Becoming a Computer Scientist

A Report by the ACM Committee on
The Status of Women in Computer Science

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It is well known that women are significantly underrepresented in scientific fields in the United States, and computer science is no exception. As of 1987-1988, women constituted slightly more than half of the U.S. population and 45% of employed workers in the U.S., but they made up only 30% of employed computer scientists. Moreover, they constituted only 10% of employed doctoral-level computer scientists. During the same time period, women made up 20% of physicians and, at the doctoral level, 35% of psychologists, 22% of life scientists, and 10% of mathematicians employed in the U.S. On the other hand, there are some disciplines in which women represent an even smaller proportion at the doctoral level: in 1987-88, 8% of physical scientists, and only 2.5% of engineers were women [21]. (1) The underrepresentation of women in computer science is alarming for at least two reasons. First, it raises the disturbing possibility that the field of computer science functions in ways that prevent or hinder women from becoming part of it. If this is so, those in the discipline need to evaluate their practices to ensure that fair and equal treatment is being provided to all potential and current computer scientists. Practices that exclude women are not only unethical, but they are likely to thwart the discipline's progress, as potential contributors to the field are discouraged from participation.

The second reason for concern about the underrepresentation of women in computer science relates to demographic trends in the U.S., which suggest a significant decrease in the number of white males entering college during the next decade. At the same time, the number of jobs requiring scientific or engineering training will continue to increase. Because white males have traditionally constituted the vast majority of trained scientists and engineers in this country, experts have predicted that a critical labor shortage is likely early in the next century [4, 25]. To confront this possibility, the federal government has begun to expend resources to study the problem further. A notable example is the establishment of a National Task Force on Women, Minorities, and the Handicapped in Science and Technology. Their final report, issued in December of 1989, lists a number of government and industrial programs aimed at preventing a labor shortage by increasing the number of women and minorities trained as scientists and engineers [5].

In light of these facts, the Committee on the Status of Women in Computer Science, a subcommittee of the ACM's Committee on Scientific Freedom and Human Rights, was established with the goal of studying the causes of women's continued underrepresentation in the field, and developing proposed solutions to problems found. It is the committee's belief that the low number of women working as computer scientists is inextricably tied up with the particular difficulties that women face in *becoming* computer scientists.

Studies show that women in computer science programs in U.S. universities terminate their training earlier than men do. Between 1983 and 1986 (the latest year for which we have such figures) the percentage of bachelor's degrees in computer science awarded to women was in the range of 36-37%, while the percentage of masters degrees was in the range of- 28-30%. During the same time span, the percentage of doctoral degrees awarded to women has only

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been in the range of 10-12%, and it has remained at that level, with the exception of a slight increase in 1989 [16, 21]. Moreover, the discrepancy between the numbers of men and women continues to increase when we look at the people who are training the future computer scientists: women currently hold only 6.5% of the faculty positions in the computer science and computer engineering departments in the 158 Ph.D.-granting institutions included in the 1988-1989 Taulbee Survey (See *Communications* September 1990). In fact, a third of these departments have no female faculty members at all [16]. This pattern of decreasing representation is generally consistent with that of other scientific and engineering fields [4, 25]. It is often described as "pipeline shrinkage": as women move along the academic pipeline, their percentages continue to shrink.

The focus of this report is pipeline shrinkage for women in computer science. We describe the situation for women at all stages of training in computer science, from the precollege level through graduate school. Because many of the problems discussed are related to the lack of role models for women who are in the process of becoming computer scientists, we also concern ourselves with the status of women faculty members. We not only describe the problems, but also make specific recommendations for change and encourage further study of those problems whose solutions are not yet well understood.

Of course, our focus on computer science in the university by no means exhausts the set of issues that are relevant to an investigation of women in computer science. Most notably, we do not directly address issues that are of concern exclusively or primarily to women in industry. Although some of the problems we discuss are common to all women computer scientists, there are, without doubt, other problems that are unique to one group or the other. Nonetheless, the committee felt that an examination of the process of becoming a computer scientist provided a good starting point for a wider investigation of women in the field. Clearly, to increase the number of women in industrial computer science, one must first increase the number of women trained in the discipline. Thus, we need to consider why women stop their training earlier than men: too few women with bachelor's degrees in computer science translates into too few women in both industry and academia. Moreover, because of the documented positive effects of same-sex role models [12], it is also important to consider why women drop out in higher numbers than do men even later in their academic training: too few women with doctorate degrees results in too few women faculty members. This in turn means inadequate numbers of role models for younger women in the process of becoming computer scientists.

