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Constructing the information society: women, information technology, and design

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Abstract

For the first time in history, women have the opportunity to play a major and visible role in a social transformation of potentially monumental proportions. The extensive reach and penetration of information technology into virtually every area of society creates enormous opportunities for women. But women's lack of representation in IT design roles may prevent them from capitalizing on these opportunities. Most current discussion and analysis focuses on the increasing numbers of women as users of information technology with great emphasis on their use of the Internet and World Wide Web. Comparatively little attention has been given to the potential role women might play as designers in an information-based society.

As the data in this paper clearly indicate, women are poorly represented in the sector that constitutes the growth engine of the U.S. economy and that bears primary responsibility for the scientific and technological development of an Information Society. The human capital requirements of the Information Society demonstrate the need for women to strengthen their participation as experts, owners and designers of information technologies. This paper argues that stronger representation by women in technical roles not only would help to redress a troubling human capital deficit, but is highly likely to modify and expand the range of technological applications, products, standards and practices to benefit all of society. On the importance of women as scientific and technical experts, see [1,2].

To develop this argument, the paper surveys across several policy areas to identify a central challenge that does not neatly fit into established policy categories. The first section of this paper distinguishes between the types of contributions that may be made by users of information technology versus its designers. The second section surveys current participation rates of women in IT-related fields within education and industry in order to gauge the near-term supply of women designers and experts. The third section argues, by analogy to the fields of medicine and psychology, that the degree of participation by women is likely to have a notable

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effect on professional practice and technological developments within the fields that constitute information technology.

The current economy presents a stellar opportunity for women to assume leadership roles in research and development of information technologies and applications. According to the U.S. Department of Commerce, use of the Internet, World Wide Web and other digital technologies continues to proliferate. The U.S. economy and its labor needs have shifted radically producing a serious deficit of IT workers. The U.S. Department of Commerce [3, p. 4] uses the following definitions and categories to denote information technology and related occupations: computer scientists, computer engineers, systems analysts and computer programmers. The classification is based on categories used by the Bureau of Labor Statistics. Demand for workers able to develop, apply and use these technologies extends beyond the computer and software industries into service industries, including health care, manufacturing, transportation, government and education. Information technology accounted for more than a third of the nation's real economic growth from 1995 to 1997 [3, p. 5]. If not addressed, labor market shortages in information technology related occupations are estimated to diminish national productivity, the development of new products and services, economic growth, and national competitiveness [4].

The Bureau of Labor Statistics reports that approximately 137 800 new jobs in information technology occupations have been and will be produced each year from 1996 to 2006.[1] The U.S. educational system awarded only 24 098 bachelor's degrees and 9658 associate's degrees in computer and information sciences in 1995 and 1996 [5, Tables 248 and 253, pp. 280, 286]. Immigration policy has recently been modified, with passage of the American Competitiveness and Workforce Improvement Act of 1998, to meet the current shortfall of IT workers [6]. Firms seek to employ skilled workers from abroad, notably from India, Russia, Eastern Europe, Southeast Asia and South Africa. But while the U.S. government has temporarily raised the quota of skilled non-immigrant visas to accommodate increased demand, the legislation includes a sunset provision that mandates lowering the cap by 2002. Even if immigration levels are not reduced, evidence of a global deficit of information technology workers (see [7] for one example) is likely to constrain the ability of firms to use immigration policy and global outsourcing of IT activities [4, p. 2]. The U.S. political economy requires modernization of domestic employment and education policies to sustain growth in the information society.

Keywords: Information technology; Public policy; Women and science; Women and technology

1. Women, technology use, and design

The enabling characteristics and effects of the Internet and the World Wide Web, as currently designed, create scope for women to become sophisticated and innovative technology users. In the Information Age, in contrast to the Industrial Age, physical power has become less important to economic competitiveness. Human, social, and information capital have largely replaced physical capital in importance within industrial economies [8,9].

[1] This figure includes both newly created jobs and the replacement of workers who are leaving the field. See U.S. Department of Commerce, June 1999 [3, p. 25].

Implementation of information technologies within and across organizations has eroded the importance of hierarchy and command-and-control authority systems that structured power within them. Increased use of multidimensional networks of organizations as vehicles for economic and political decision-making requires a distinct set of organizational, communication, and managerial skills, at which women tend to be proficient (see [10] for one example. Note that the sample size for executive women is small at n=25, 26, and 31 for the three assessments reported. Nevertheless the findings are statistically significant at the $p < 0.05$ level. Moreover, these findings are supported by a wide array of observational and anecdotal evidence in the management literature). The creation of social capital, a key to innovation in network structures, demands openness to uncertainty and ambiguity; to dynamic management processes; to multiple, partially overlapping rule regimes; and to collaboration as well as competition [11–13]. Women have traditionally managed well under these conditions.

