Personal Factors

Previous research by Kerr (1997) sought to identify common patterns in attitude change among early adolescent girls and how these changes could affect the girls' achievement and motivation. In 1991, the AAUW conducted a landmark study documenting a steep decline in self-esteem among Caucasian adolescent girls, with a lesser decline for African-American girls. Other findings indicated a circular relationship among girls who enjoyed mathematics and science in that they had higher self-esteem and aspirations. Conversely, girls who had higher aspirations enjoyed mathematics and science. Family and school had a greater impact on self-esteem than the peer group (AAUW, 1991). Kerr noted that "pride in schoolwork, the belief that one is able to do many things well, and the feeling of being important in one's own family were the major contributors to self-esteem in this study" (p. 169).

Adolescent Girls

In elementary school, gifted girls demonstrate excellent social knowledge and achieve better grades than gifted boys (Kerr, 1997). By high school, however, while girls continued to attain high grades and were highly involved in extracurricular activities, many took less rigorous courses and suffered declines in their IQs (intelligence quotients), self-esteem, and confidence. Researchers have reported conflicts between conformity and achievement among gifted high-school girls (e.g., Arnot, David, & Weiner, 1999). Kerr reported that, throughout adolescence, girls tend to lower their expectations, choosing moderate over high prestige careers, attending less selective postsecondary institutions, and dropping out of graduate programs and professional training more often than men.

Parents, Teachers, and Mentors

Evidence exists that some teachers and parents have different expectations for girls and boys, and these expectations can impact children's achievement (e.g., Leder, 1992). While Lareau (1992) noted that mothers bear primary responsibility for their children in schools, Stevenson and Baker (1987) found that a majority of mothers spend more time and effort in helping their sons with schoolwork and are less likely to accept poor grades from their sons than their daughters. Hanna, Kundiger, and Larouche (1988) found that countries with high support for learning mathematics had fewer gender differences in achievement, but that in countries with low support for learning mathematics, the achievement gap increased in favor of males.

MODELING EDUCATIONAL PERSISTENCE INTO IT CAREERS

A general open issue is modeling educational persistence leading to undergraduate study in IT careers among young women who take college-prep algebra by eighth grade. Some specific issues include the following.

- Identification of school, social, and personal factors associated with young women's decisions to pursue and persist in undergraduate study in IT fields
- Creation and testing of models using the above factors to predict young women's decisions to pursue and persist in IT undergraduate study
- Development of appropriate tools and interventions to increase young women's interest in IT careers based on the Women in Information Technology (WIT) model

Approach and GoT Activities

From 1999 to 2003, NSF funded Girls on Track (GoT; NSF 9813902) to provide a year-round enrichment program for more than 200 talented girls in Grades 7 and 8 who were selected to take Algebra I on the fast track. The project has been so successful that the GoT camp still runs every summer. All GoT information and deliverables are online at http://ontrack.ncsu.edu.

The ages of the girls in GoT range from 11 to 13, with 60 to 65% of them being Caucasian, 25 to 30% being African American, and 10% being Asian. The girls attend a 2-week summer camp where they investigate community problems using mathematics and information technologies. In addition, girls in the program may receive tutoring in the fall and math mentoring in the spring. In the first few years, GoT also incorporated a professional-development component for middle-school math teachers, preservice teachers, and guidance counselors. As part of GoT and WIT (NSF 0204222), we have collected 7 years of quantitative and qualitative data from these girls, teachers, counselors, and parents. We are currently building models to assess and predict the factors that influence the decisions of our participants to pursue IT careers.

Types of quantitative data about the girls over time include standardized test results in mathematics and computer literacy; mathematics, science, and computer-science course selections; confidence in mathematics and information technologies; proportional reasoning scores; and career interests. Qualitative data include individual interviews, reflections, Web pages, and focus-group discussions. Additionally, data were collected from camp counselors and parents.

Completed analyses disclose several interesting findings. First, the data still indicate that proportional reasoning appears to be an important indicator of success in Algebra I for these talented girls. Overall, the correlation between proportional-reasoning scores and the aptitude and achievement scores seems to indicate that an understanding of proportional reasoning is an important contributor in both standardized measures of aptitude and achievement for Algebra I and for staying on track in math.

Another finding is that, although the girls enjoyed working with information technologies, many of them had not had extensive prior experience using IT tools. Before coming to the GoT summer camp, many girls did not use IT for academic purposes. For example, 82% percent of the Year 2 girls had either rarely or never used a spreadsheet. Similarly, 65% of these girls had rarely or never used IT tools to solve math or science problems. During the camp, girls were given opportunities to use the Internet and spreadsheets to investigate and research community problems. They created graphs, Web pages, and PowerPoint presentations to showcase their findings to parents, camp counselors, and other girls. In their postcamp surveys, 100% of the girls rated their PowerPoint experiences positively, and 96% rated their Web-page construction positively. Prior to Girls on Track, girls tended to use the Web often, but in service of personal rather than scholarly interests.

In terms of mathematics attitudes, survey results for the girls from the first 3 years of camp reported high or very high levels of confidence in their abilities to do math-related activities. A postcamp survey highlighted that for Year 2 girls, 93% acknowledged that Girls on Track helped them "understand that math is a part of everyday life." One year after camp, the Year 2 girls reported statistically significant increases in their readiness to study advanced mathematics and increased confidence in their abilities.