What is Special about Computer Science?

There are many professions in which women are underrepresented. Indeed, as we noted earlier, underrepresentation of women is a fact in most scientific disciplines, and the pipeline shrinkage pattern seen in computer science is common to most sciences. Thus, one of the first questions we need to ask is: what, if anything, is different about computer science? Are there any special characteristics of the discipline that lead to unusual problems for women? Studies addressing these questions have been undertaken by both computer scientists and social scientists, and have identified cultural factors that are significant contributors to women's special experience in computing. These factors range from influences present in elementary-school educational software through the experiences of computer science graduate students.

Computers are encountered today by most children in this country more so than the artifacts of other science and engineering fields, even if they never study computer science in a formal educational setting. The earliest computer artifacts that children encounter are not gender neutral. Recreational and educational software programs reflect the gender biases and stereotypes of their designers, and studies reveal that educational software is generally designed to appeal to boys. For a host of reasons that are beyond the scope of this report, girls and boys have been shown to prefer different kinds of software programs. It is thus disturbing that, in an experimental setting, teachers instructed to design software for students tended to build programs that have the characteristics that boys prefer, and few characteristics that girls prefer-even when they are aware of these differences [13].

In addition to abstract characteristics of software use, the cultural values embedded in educational software and computer games that target adolescents almost exclusively reflect what is commonly identified as adolescent male culture. The predominant themes of recreational computer games are war, battles, crimes, destruction, and traditionally male-oriented sports and hobbies [14]. Thus, it is not surprising that boys use computers in courses and summer camps both earlier and more often than do girls.

Experience in computer use, and a resulting comfort with and affinity for computing, have a strong effect on the study of computer science in the university. When college students encounter computer science, they already perceive its strong cultural component. Those who are knowledgeable about computers are differentiated by special names (wizards, hackers, wheels), and are expected to have distinguishing characteristics, language, and behaviors. This "hacker elite" system, along with the relatively new academic structure of computer science which may seem chaotic and confusing to students, results in many "computing dropouts" who are alienated by the foreign culture [23]. Of course, these problems may affect male as well as female students, but the situation is likely to be more pronounced for females who, because of the differences in early experiences with computers, are less likely to be a part of the elite.

The cultural factors we have described thus far appear to have an effect even on women who are making their way

successfully through the computer science pipeline. A study of doctoral students in a world-class computer science department found that while male and female students exhibited comparable performance quality in their studies, the women students felt much less comfortable, confident, and successful than did the men [3].

It is important to acknowledge the significance of cultural influences in the acceptance and success of women in computer science. The studies we referred to show that there are a number of aspects of the computer science culture that may act against women. Unfortunately, there are no easy solutions to this problem. There are a few specific and obvious recommendations that can be made; for instance, more educational software appealing to girls should be developed. Similarly, educators and educational institutions must make a concerted effort to ensure equal access to computers for boys and girls. However, more far-reaching solutions are less tangible. What appears to be needed is increased sensitivity on the part of male computer scientists to their female students and colleagues, an increased awareness by women so that they will not be easily discouraged, and quite simply, an increased number of women in the field.

In addition to the cultural barriers women face, they also encounter issues of physical safety. This is because, as is also the case for those in the laboratory sciences, computer scientists must often be at their workplace after dark. This is particularly true of students who often do not have computers or terminals at home. The inability to use public terminal areas after hours not only makes it difficult to complete one's assignments, but also precludes informal interactions with other students, an integral part of one's education. For more senior computer scientists after hours access to sophisticated computing systems that cannot be duplicated at home may be necessary.