The economics and architecture of the Internet and World Wide Web enable disintermediation, allowing women in many cases to bypass traditional gatekeepers and power brokers. The Internet and World Wide Web provide an exceptional medium within which to expand and strengthen interconnections, linkages, and networks independent of distance rendering the coordination costs of organization by geographically dispersed women less burdensome. Finally, the capacity of information technologies to enable more flexible, family-friendly work arrangements may assist women to combine work and family in ways that offer new possibilities for professional career and social development.

Women are the predominant users of information technology in the workplace. In 1997, 56.5% of women and 44.1% of men used computers at work [5, Table 424, p. 481]. Women's role as user allows for influence of plastic functions of new media and technologies. Customization of screen displays, modification of electronic commerce experiences, use of agents and filters allow users to shape their applications. Software developments enable users to undertake functions that until recently were the preserve of programmers. Moreover, users will shape future design indirectly through political and economic influence. In sum, the value to women of information technology use is undeniably substantial.

But the influence of users, though important and far-reaching, is limited. Designers fashion technology more deeply, pervasively and fundamentally. The socio-technical perspective invites consideration of technology as "a system of human beings cooperating in quite complex ways, creating a new or improved capacity which others may use to alter their lives" [14–17]. This perspective suggests inquiry into the question "Who is technology?" as well as "What is technology"? [18].

Social possibilities offered by information technologies are in large part products of "deep" design, characteristics and properties not readily, or not at all, open to modification by users. Designers exercise influence by defining the technological needs of users and those affected by technology. They develop structures and processes, design construction codes, build the rule systems that constrain Web navigation, formulate protocols for communication and conduct in cyberspace, and choose the extent to and ease with which tools may be customized by users. Designers affect society through technology in ways that users cannot.

Women are poorly represented as information technology designers and experts. Women comprised 28.2% of computer scientists in the U.S. labor force in 1995 [19]. The Office of Technology Policy uses Census figures to estimate that women represent 26.9% of computer systems analysts and 28.5% of computer programmers [3, p. 94]. They comprise less than 30% of computer professionals. The importance of design and its critical role in the construction of an information society underlies the argument for a more powerful role for women.

2. Fifty/fifty by 2020? Participation, gender and computing

Any analysis of women's participation in the fields that support information technology must begin with child development. Science and education policies designed to reduce gender inequity in post-secondary and graduate study miss critical periods during childhood and adolescence that later constrain education and career decisions. In other words, attitudes that relate identity, gender and technology are acquired early in life. Children choose toys according to their perceptions of gender appropriateness by the age of one [20, p. 35].

Until recently, the consumer software industry took for granted that no market existed for computer games designed for girls [21]. In November 1996, Mattel Media, a division of Mattel, Inc. (the only Fortune 500 company at that time led by a female Chief Executive Officer) introduced the computer software, Barbie Fashion Designer™. It became a stunning commercial success selling more than 500 000 copies during the first two months after its introduction. This clear signal from the market led to a stream of software designed for girls by Mattel and other firms. It is well documented in empirical research prior to 1997 that fewer girls than boys play computer games [22–24]. But the empirical phenomenon is changing, possibly as a result of the development of girl-friendly games. Beginning in 1997, data indicate that girls and boys play games with similar frequency beginning in the preprimary years to the 8th grade, and that girls' use of computer games decreases beginning in grade 9 [5, Table 427, p. 483].

Evidence suggests that the Internet and Web also are drawing girls to computers. The proportion of elementary and middle school boys and girls using the Internet and Web was almost identical in 1997 [5]. New media allow girls to exercise creativity and communication skills. Growth of chat rooms, interactive Web sites for girls and other forms of on-line community mean that computer use need no longer be solitary or restricted to game playing. Particularly during adolescence, Internet and Web use may promote a sense of identity and independence, while simultaneously building confidence in computing, see [25] for one example. Recent developments invite reexamination of assumed intransigent gender differences in attitudes toward computing.

2.1. Trends in secondary education

Among high school students, the percentages of men and women using computers are similar. Of students in grades 9 to 12 in 1997, 71.3% of men and 69.6% of women report using computers at school; 49.3% of men and 48.1% of women report using computers at home [5, Table 428, p. 484]. Predominant use of computers at school and home is restricted to word-processing, game playing and the completion of homework assignments in non-technical fields [5, Table 427, p. 483].

