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Perspectives on Improving the Gender Composition of Computing

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ABSTRACT

Collective action at the local and national levels is needed if we wish to achieve women's full participation as creators of computing technology. This paper reviews themes from research on the gender composition of computing with particular emphasis on the United States. The author highlights evidence that both culture and social structures contribute to creating and maintaining women's underrepresentation in this increasingly influential field.

KEYWORDS

Gender; women; computing; underrepresentation; intervention

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INTRODUCTION

Computing is a large, important, and rapidly growing field in the United States and around the world, but the community of its creators is increasingly gender imbalanced. Beyond the ethical and practical implications of this imbalance, the situation warrants particular concern because information and communication technologies mediate almost every aspect modern life. These technologies exert enormous influence, yet currently they tap and convey the experiences, knowledge, and values of only a portion of the population. They create our world and our future without adequately including half of humanity's views, needs, and priorities. In order to reverse this trend, we must apply research findings to purposeful and strategic interventions, and adjust our efforts in response to assessment of impact.

Scholars have established the influence of social factors, including gender, on technology creation and use (see, for example, Mackenzie and Wajcman, 1999, for an exposition of the 'social shaping of technology', including through gender relations). This insight has important implications for the gendered power relations and values inscribed in the technology created by a largely white male community of computing professionals. Unless women fully engage in the creation of computing technology, the persistent gender imbalance in computing is likely to contribute to subtly maintaining those relations and values.

This paper contains a brief overview of themes from research on the gender composition of computing with particular emphasis on the United States in a global context. New U.S. evidence corroborates that both culture and social structure contribute to creating and maintaining women's underrepresentation. Efforts to address this complex issue too often fail, or remain only localized successes, in part because they are carried out by under-resourced computing professionals with many competing commitments and too little knowledge of the relevant research. Increasing the success of interventions requires effort on both the local and national level, with computing professionals and social scientists sharing their experiential and research-informed knowledge of what works.

Few Women Create Computing Technology

The gender imbalance in computing grew as women's participation increasingly lagged behind men's. Every measure of gender composition documents a pattern of fewer women than men intending to study, studying, and working in computing in the U.S. and most economically developed countries around the world. This gender segregation occurs regardless of whether the numbers of professionals increase or decrease.

In the United States, young women comprise few of the college-bound students who intend a computing major. Their representation in this group has declined for more than twenty years, and since 2005 has hovered at about 12 or 13 percent¹. Looking beyond intention to the students best prepared for a computing major in

college, we see that young women are a small portion of students who take the Advanced Placement test for computer science. They have been about 14 or 15 percent of this small population since the late 1990s, but the recent trend looks hopeful – in 2010 girls were 19 percent of these test-takers (The College Board, 1997, ..., 2010).

Similar trends are evident in data from colleges and universities in the United States². Among the students preparing for a computing career by majoring in computer science (the category includes numerous disciplines that fall under the heading of computer and information technology), women's share of Bachelor degrees fell from more than 30 percent in the mid-1980s to less than 20 percent from 2007 onwards. In contrast, most other science and technology disciplines report improved gender balance at all degree levels, or at worst, little change. For example, women's representation exceeded 40 percent of Bachelor degrees since 2000 or earlier in the physical sciences, mathematics, and biological sciences. In engineering, women's representation among Bachelor degree recipients increased from the single digits to 18 or 20 percent in recent years.

Likewise in the U.S. workforce, women's representation among those working in computer or mathematical occupations declined for years. In 2000, it was at 30 percent, but in 2008 and 2009, U.S. Bureau of Labor Statistics data³ show that women were only 25 percent of the computer and mathematical workforce. U.S. Bureau of Labor Statistics data also show that substantial declines in women's representation are unique to computing. In the U.S. science workforce, women are more than 45 percent of the life, physical and social science workforce, up from 40 percent in 2003.

The United States is not alone in its poor representation of women in computing. Degree data from OECD countries show that women earned a relatively small number of computing tertiary degrees in recent years. Compared with women's representation in other disciplines, women in computing were underrepresented in every OECD country, although to varying degrees. For example, women's share of tertiary computing degrees was at least two standard deviations less than in the average discipline in Sweden, Spain, Slovenia, the Slovak Republic, Portugal, Poland, Norway, New Zealand, Netherlands, Italy, Israel, Iceland, Hungary, Germany, Finland, Estonia, Denmark, Canada, Brazil, and Austria, as they are in the U.S. (Cohoon et al., forthcoming). The general pattern and the variation observed cross nationally (see Charles and Bradley, 2006 for another cross national analysis of gender and computing), and observed cross institutionally elsewhere (Cohoon, 2006), point to both culture and social structure as key influences on the gender imbalance in computing.