All computer scientists, male and female, require safe access to the workplace, particularly at night. Yet, for obvious reasons, such access is even more essential for women. Availability of a well-lit, short route to the office from well-lit, safe parking and a sense of safety in the department at night are crucial. It is accepted academic and professional practice to work at night, and women should be able to do so safely. As noted previously, working at home is not always possible. If working at night in the department or on public terminals is not feasible, a woman's working hours are restricted to a subset of those available to her male colleagues. As one woman professor put it, "in many places it is a real problem to do work at night for security reasons, but it is a necessity for professional reasons" [16, p. 32].

One partial solution to this problem is to make campus administrators aware of the issue, so that they will address it when planning new buildings and parking areas. Also useful are services that provide escorts for those walking around campus after dark. In addition, because the issue of safety inside the office at night is equally important, it is crucial that safety procedures such as keeping the building locked at night always be followed. Consciousness-raising within computer science departments may help guarantee that safety procedures are developed and consistently followed. Finally, we should find ways to take advantage of the fact that much computer science research can be done remotely. One recommendation is that funding agencies, such as the National Science Foundation (NSF), provide small grants to female professors to purchase terminals or workstations, printers, and modems for home use, to redress partially the problem of unequal access to resources [16, p. 32]. Male and female faculty advising female graduate students might also find ways to loan such equipment to them. Access to computing equipment at home can also help women who are attempting to balance their careers with family responsibilities that require them to be home in the evenings. As we will describe, the conflict between these two sets of responsibilities is another source of difficulty for many women.

Other Obstacles for Women

Previously we described special characteristics of our discipline that present challenges to women who are attempting to become computer scientists or who are training future computer scientists. The majority of obstacles for women in the discipline are also shared by ocher women scientists and engineers, and to a lesser degree, by all other women employed outside the home. In our view, there are four primary and interrelated challenges facing women:

- Difficulties with self-esteem,
- Lack of mentoring and role models,
- Gender discrimination, and
- Difficulties balancing career and family responsibilities.

We discuss each of these problems in turn, attempting again to suggest ways to combat them. Of course, since these problems are not unique to women becoming computer scientists, the solutions we propose may also have wider applicability.

Diminished Self-Esteem

Several studies of college students have shown that women experience a much greater lack of self-esteem during their college years than do men. In the 1988 American Association for the Advancement of Science Presidential Lecture [25], Sheila Widnall noted that a recent survey of graduate students in medicine, science, and engineering at Stanford University [26] found that

> "the women were indistinguishable from the men in objective measures of preparation, career aspirations, and performance in graduate school. They differed significantly in their perceptions of their preparation for graduate study, in the pressures and roadblocks that they experienced, and in the strategies that they developed for coping with these pressures .... 30% of the women versus 15% of the men questioned their ability to handle the work; 27% versus 12% found criticism difficult to accept; only 30% of the women versus 57% of the men felt confident speaking up in class; and 33 versus 9% feared that speaking up would reveal their inadequacies [25, pp, 1741, 1744]."

Widnall also reports on the Illinois Valedictorian Project, which followed 80 high school valedictorians (46 women, 34 men) through their college years [1]. At the end of their college careers, the women had a slightly higher final grade point average than the men (3.6 vs. 3.5). But the women had experienced a significantly higher loss of self-esteem. As high school seniors, about 20% of both men and women ranked themselves as "far above average," and about 45% as "above average." As college sophomores, about 20% of the men thought they were "far above average," as opposed to about 3% of the women; about 50% of the men and a little more than 40% of the women ranked themselves "above average." By their senior year, 25% of the men and *none* of the women thought they were "far above average," with about 55% of the men and 70% of the women considering themselves "above average." Overall, the self-confidence of the men increased slightly during college, while that of the women decreased significantly.

It seems clear that the diminished self-esteem of female college students contributes to the pipeline shrinkage problem. Indeed, while the studies that Widnall reports on refer to self-esteem problems of undergraduates, similar problems may be even more significant at the graduate level, where students receive primarily subjective feedback from their advisors and peers, as opposed to the more objective feedback of test scores and course grades available to undergraduates. An additional complicating factor is the differing communication styles of men and women. Studies have shown that in group settings, women are interrupted more frequently than men and their contributions are often either attributed to men or ignored altogether [10, 11, 25]. Such experiences are likely to exacerbate an existing lack of self-confidence.