High school science and math course taking should be a strong predictor of entry into technical fields. Students who graduated from high school in the 1990s, whether men or women, are more likely to have taken advanced science courses — such as physics, chemistry and biology — than they were in the 1980s or previously. Women have made substantial gains in science course participation during the past decade. Female high school graduates remain less likely to have taken physics, but are now slightly more likely to have taken biology and chemistry courses. Women's participation in physics courses has been increasing since 1982, narrowing but not yet closing the gender gap in physics [19]. Women have achieved even greater gains in mathematics coursework. They are more likely than men to have taken courses in geometry and algebra II and nearly equally likely to have taken calculus. Women remain under-represented in many math and science advanced placement subjects. In 1997, they comprised between 35 and 45% of those taking advanced placement calculus and chemistry, less than 35% of those taking the advanced placement physics exam and just 17% of those studying advanced placement computer science [26]. Overall, these data indicate substantial gains in course taking for young women.

Results of standardized examinations indicate lower levels of technological confidence or competence of young women than implied by courses taken. The results of the science component of the National Assessment for Educational Progress (NAEP) examination indicate no statistical difference between genders in science proficiency at age nine. But young men outperform young women by a small, diminishing, yet statistically significant margin at ages 13 and 17 (see Fig. 1) [19, Based on data from Appendix Table 1-3, p. A-11].

Average performance of young women on the National Assessment of Educational Progress mathematics examination is similar to, but generally below, that of young men (see Fig. 2) [19, Based on data from Appendix Table 1-10, p. A-18].

Results of the Scholastic Assessment Test (SAT) are troubling (see Fig. 3) [5, Based on data from Table 132, p. 146]. Since at least 1972, women have scored, on average, 39 points below men on the mathematics portion of the SAT. (Note that the range of scores is 200 to 800.) This gap has remained constant. Only 14% of women achieved mathematics scores in the top range (600 to 800) in 1994, whereas 24% of men scored in this range [27]. The persistent gender gap in math performance on the SAT requires explanation considering the exam's importance as an admissions criterion for post-secondary institutions and major fields of study. Given increased course taking in math and science by young women in high school during the 1990s and statistically similar grade point averages in those courses, the results present a puzzle.

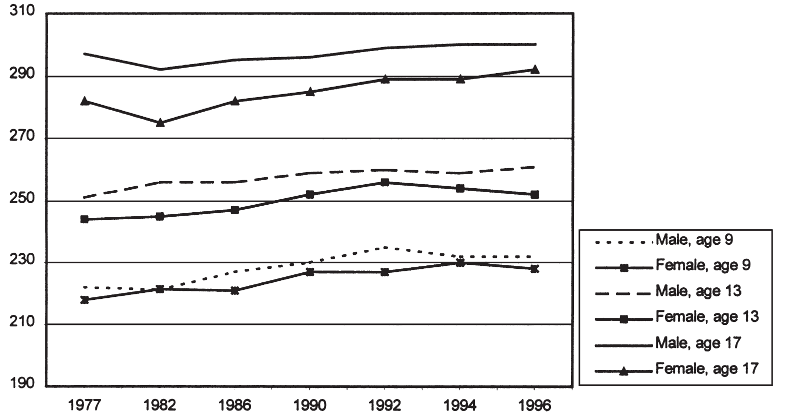

Fig. 1. National assessment of educational progress science scores, by age and gender, 1977–96.

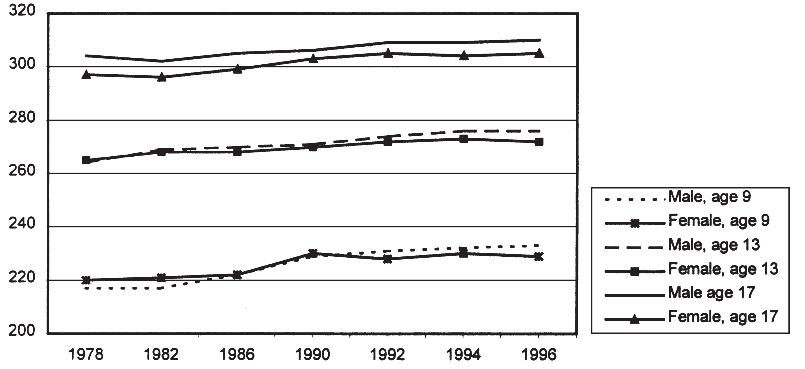

Fig. 2. National assessment of educational progress mathematics scores, by age and gender, 1978–96.