Context Matters

Effective methods for attracting and retaining men and women in computing depend on context. Social structures such as education systems and policies or reward systems or care options in specific environments, interact with beliefs about the nature and requirements of computing to promote or inhibit men and women's participation. In short, context matters.

The significance of particular contextual factors also changes at different stages of life (Castaño and Webster, 2011). An example of this interaction can be seen by focusing on adolescence. At this stage of life, gender identities exert a strong influence; students are in secondary school, possibly with course-taking options that keep open or reduce their opportunity to succeed in computing at the tertiary level. Educational policies about the extent of student choice, the courses offered, the competing opportunities available, parental, teacher, and peer influences, all exert influence on adolescent engagement in computing (Barker and Aspray, 2006). Together, life stage and environmental conditions create the context in which student's beliefs about their ability to succeed in computing and their perceived interest in computing lead to a decision about whether they will study the subject (Wigfield and Eccles, 2000; Lent, 1994).

At midlife, the context is different. Gender and occupational identities are often established; employment status has a strong effect. For those working at the creation of computing technology, the decision is about whether to continue. For those who took time off from such a career, the decision is about whether to return. At this life stage, choices are created or constrained by contextual factors such as options for managing commitments to care for children or parents, opportunities to update skills, the job market, employer support, and occupational ladders (Bartol and Aspray, 2006).

Cultural Beliefs about Gender and Technology Create and Maintain the Imbalance

Even as local contexts vary, underlying beliefs about gender and computing technology create the general climate. These climates, while inhibiting women's participation in almost all countries, vary from country to country. Women are better represented in countries where computing is perceived as a good career for women, e.g., Malaysia, where the sedentary indoor office environment, regular hours, and good pay are believed suitable for women (Lagesen, 2007; Mellstrom, 2009). Likewise, better gender balance in computing exists where gender essentialist beliefs are less indulged through career choice (Charles and Bradley, 2006), e.g., Turkey, where women are not very well represented in higher education overall, has a relatively high representation of women in computing. According to Charles and Bradley (2006), a likely cause is the Turkish tertiary education system, which employs a quota system based on entrance exam scores and preferred program of study (Caner and Okten, 2010)

Changes in gender balance over time provide further evidence for the powerful influence of cultural beliefs about gender and computing. Since the mid-1980s, women's representation declined almost simultaneously in both educational and workforce settings in the U.S. (Hayes, 2010). The declines were in response to media popularizing the image of computing as a masculine endeavor; professional societies aligning computing with high-status managerial occupations (Haigh, 2010; Hicks, 2010); and employers' hiring practices that institutionalized the detached, asocial image of computing professionals (Ensmenger, 2010).

Finally, Hayes' (2010) research provides additional evidence from the U.S. suggesting that cultural influences have a strong effect on the gender composition of computing. Figure 1 updates Hayes' data and illustrates the almost simultaneous changes in women's share of both college computing degrees and computing professionals.