Diminished self-esteem may well cause a woman to not consider valid career options, because she believes that she is not sufficiently well qualified. Even women who consider themselves to be as well qualified as most of their male peers may lower their career goals when they recognize the additional problems that women may face. As Widnall points out:

> "A second trend noted in [the Illinois Valedictorian Project] was the lowering of career ambitions by the women students. The researchers linked lowered career ambitions in part to the unresolved dual career problem . . . . One of the most effective antidotes for these uncertainties about career goals was the opportunity for successful professional experiences: independent research, professional employment, opportunity for interaction with graduate students, and the support and encouragement of a faculty mentor [25, p. 1743]."

Those who train women to become computer scientists need to become aware of the problem of diminished self-esteem, and work to combat it. Toward this end, it is important to give students unambiguous feedback concerning the quality of their work, to provide equal attention to and have equal expectations of female and male students, and to increase awareness of different, especially less aggressive, communication styles. In addition, it is essential to provide women with the opportunity for successful professional experiences. Computer science faculty need to make an effort to draw women into their research projects. While this is of course true of faculty members training graduate students, efforts to include females in research projects should ideally begin at the undergraduate level. Support must therefore be given to funding that will facilitate this, both at the national and institutional levels. An example of a model program is the National Science Foundation's Research in Undergraduate Institutions (RUI) program [19], the goal of which is to provide research opportunities for undergraduates in the sciences. RUI awards are limited to projects that include significant undergraduate participation. By using programs such as the RUI to bring women to research early in their careers, faculty members may help combat diminished self-esteem in women and its impact on attrition.

Mentoring and Role Models

Another major problem facing women in the process of becoming computer scientists is a shortage of mentors. Mentors play a crucial, though usually informal, role in the training of young computer scientists. In general, a mentor shares with a less experienced colleague information about how to get research funding, avenues for publication, the informal power structure within a department and within the discipline as a whole, and so on. Mentors may invest a good deal of time in their junior colleagues and may offer them important opportunities for research collaboration.

Currently, women are much more likely than men to be mentored by female fatuity members [1, 19]. However, there is no reason that men cannot serve as mentors for women, given an appropriate sensitivity to the problems that women in computer science may face. Indeed, because the number of women computer scientists shrinks as one progresses through the pipeline, it is unreasonable to expect senior women to mentor all of the junior women. Men in computer science must also support younger women.

Related to mentoring is the issue of role models. While young computer scientists can benefit from mentors of either gender, it is desirable for women to be exposed to female role models. A role model can serve as evidence that a successful career in computer science is not only a possibility, but a normal and unremarkable option for women. The existence of role models *does* matter, and it matters to women at all stages of their careers. For students, female faculty members prove, by their very existence, that Ph.D. degrees and faculty slots can be attained by women [11, 12]. A similar phenomenon is true of female faculty members who serve as role models for their more junior colleagues. Junior women who have access to senior female faculty members adjust to their positions and establish research programs more quickly than those who do not [7].

Of course, the only real solution to the lack of role models is to increase the number of women in computer science: recall that only 6.5% of computer science and computer

engineering faculty at the Taulbee institutions are female. However, until this situation improves, programs that make successful women more visible can help. Examples are programs that bring women scientists to campuses for a short period of time to give a talk, or for a longer period of time in a visiting faculty position. Activities of the former sort can be encouraged by anyone who is involved in a departmental colloquium or seminar series. Invitation for a longer period requires additional funding; one source of support is the NSF's Visiting Professorships for Women program [22].

At the undergraduate level, it is useful to design programs in which undergraduates are paired with female graduate students and/or faculty. Examples of successful programs of this kind include one run by the Women's Science and Engineering Network at Stanford University [24] and the Women in Science Program at the University of Michigan [25]. Such programs can have the additional benefit of providing graduate women with the experience of being viewed as capable and successful scientists.

Finally, we should point out that role models are important even to precollege women. Without sufficient role models, high school girls may end their mathematics and science training prematurely, thus precluding a major in science or engineering before they even begin college. High school guidance counselors and math and science teachers can play a role here by encouraging capable young women to consider science and engineering as valid career options. Several programs have been developed to encourage high school girls to acquire sufficient training to keep their options open. Perhaps the most extensive program of this kind is administered by the Math/Science Network, a non-profit organization that organizes conferences under the title of "Expanding Your Horizons in Science and Mathematics" [7]. These conferences bring high school girls together with local female scientists. Other more local programs include science fairs, sponsored by schools, scouting troops, or similar organizations, in which women are included among the judges. To increase the influence of science fairs, they may be augmented with career awareness workshops in which participating students can meet with local scientists and engineers to learn about career paths and the educational prerequisites for technical careers.