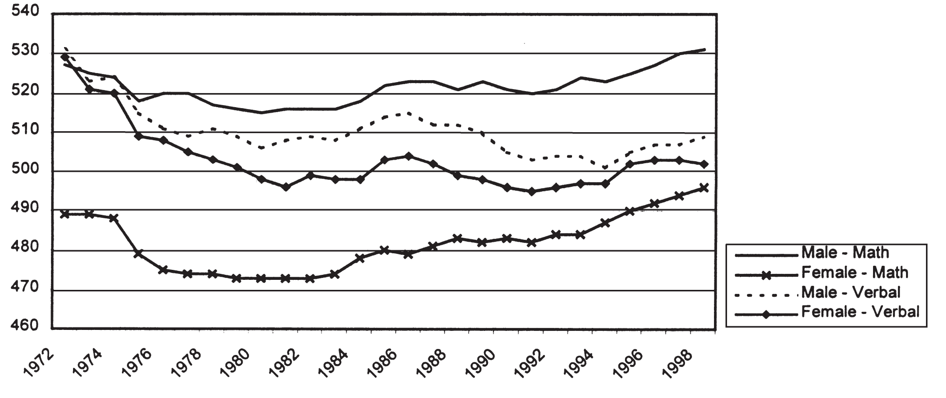

Fig. 3. Scholastic aptitude test (SAT) mathematics and verbal score averages for college-bound high school seniors, by gender, 1972–98.

Persistence of the gap in SAT mathematics scores is difficult to interpret. It may be that young women exhibit greater lack of confidence, fear of success, or sub-optimal test taking preparation and strategies. Gender bias may exist in the construction of this standardized test. Administrators of the SAT discount the likelihood of bias. But a recent small amendment to the Preliminary SAT exam in mathematics, involving the introduction of a writing component, reduced the gender gap by 40%.[2]

Women score below men even in the verbal section of the SAT in spite of higher levels of course taking and stronger grade point averages. Throughout the 1980s, the gender difference in verbal scores was approximately 11 points. Beginning in 1990, this gap began to close. By the mid-1990s women scored approximately four points below men, on average, but this stretched to seven points in 1998 [5, Table 132, p. 146].[3]

It appears that young women have strengthened course taking in science and mathematics, modestly since the early 1980s and dramatically since the late 1980s. Based on these indicators, we might expect women who graduated from high school from the early 1990s onward to enter information technology related fields in greater numbers. However, a survey of intended majors reported by high school students who take the SAT and plan to attend college found that unusually large numbers of women are dissuaded from some fields, particularly from engineering, before arriving at college (see Table 1).

Table 1
Intended undergraduate major of college-bound seniors taking the SAT, 1994[a]

Intended major	Male	Female
Science and engineering	**40%**	**28%**
Agriculture	2%	1%
Biology	5%	6%
Computing	4%	2%
Engineering	17%	3%
Mathematics	1%	>1%
Physical sciences	2%	1%
Social sciences/history	9%	15%
Non-science and –engineering	**60%**	**72%**
Business and commerce	15%	13%
Education	4%	11%
Health and allied services	13%	24%
Other	28%	24%

[a] Based on data from NSF, *Women Minorities and Persons with Disabilities in Science and Engineering: 1996*, Appendix table 2-30, p.140.

[2] See the discussion of this issue in [28, p. 149]. For an alternative perspective, see FairTest, press release, http://www.fairtest.org/pr/psatgap.htm.

[3] Note that women perform better than men, on average, on the English component of the American College Testing (ACT) exam, the other main college entrance exam: [5, Table 135, p. 149].

2.2. Undergraduate education

Women comprise 51% of the U.S. population and earn more than 50% of all bachelor's degrees [4, p. 25]. During the past twenty years, the number and share of bachelor's degrees awarded to women in the natural sciences and engineering has increased markedly.[4] While this trend suggests that women have made strides in attaining educational equality overall, women hold only one out of six bachelor's degrees in engineering, considered the entry level degree to many technical careers. Moreover, women earn only about 25% of computer and information sciences bachelor's degrees.

Women's participation has increased in most fields. In 1975, they earned only 2% of engineering degrees and approximately 25% of natural sciences degrees. By contrast, women earned 47% of natural science degrees, 35% of mathematics and computer science degrees and 17% of engineering degrees in 1995 [19, pp. 2–19].

Indicators of proportional increases must be interpreted carefully. In each year since 1983, more women than men have earned bachelor's degrees, and the numbers of women in every field of science and engineering (except for mathematics) have increased in absolute terms during the past twenty years [19, Appendix Table 2-20, p. A-64]. The number of men earning bachelor's degrees in the natural sciences and mathematics has decreased and markedly so in some fields. Measurements of the proportion of women in various fields neglect the decreasing proportion of men in undergraduate education overall, and the steep decline in male enrollment in the natural sciences. Whereas the share of bachelor's degrees awarded to women in mathematics and engineering increased slightly from 1985 to 1995, the actual number of degrees awarded to women in these disciplines dropped.[5]