It should be noted that GoT subjects were turning 14, the age at which a plunge in self-confidence has been found by a number of researchers. In terms of career choices, 66% of the Year 1 (1999) girls planned on entering math- or science-related careers. For Year 2 girls, survey results indicated that 81% of these girls expressed interest in working with computers and mathematics in their future careers. During the camp, they were given the opportunity to examine the relationship between various careers, salaries, and the mathematics needed to succeed in those careers. Over half of the girls agreed that the program helped them to "think of new ideas about careers, especially with technology." Results were similar for Year 3 girls. Unfortunately, recent telephone interviews indicate that most of the girls that are on track with respect to algebra are not thinking of continuing in IT careers (Berenson et al., 2005). We suspect that one of the reasons could well be the way we teach and deliver technology in schools and colleges.

Information Technology

What can be done about the issue? The next generation of IT users should, and do, expect not only the provision of effective, high-quality computing engines, but also equally good educational, training, and outreach (ETO) services. These diverse users will require differentiated support that is smoothly integrated with advanced computational and networking frameworks, and with the users' day-to-day operations. Next-generation users (including students and teachers) expect IT to come to them in the form of an appliance or service that aids their work flows (e.g., computational genetics, or the provision of state-of-the-art training in a remote school) rather than hampers them with excessive overhead.

Unfortunately, the seamless and widespread integration of new technologies into everyday operational and educational work flows is still to come. The situation is particularly acute in the following areas.

a. In very rapidly moving fields, such as bio and medical sciences, where users must keep pace with both rapid advances in their own field and the latest developments in computing and networking. These users often suffer from technological overload and ETO-service deficiency.
b. In the case of groups that are traditionally underrepresented in IT, for whom technological and ETO obstacles are exacerbated by economic, social, and other factors (e.g., women, minorities, rural school districts, smaller universities). These groups face a daunting catch-up task at best, and a continuously widening and dangerous technological and skills gap, with all that it implies, at worst.

What is needed is the development of methods and approaches for effectively reaching communities at technological risk, especially those concerned with math and sciences education, via facilitation, mentoring, and training programs. We saw the GoT effort as a major opportunity for the exploration and piloting of IT appliances for (a) the teaching of math and sciences and (b) the on-track steering and retention of underrepresented student populations in IT. We see WIT as doing that by assessing methods for the following.

1. Reducing the technological overload through the introduction of appliance-like high-technology solutions that enhance user activities and allow users to concentrate on their work flows
2. Promoting and increasing exposure to state-of-the-art ETO services in appropriate communities

An appliance-like solution does not mean just technological leveling of the field, but also the development of community- and group-appropriate pedagogical, training, and social interventions that increase the technological awareness of the community, reduce its aversion to technological change, ease that change, and advance its workforce into a state where it can sustain an influx of innovation through a combination of stable remote and local resources. This means easier access to state-of-the-art equipment (through network-based solutions), a better trained and continuously upgraded local instruction cadre, and an active technology assistance program that makes new technologies readily accessible and a source of eager anticipation rather than frustration for both teachers and students.

In addition to making IT more accessible, it is also important to involve young children in understanding and exploring the uses of IT for careers and real applications, and to carry this emphasis through the college level. We may also need to involve both parents and counselors early on to engage and interest girls in IT.

FUTURE TRENDS

As indicated by Blum and Frieze (2005) in their analysis of women in computer science at Carnegie Melon, the field of IT itself changes as the population of IT workers changes. Highlighted differences between men and women, such as choice of topic for study, are diminished when the number of women passes a certain threshold. When the workforce becomes more balanced, it is easier to recruit women, and opportunities for leadership and full participation become much more available (Blum & Frieze; Cohoon, in press). We also foresee that this broadening of participation will introduce new innovations and improved working conditions for all IT workers (CCAWM, 2000).

CONCLUSION

Although the demand for IT jobs continues to grow, the percentage of women in IT-related fields continues to decline. Some of the possible reasons for this decline include gender socialization, a lack of experience with and access to computers, a lack of career guidance, and perceptions of IT through the nature of computer games and work environments.

Findings from our Girls on Track and Women in Technology programs indicate that parental influence may also be a very strong factor in girls' career choices. We find it disconcerting that even girls who are excellent in math may not choose to enter IT careers. To address these issues, we believe it is important to make IT more accessible and to involve young children and their parents, teachers, and counselors early in the discovery of what makes IT exciting and useful.

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KEY TERMS

ETO Services: Educational, training, and outreach services. IT used for these services is often the only exposure that underrepresented populations may have to computers and IT.

Girls on Track: An intervention program designed to keep talented middle-school girls on the "fast math track." (http://ontrack.ncsu.edu)

IT Appliance: Software that can be readily used by novices in a natural way, without technical training, much like a refrigerator or toaster.

IT Career: A career requiring an electrical-engineering, computer-science, or computer-engineering degree. Emphasis is placed on technical and creative roles rather than support roles.

Network-Based Education: The use of tools over a network for education and training.

Pipeline: It identifies sources of potential IT workers, including preparatory courses such as algebra and calculus. Particular focus is paid to places and issues where people, and particularly women, leave the pipeline, such as the choice of less advanced math classes in high school.

Women in Technology (WIT): A longitudinal study of the Girls on Track program designed to model the educational persistence of young women in IT-related fields. (http://wit.ncsu.edu)