Discrimination

The issue of gender discrimination is of course a large one, which cannot be discussed in great depth here. By gender discrimination, we mean patronizing behavior and assumptions that women are less qualified and/or committed than men, regardless of whether the assumptions are conscious or unconscious. A detailed discussion of the problem of gender discrimination as it relates to women in computer science departments can be found in the 1983 report "Barriers to Equality in Academia," which was written by a group of female graduate students and research staff in the computer science department at MIT [2]. This influential report notes that the cumulative effects of subtle discrimination may be even more harmful than relatively infrequent incidents of overt discrimination:

> "Often, subtle behavior is not recognized as discriminatory, for two reasons. First, the actions often are not *intended* to be discriminatory; the people who convey biased attitudes toward women may be well-intentioned. Nevertheless, the *effect* of their behavior is to undermine the professional image of women held by their colleagues and the women themselves. Second, any particular incident might appear trivial when viewed by itself. However, when women experience such incidents daily, the overall effect of the environment is much greater than the sum of the individual incidents. Because subtle discrimination is harder to recognize than overt discrimination, it sometimes does more damage. Constant exposure to negative comments diminishes a woman's self-esteem and may lead her to believe that she cannot succeed [2, p. 3]."

Several reports issued by the Project on the Status and Education of Women (PSEW) of the Association of American Colleges address the subject of gender discrimination as it relates to women undergraduates, graduate students, and faculty [10, 11]. These reports concur with the MIT report's observations on the chilling effect of cumulative incidents of discrimination:

> "Overtly disparaging remarks about women, as well as more subtle differential behaviors, can have a critical and lasting effect. When they occur frequently-especially when they involve "gatekeepers" who teach required courses, act as advisors, or serve as chairs of departments-such behaviors can have a profound negative impact on women's academic and career development by: . . . causing students to switch majors or subspecialties within majors . . . ; minimizing the development of the individual collegial relationships with faculty which are crucial for future professional development; dampening career aspirations; and undermining confidence [10, p. 3]."

The PSEW reports, by documenting manifestations of both overt and subtle gender discrimination throughout academia, provide evidence that the problems described in the MIT report are not unique to computer science.

A recent study of several science and engineering departments also draws the connection between gender discrimination and the effective exclusion of women from first-class citizenship in their departments. The study states that "differential attention to women students was felt to promote performance stress while exclusion from informal relations was . . . a career handicap" [6].

A particular manifestation of the differential attention paid to females in the field is what has been called the "invisibility syndrome." Not only is the percentage of women in computer science smaller than the percentage of women in the general population, but also, even within the field, women are underrepresented in many important professional activities. Ideally, the representation of women in the perceived power structure of a community should reflect their numbers in that community. One would expect reasonable,

non-token representation of women on the editorial boards of technical journals; as guest editors of special issues of journals; on program committees of technical conferences; as invited speakers both at conferences and at departmental colloquia; on executive boards of professional organizations such as ACM and IEEE; and on policy boards such as the Computing Research Association (formerly the Computer Research Board) and the Computer Science and Technology Board.

Unfortunately, even those women who have been successful often appear to be invisible, and are not invited to participate in activities of this type to the same degree as their male counterparts. One way to address this problem is to make people aware of it, so that those whose job it is to nominate or appoint people to boards, program committees, etc., can make a conscious effort to include qualified women. Another solution, towards which some women in the field have begun to work, is to compile lists of qualified women in various areas of computer science who can be suggested to those who are responsible for issuing invitations and nominations.

Not only do women often find themselves subject to the type of unintentional discrimination described so far, but they may also be confronted with instances of more overt discrimination or even sexual harassment. It is therefore necessary that departments and universities develop and institute grievance procedures that guarantee confidentiality and freedom from retaliation. We recommend further study of already implemented grievance procedures to determine policies necessary to ensure their effectiveness.