The trend in computer sciences shows that women's participation has been steadily declining as a proportion of bachelor's level graduates. The percentage of computer science degrees earned by women peaked in 1984 at 37.2. The absolute number of computer science degrees awarded to women peaked in 1986 at 15 126 [19, Appendix Table 2-20, p. A-64]. From 1986 to 1995, both the number and proportion of degrees awarded to women dropped sharply. In 1995, women earned 7063 (28.5% of) bachelor's degrees in computer science [19]. More recent data do not indicate a change in the trend. Men are three times more likely than women to select computer science as a field of study [3, p. 95]. The recent explosive growth in computer science enrollments has been accompanied by a slight decrease in the proportion of female graduates [29].[6]

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[4] The NSF classification of natural sciences includes "the physical, chemical, biological, agricultural, earth, atmospheric, and oceanographic sciences, as well as mathematics and the computer sciences" [19, p. 2-4, n.1].

[5] A sharp decline in male enrollment in computer science occurred in the early 1990s, but has increased dramatically since 1995 [29].

[6] A sharp increase in bachelor's degree awards suggests that results are beginning to be produced. In 1998, 15% of the graduating class was female, as against 16% in both 1996 and 1997, and 18% in 1995. However, these figures should be treated with some caution. They are based on a survey of Ph.D.-granting computer science and computer engineering departments only. The response rates for 1997 and 1998 were 80 and 77%, respectively.

It is intriguing that women whose adolescence preceded the personal computer revolution were more likely to study computer science than female high school graduates of the past decade. Possibly, lack of easy access to computer technology (specifically, computer games) in the 1960s and 1970s created a more level playing field on which women did not perceive themselves to be at a disadvantage to men in pursuing computing [30]. It would be ironic if home computing widened the gender gap in information technology.

2.3. Graduate education

In 1997 and 1998, 16% of assistant professors, 12% of associate professors and 8% of full professors in U.S. and Canadian Ph.D.-granting computer science and computer engineering departments were female [29, 1997–98].[7] 1992 data indicate that 20% of full time instructional faculty and staff in U.S. computer science higher education were women [5, Table 229]. These positions include non-ladder appointments such as lectureships and instructorships. In 1995, women earned 41% of master's degrees in natural sciences but only 16.2% of master's level engineering degrees. Women's participation at the doctoral level declines further (see Fig. 4) [19, Based on data from Appendix Table 2–30, p. A79]. At this level, women earned 31.2% of all science and engineering degrees, 20.6% of degrees in mathematics and computer sciences, less than 12% of all engineering degrees, and slightly less than 10% of electrical engineering degrees in 1995 [19, Appendix Table 2-30, p. A-79].

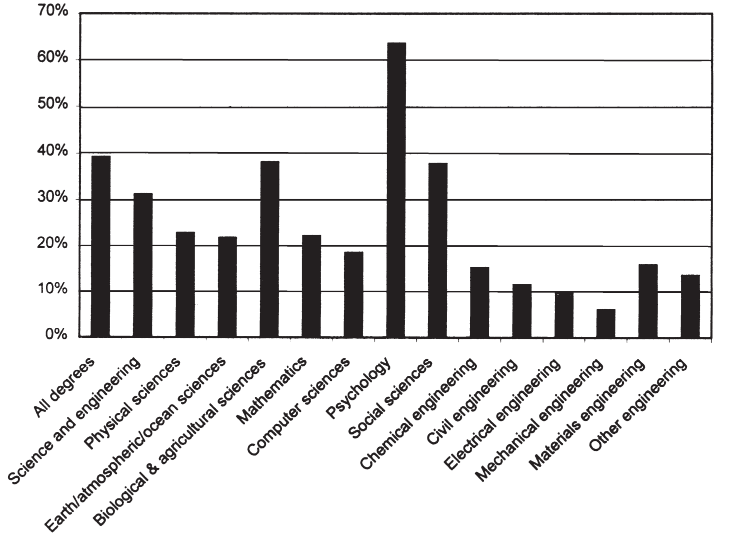

Fig. 4. Percentage of doctoral degrees awarded to women, by science and engineering field, 1995.

[7] The comparable figures in the 1994-95 Taulbee survey indicated that at that time 20% of assistant professors, 10% of associate professors and 5% of full professors were women [29, 1994–95].

These figures forecast low female representation in computer science and engineering faculty during the next 20 years, a critical time period for the construction of information infrastructure and the development of a range of information-based products and services.

Cultural norms clearly function as barriers to entry and retention in engineering and computer science [31, pp. 37-42; 32, pp. 243–65; 33]. In a study of college students, 38% of the women, but only 20% of men, who transferred out of science and engineering majors reported doing so primarily because of concerns regarding career lifestyle [32, pp. 232–233]. The culture and norms of these fields include a range of assumptions, practices and behaviors hostile or alienating to women [34]. Specifically, women tend to be seriously demoralized by courses designed to weed out weaker students, by a lack of positive feedback relative to their experience in secondary school and by a near absence of external social support, for example [35]. Perceptions of science and technology careers as socially isolated, all consuming, intensely competitive and incompatible with healthy families encourage women to avoid them.