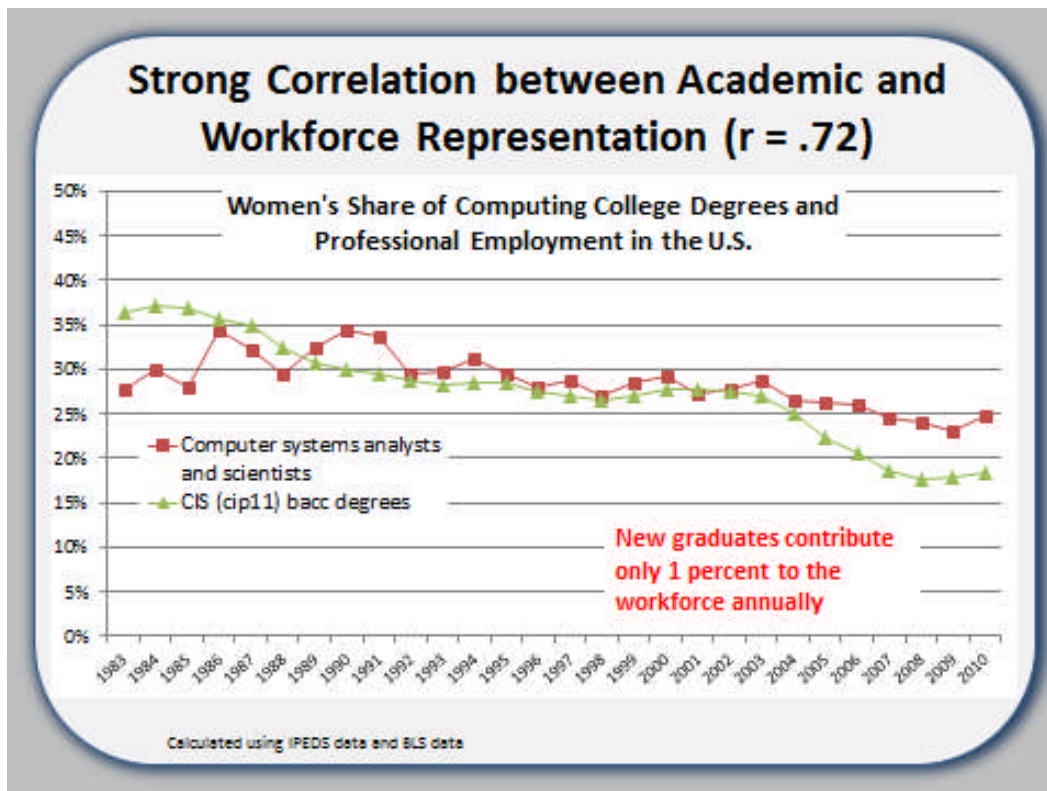


Figure 1. Women's Share of Computing Workforce and Tertiary Degrees in U.S., 1983-2010

Women's representation rose and fell in the workforce and educational settings at almost the same time. The strong correlation ($r=.72$) between women's share of computing professional employment and their share of the much smaller population of computing graduates, makes clear that this is not primarily a pipeline effect. It would take years for the gender composition of graduating seniors to affect the workforce gender composition. Further investigation also shows that these changes in the relative proportions of female computing students and employees were driven largely by changes in the absolute numbers of men, while the numbers of women remained relatively steady. In other words, broad influences acted mostly through attracting more or fewer men into computing, which changed computing's gender composition. Evidence about variation across cultures and across time makes clear the connection between broad cultural beliefs about gender (male and female preferences and talents) and computing (the nature of the endeavor and its position in the existing structure of gender relations) (Charles and Bradley, 2006; Cohoon et al., forthcoming). It also suggests that substantially more effort should be invested in understanding how men's engagement in computing is affected by varying macro-level conditions.

Local Interventions Can Be Effective

With existing knowledge and carefully documented actions and outcomes, some local efforts have succeeded in countering generally prevailing conditions. Using research-informed practices, such as the following, women's representation increased⁴:

- Active recruiting: For example, Seth Reichelson, a Florida high school computer science teacher increased girls' enrollment in his Advanced Placement course from 12% to about 33% by actively recruiting girls.
- Mentoring, encouragement, and appreciation: For example, undergraduate women's retention generally approached men's in U.S. departments where faculty said they mentored to promote diversity in computing (Cohon et al., 2004)
- Inclusive, effective pedagogy: For example, pair programming has been shown to improve student success and to particularly benefit women (probably in part, because they are likely to have less programming experience than men) (Braught et al., 2011; Werner et al., 2004). One other example of good pedagogical practices rests on providing students with feedback for realistic self-assessment. Correll (2001) found that women more than men relied on performance feedback related to their mathematical abilities.

Published examples of Carnegie Mellon University's and Harvey Mudd University's intervention programs comprising many of these practices demonstrated how very effective the practices can be. Each institution quickly went from 10 percent or lower representation of women to more than 40 percent women in their undergraduate computer science programs or incoming classes (Margolis and Fisher, 2002; Alvarado and Dodds, 2010). In both cases, applying a coordinated set of research-based practices brought about the dramatic positive results. The School of Informatics and Computing at Indiana University Bloomington also reports substantial success with a similar approach; they doubled the number of incoming women from 75 to 150 in 18 months. These examples demonstrate that impressive results can be achieved through strategic effort at the local level (Biggers, 2011).

Effective as research indicates these practices should be, they appear to work best under certain conditions. For these three academic examples, the necessary local conditions appear to be high-level institutional commitment, entry experiences that accommodate the gendered situations of typical students beginning college-level computing, and instructors who put concepts into contexts familiar and interesting to diverse students.