The authors of the MIT study, like those of the PSEW reports, state that "responsibility for change rests with the entire community, not just with the women," and that "many problems would be alleviated by increasing the number of women" [2, p. 1]. We agree completely, and recommend that the kinds of actions we have proposed elsewhere in the report be adopted to help increase women's representation in the field.

Balancing Responsibilities

A final issue that is of central concern involves the difficulties in balancing the responsibilities of a career in computer science with the responsibilities of raising a family. Concern with this problem may lead young women to abandon the possibility of a career in computer science (or any other science) at a very early stage in their training, as indicated in the quotation from the Widnall report noted earlier ("researchers linked lowered career ambitions in part to the unresolved dual-career problem"). Actual difficulties encountered in achieving this balance may result in women leaving computer science later in their careers. Of course, in their concern with this problem, women considering or pursuing careers in computer science are not very different from women in a wide range of other careers-or, for that matter from many men in those careers. Last April, a *New York Times* article noted, "fathers, too, are seeking a balance between their families and careers." However, while achieving such a balance may be difficult for people pursuing many different careers, there are certain aspects of a tenure-track position in a scientific field that render the balancing act particularly difficult [18].

The typical "tenure-track" career path appears to be generally incompatible with outside interests and responsibilities including, but not limited to, childbearing and rearing. Junior faculty in tenure-track positions (like junior lawyers working towards partnerships, junior investment bankers trying to become vice presidents, etc.) are expected to devote enormous amounts of time and energy to their careers: so much time and energy that serious outside interests are precluded or at least greatly constrained. The model for an academic career was developed during a time in which faculty positions were primarily occupied by men who had wives to tend to their home responsibilities. We call this the *helpmate-in-the-background* model. It is one that is still present today: an illustration can be found in the acknowledgments statement of many academic books. An example, from a recent book authored by a male computer scientist, includes a statement of gratitude to his wife "for sheltering [him] from the travails of the real world."

The problem is that the helpmate-in-the-background model is inappropriate for today's society, in which both men and women should have the right, and often have the obligation, to have careers. The model is most obviously inappropriate for women. Women *were* the helpmates-in-the-background: they do not typically have helpmates of their own.

Further complicating the situation is the fact of women's "biological clocks." Most students do not complete the Ph.D. until the middle or late 20s and tenure is typically not granted until the middle 30s. Hence, the childbearing years directly coincide with the period of time during which a woman is completing her Ph.D. and working towards tenure. Both rearing small children and achieving tenure are tremendously time-consuming efforts; doing both at the same time seems to many women to be exceptionally difficult, if not impossible [6].

There are a number of things that can be done to help women achieve a balance between family responsibilities and career demands. For example, universities can and should provide affordable, quality childcare. Sufficient maternity leave policies are also necessary. Many universities have no formal leave policy at all, while others grant only minimal leaves (e.g., one month or less). A few will allow women a semester off from teaching responsibilities, at reduced pay. At those universities that do not offer this option, female faculty are often put in the position of having to try to "time" their babies for semesters that they had planned to take off anyway, such as summer semesters, sabbatical periods, or semesters during which they used grant money to "buy out" of teaching. However, the first. of these

options is often not viable, since most computer science faculty do not have the summer off; instead, they use this period to work on research grants, generally a requirement for tenure. The latter two options generally require that the woman already have tenure or at least be fairly close to it. Moreover, attempts to schedule a baby's arrival are far from reliable, and often fail. Thus, better maternity leave policies are obviously needed.

But solutions like these do not go far enough. Fundamental changes in the patterns of academic careers are required. These changes must rest on a realization that it is the responsibilities of *parenting* a small child, and not the responsibilities of *mothering* a small child, that are incompatible with current work requirements. The model of a helpmate-in-the-background should be as untenable for men in today's society as it is for women.

It is true that there are issues that will always be specific to women—pregnancy, childbirth, and lactation-and career paths must be designed with these in mind. But there are other realities of women's lives that should be seen merely as traditionally women's. Many of these can and should be shared by men. For example, universities must develop not just maternal policies, but parental policies that will allow male as well as female faculty members to be involved in the rearing of small children. Many universities today provide no parental leave at alt. Yet, fathers not only need tune off immediately after the birth of a child, but also, like mothers, need reduced workloads for an extended period of time, to enable them to participate in the rearing of their small children. Thus, another important policy that must be developed, for both risen and women, involves changing the way in which the tenure clock operates.