2.4. The information technology industry

The Office of Technology Policy estimates that women currently represent 26.9% of computer systems analysts and 28.5% of computer programmers [3, p. 94]. Female computer scientists typically are employed at the lower end of the corporate hierarchy. Only 7% of the nation’s 500 highest IT-using companies in 1996 employed women in their top-ranking IT position [36]. Reports estimate that 2% of executives in high technology firms are women [37]. Women accounted for 6% of software and engineering board members in 1997 [38].

Impediments women encounter during their education are replicated in the workplace as professionals, socialized in their higher education institutions, continue to think and act in ways that tend to disadvantage women.[8] Women are more likely to interrupt their careers, to work part time, and under short-term contracts, patterns that shunt women out of high potential career tracks. The pace and time constraints of work in high technology firms make it nearly impossible to balance work and family obligations. For these reasons and others, women are choosing not to pursue or remain in information technology occupations.

One might argue that women in high tech fields share challenges similar to those of other professional women. One might further argue that, over time, gender equality will increase in information technology just as it has in other fields. But compelling and distinctive features of IT-related fields require particular attention. The history of computing varies from that of other professions with respect to representation by women. While the proportion of women in professions such as law, medicine and

[8] Female scientists and engineers at a 1994 conference sponsored by the Committee on Women in Science and Engineering complained of paternalism, sexual harassment and allegations of discrimination [39]. See also [40, pp. 76–118; 41].

dentistry has been increasing nearly linearly from a low base, computer programming exhibits the reverse trend. It is one of the few professional fields originally well represented by women.[9] Programming was regarded as clerical work during the 1940s and 1950s. Women were considered to possess the skills and attributes necessary for this clean, safe, mundane, new field.[10] Their participation in computer science plummeted in the 1960s, began to recover during the 1980s, and declined again in the 1990s (see Fig. 5) [56, Based on data from Table 672].

3. How would women affect information technology design?

How might the Information Society be affected if more women participate as experts and designers? Two avenues of exploration illuminate future scenarios. First, one can examine impacts on other fields as women have increased their level of expertise and involvement. Second, one can probe recent contributions of women in information technology and speculate on the effect if multiplied.

Consider the development of psychology since the late Nineteenth Century. Until recently, research subjects almost invariably consisted of white males to minimize uncontrolled variance within samples. Research findings of psychologists in the United States revealed a wealth of knowledge regarding the thinking patterns, behaviors, and psyche of American white males. Survey instruments and simulations, including personality indicators and assessments of leadership and management

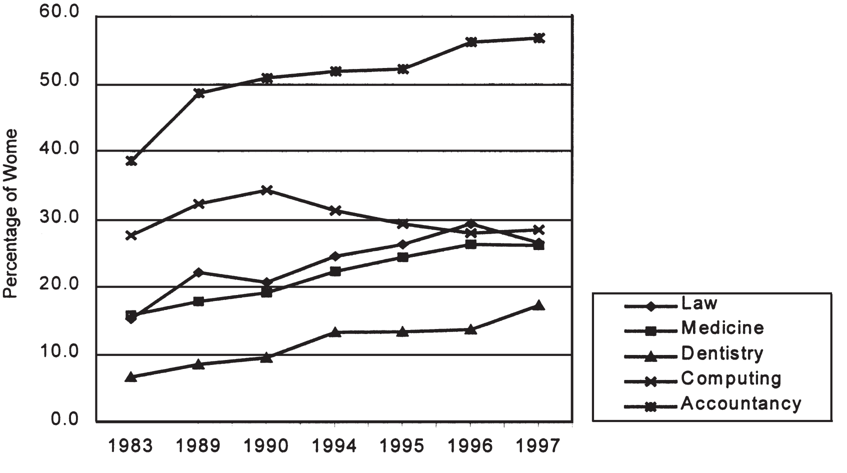

Fig. 5. Percentage of women in selected professions, 1983–97.

[9] For example, the world's first computer, the ENIAC, was programmed by six women to calculate trajectories during World War II. See, for example, [42].

[10] In 1966, Het Vrije Volk commented that "the best programmers are intelligent girls who are good in embroidering because they have the patience and the conscientiousness that is needed", quoted in [31, p. 39].

potential, were validated on data exclusive of women and people of color. Many of these instruments, normalized on the responses of white men, continue to be used widely for diagnostic purposes in educational and corporate settings. They often produce anomalous results when applied to women. It was not until psychologists, such as Jean Baker Miller and Carol Gilligan, began to develop theories of women's personality that the development of women has come to be considered a distinct area of study [43,44].