In every one of these three examples of localized success, there was strong, explicit, and highly visible encouragement from institutional leaders as well as knowledgeable activists working with faculty. At Carnegie Mellon, Alan Fisher was a dean in the College of Computing. At Harvey Mudd University, changes took place after a well-known advocate of women in computing, Maria Klawe, became president of the university. At Indiana University, the new dean of the School of Informatics and Computing, Robert Schnabel, committed to doubling the number of

women enrolled within two years and encouraged faculty and a dedicated staff member to develop comprehensive strategic plans to make that happen.

Each of these examples also shares an introductory course section limited to inexperienced students and specifically designed to prepare these students for mainstreaming in the second course. These course sections tend to be demographically different from standard open enrollment first computing courses, because women and minorities are more likely than white men to have no programming experience when they enter college. The demographic difference creates a course environment where students who would typically be underrepresented comprise more than half the enrollment. It also avoids the intimidating effects of unfavorable comparisons with students who give the impression of being already well-versed in the course content.

Each of these academic examples of local successes also employs pedagogy designed to engage the interests of diverse students by putting concepts into contexts the students find appealing. The value of this approach also can be seen in a form of voluntary engagement with computing. Electronic components that allow people of all ages to write programs and develop interactive computing projects attract different demographics (<http://web.media.mit.edu/~leah/LilyPad/>). When the projects employed sewable fabric-based kits, 72 percent were built by women; when they employed the more common embedded computing platform, 2 percent were built by women (Buechley and Hill, 2010). This radical difference illustrates the influence established gender stereotyped contexts can have on engagement with a new activity such as computing.

Widespread Change requires collaboration and infrastructure

Hard won successes have not yet spread into a clear positive national trend in the U.S., although there are some indications we may have turned the corner. Almost 30 years of effort have made clear that generally effective practices may only work under certain conditions, and when properly implemented (Durlak and DuPre, 2008). Numerous considerations at the individual, organizational, and community levels affect whether desired outcomes are obtained. For example, consultants from the National Center for Women & IT Extension Services for Undergraduate Programs found that practitioners often misunderstood the meaning and methods of practices that proved effective elsewhere, and that lone activists seldom had any broad impact. When lone activists had an impact, the impact disappeared or attenuated if the activist left for another institution or company.

Beyond the challenge of implementation understanding, fidelity, and other complexities, sustained success may require on-going attention that can only be supplied by a dedicated organizational structure. For example, since the departure of the two leaders who engineered Carnegie Mellon University's remarkable accomplishment, women's share of students graduating from there with computing Bachelor degrees declined to 14 percent in 2010 (calculated with Carnegie Mellon University data, 2010). This share of undergraduate degrees was still good compared with peer institutions, but it was far from the more than 30 percent achieved while the intervention leaders were active.

Lack of widespread adoption of promising practices, and post-intervention decline in women's representation illustrate the need for moving beyond individual or small group actions. Reforming the social structures that support gender segregation in computing may be too much to expect of already busy professionals. Even if it could be accomplished, cultural stereotypes about gender and technology will likely require nothing less than a social movement. Sustaining and spreading efforts until that goal is achieved will call for an infrastructure and community that keeps reformers motivated, on task, and informed. Practitioners need help from people whose day jobs are to promote and sustain gender equity in computing. Only with coordinated efforts and support from such an infrastructure are practices likely to change toward gender mainstreaming, until women's participation in the massive and rapidly growing field of computing is transformed (Rees, 2005).

ENDNOTES

¹ The figures stated in this paragraph draw on two datasets produced annually by The College Board:

- a. SAT Data & Reports: College-Bound Seniors (Years 1996 to 2010). Available online at <http://professionals.collegeboard.com/data-reports-research/sat/archived>.
- b. Data, Reports & Research: AP Data & Reports (Years 1997 to 2010). Available online at <http://professionals.collegeboard.com/data-reports-research/ap/archived>.

² The Integrated Postsecondary Education Data System (IPEDS) is conducted by the U.S. Department of Education's National Center for Education Statistics. Data used for Years 1976 – 2009, and these are available online at <http://nces.ed.gov/ipeds/datacenter/>.

³ U.S. Bureau of Labor Statistics. (Years 2003 to 2011) Labor Force Statistics from the Current Population Survey. Table 11. Available online at <http://www.bls.gov/cps/tables.htm#charemp>

⁴ See <http://www.ncwit.org/resources.res.practices> for brief summaries of the research on these and other types of promising interventions.

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