Medical research protocols excluded women as subjects in clinical trials and across a range of research designs until modernization of health policy less than a decade ago. Research on the etiology of diseases in women, such as cancer and osteoporosis, was severely under-funded until recently. Perceptions of women's health issues — by society, in general, and by the medical community — have undergone fundamental adjustment. Better educated women have demanded higher quality care. The National Institutes of Health Revitalization Act of 1993 requires that research examine differential effects of diseases and treatments by gender, that women be included in all Stage III clinical trials and in research designs preceding those trials.[11] As the proportion of women in clinical practice and medical research has grown and as the percentage of women in decisionmaking positions in politics and policy has increased, women's distinct medical needs have received greater attention [45]. The medical knowledge base, research activities, clinical practices, funding patterns, and institutional arrangements have changed as a result.

These illustrations raise two points regarding cultural change and development. First, fundamental changes for women, and therefore for society, have taken place. Little reason to expect a slackening of the pace of change as society enters the Information Age. Second, none of the advances just described occurred as natural, evolutionary developments although they may be viewed as inevitable and eminently reasonable from most current perspectives. The exclusion of women from politics, from the field of psychology and from medical research comprised societal norms generally accepted and largely unnoticed by most of society including women. Each change was considered radical, abnormal, ludicrous, and outrageous at its inception. Most importantly, each advance required difficult and sustained political, organizational and intellectual action by women and men for its achievement. Advances did not simply evolve.

Consider recent contributions of women in information technology. We may use these illustrations as a base to further consider the types of development we might expect. This section is necessarily speculative. There is limited direct empirical evidence to support analysis of the impact of female designers. Speculation on gender differences easily leads to stereotyping, assuming that all female programmers would adopt similar "female" approaches and concerns. Clearly, this is not the case. Evidence is strong, however, to support the argument that women tend to hold different perspectives from men on the technological needs of society and a greater affinity for the attitudes, competencies, and interests of users.

[11] National Institutes of Health Revitalization Act of 1993, Public Law 103-43, June 10, 1993.

An experiment, in which subjects were asked to imagine the effects of replacing every man in the computer industry with a woman, elicited responses by both male and female participants that the basic perceptions and assumptions of information technology could be dramatically changed [31, pp. 162–163]. Empirical studies document relatively higher levels of concern of many female computing students and professionals with users' needs.[12] This focus contrasts with conventional computer design culture and the tendency to promote technical achievement over practical utility, see, for example, [31, p. 165]. Some students of gender and technology have argued that the conventional approach engenders elitist, potentially dismissive, attitudes towards users. For example, Grundy describes programmers who refer to end-clients as “peasants” and “blockheads” [46].

User-oriented design tends to be disparaged, regarded as “soft computing” in traditional computing culture [47, p. 321].[13] Such a distinction is problematic for business and industry. As computing permeates society, the attitudes and needs of users increasingly affect profits [49]. Social properties of technology — of which user friendliness is one — gain in importance. To discount the needs of users invites adverse economic consequences. For example, a 1979 General Accounting Office survey of major computer systems ordered by the Department of Defense found that of the $6.8 million of software purchased, only $119 000 worth could be used as delivered. All other software required extensive reworking, was not delivered or was never used [49, p. 322].

Three examples of research follow that offer a window on the possibilities for women in design. By broadening the variety of design possibilities and development approaches used in technology, they encourage wider variation in the expression of men's skills and creativity as well.

3.1. *The sociable web*

As the number of people using the Web grows dramatically, it is interesting that searching the Web remains a solitary activity. The Web is viewed primarily as an information space. But it may also be viewed as a social space. The Sociable Web project develops visual and interactive interfaces to support community, specifically to make “Web exploration a more communal endeavor”.[14] The applications under development include a server and client that show users of a Web page others who are accessing the page. These developments will make it possible to communicate

[12] Rasmussen and Hapnes [46] explore the culture of various subgroups of computing students at the Norwegian Institute of Technology. The authors comment that “the female students all emphasize the importance of making computer technology user-friendly. This explicit reference to the users is not all that popular in the computer science department where they want to be dealing with science and not with practical problems” (p. 1113).

[13] See also Turkle's description of the “soft mastery” approach adopted by some women programmers. She describes their greater use of “bricolage”, or nonlinear trial and error, in manipulating technology as producing a focus on technical flexibility and compromise rather than rule-based hierarchies [48, pp. 51–59].

[14] See http://judith.www.media.mit.edu/SocialWeb/SociableWeb/html.

with other users of the same Web page or to search the Web as a group. The applications not only facilitate community but also may improve and enrich information search, knowledge production and management, and academic research.

Sociable Web research is based on the assumptions that relationships are desirable in cyberspace and that the rule systems that constrain search should be designed to facilitate relationship building. This stream of research integrates the power of Internet-based information retrieval applications with an understanding of the benefits of collaborative problem-solving and the synergies that often lead to innovation in collaborative task engagement [11].

3.2. Affective computing

A broad area encompassed by the term “affective computing” includes all aspects of computing that relate to the influence of human emotions on cognition [50].[15] The Affective Computing Research Group at MIT pursues development of applications and devices that will recognize and respond to emotional, or affective, communication transmitted through facial expression, gesture, and other physical signals. The objective of the research is to design and construct computers that may be said to “have” emotions and to “intelligently respond to, and manage, emotional information” [50].

Underlying affective computing research are recent neurological studies that demonstrate the vital role of emotions in cognition and rationality. Psychologists, as well as neurologists, have emphasized the centrality of “emotional intelligence” to human information processing, see, for example, [51,52]. Specific emotional attributes of importance to human information processing include, but are not limited to, empathy, control of impulsive behaviors, self awareness, flexibility, openness to new ideas, and confidence.

Given the traditional dichotomy in science between the emotions and reason, the initiation of research on “affective computing” marks an important scientific and technical advance. Affective computing does not result in greater speed, more power (at least not power as typically defined), or greater efficiency. Its implications, however, are extremely powerful because of the relationship between emotional intelligence and the ability to persuade and lead. By constructing computing that is more nearly human, the researchers broaden and deepen technology changing its relationship to society.

3.3. User involvement in design

The Institute for Women and Technology at XeroxParc is engaged in the development of new computer-based products through a process of community consultation, with the result that much of its technical work springs from ideas generated at community meetings [53]. The Institute has engaged a range of initiatives, including a

[15] See also http://www.media.mit.edu/affect/AC_about.html.

series of community meetings throughout the U.S. in 1998 and 1999 to develop and elicit women's perspectives on desired technological developments. Suggestions from the first series of community workshops included development of a wall-sized view into another room or another place, allowing distant family members to virtually connect their living spaces, and a centralized family scheduler capable of integrating the schedules of an entire family [54].

The Institute is developing a methodology and tools to assist non-technologists, especially women, to participate in technology development brainstorming sessions.[16] The objectives are to engage and equip non-technologists to exercise more effective influence on technological and product innovation. The level and type of consultation with users being developed is expected to provide greater community ownership of technical developments and increase the likelihood of developments in information technology to meet user needs.

4. Conclusion

A steep rise in digital information processing and infrastructure, including the catalytic and interconnectivity value of the Internet and World Wide Web, have made feasible fundamental societal and economic changes that are revolutionary in their aggregate impact. I have argued in this paper that an increase in the participation of women in the design of information technology at all stages will both redress a significant shortfall in human capital and influence the construction of an increasingly information-based society.

While the timing for increasing women's participation in information technology fields appears propitious, the brief survey of participation rates presented in this paper makes clear that the current supply of women as potential designers of IT is alarmingly low. Further, although women have made significant strides in several fields — notably in the natural sciences — their participation in engineering, mathematics, and computer science remains persistently low. Any attempt to strengthen the representation of women in design requires increasing the numbers of women in these educational pipelines. Emphasis on the potential of the Internet for users, while important, obscures the importance of design. Based on the unanticipated and strong societal impact women have had on other disciplines, it seems reasonable to hypothesize that stronger representation of women in information technology will have a deep influence on technology outcomes and processes.

As a cross-cutting policy issue at the nexus of science and technology, employment, education, immigration and corporate policies, it is important to increase public awareness of the distinctive and underrepresented role women presently play in information technology. Young women, in particular, require exposure to role models in these fields. This paper has reviewed and integrated empirical research regarding the

[16] See XeroxParc, Institute for Women and Technology Web site: http://www.iwt.org/ongoingprojects/html#familyWorkshop.

importance for women of mentoring at all stages of development as well as the need for support, guidance and encouragement [55]. Findings across educational, engineering, and management research all recommend that university and industry policies modernize to recognize the importance of collaborative problem solving and balance between work and family. I have noted the danger that changes in immigration policy designed to fill the gap in information technology workers will almost surely dampen pressures to increase gender equity in science and engineering programs and in the workplace.

The wide, intractable disparity in participation rates by gender in the fields that undergird the production of information technologies should be viewed as a policy problem of major proportions. Women comprise slightly more than half the U.S. population. Gains to be derived from effective leveraging of human capital and from broadening the range of technological innovation for the entire society are difficult to overestimate.

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