As with maternity leaves, different universities have different policies regarding slowing the tenure clock to allow a faculty member to care for a small child. Differences involve: (1) whether any slowing of the tenure clock is allowed at all; (2) whether it is permitted only for the "primary caretaker" or whether it is permitted for both parents; (3) whether it is permitted for adoptions; (4) the period of time for which the clock is stopped (typically, one semester); (5) the number of children for which this is allowed (typically one, sometimes two). In our view, some kind of reduced work load is essential to permit faculty members who wish to do so to better balance their family responsibilities with their careers. Moreover, this option should be available to fathers as well as mothers. There have been some doubts expressed about this solution: the claim is that fathers will "take advantage" of the situation by stopping the tenure clock even though they are not participating heavily in the rearing of their child. The worry is that if this happens, the default tenure period will simply become seven years instead of six, and women who do take primary responsibility for the rearing of their children will once again be at a disadvantage.

In our view, this possibility must be faced, but it appears that one solution is to make a strong effort not to change the standards for tenure. That is, departments must continue to impose the same tenure requirements as they do now, but must assume that some faculty members will take seven or eight years to meet those requirements rather than six. We need to expect that, at least in the beginning, some faculty members may take the extra year or two even if they do not have additional child-rearing demands. As long as the standards are not raised, which would penalize those with additional responsibilities, this is not a dire consequence.

Because the issues surrounding leave policies, deferred tenure, and related issues are so complex, we recommend a systematic study of policies in academic departments, to better evaluate the options. It is even possible that the conclusion of such a study will be that the entire tenure process is incompatible with the demands of a dual-career society. After all, the demands of rearing a small child do not stop after six weeks or one semester or even one year of a leave. When the helpmate-in-the-background model is thrown out, it needs to be replaced with a much more flexible one in which people are free to move on and off of a "fast track" at different stages in their career, without those moves permanently jeopardizing that career. This is exactly what tenure precludes: if a faculty member is not fully committed to his or her academic career during the very same period of time in which he or she is most likely to face the demands of raising small children, tenure is unlikely to be granted and the academic career will be permanently stalled.

Although we have emphasized that the traditional helpmate-in-the-background model works against women with children, we believe it also works against women without children and men with employed wives. Few of these people have such helpmates.

In our view, it is important to work to change the helpmate-in-the-background model. It must be possible for both women and men to work hard and well at a career, without neglecting their personal lives. We believe this will eventually be advantageous for both men and women. There is great satisfaction to be found in one's work, but there is also great satisfaction to be found in one's personal life. No one should have to choose one at the expense of the other.

Reopening the Pipeline

As a result of the kinds of problems we have discussed, many women have dropped out of the computer science pipeline prematurely. Although we have been focusing on ways to reverse this trend, an additional approach to correcting the problem of underrepresentation is to help women reenter the pipeline after dropping out of it early. One example of a particularly successful reentry program is the University of California at Berkeley program, which has been in existence since 1983. It is aimed at making graduate study in computer science possible for women and minority students who have received a bachelors degree in another Field. Students in the Berkeley reentry program take regular computer science courses along with undergraduates, and in addition receive a host of support services. The program has

been producing graduates for seven years now, and students who have completed the program have been quite successful in gaining admission to competitive graduate programs in computer science [9].

A second set of women for whom reopening the pipeline may be useful are those with science degrees who are not employed in science. A 1976 NSF program, called the Science Career Facilitation (SCF) Projects, was aimed at such women. This extensive program, which was later discontinued, funded 21 projects in fields where women were poorly represented even though jobs were readily available. Three of these 21 projects dealt with women reentering computer science.

An evaluation of the SCF projects led to several important findings, The primary reasons most women cited for having dropped out of science involved family responsibilities. Research supported by the SCF projects surveyed more than 2000 organizations providing potential employment to scientists, and revealed that none of them attended to the needs of reentering women. Yet programs that do address this would appear to be very useful: after all, more than 585.000 women scientists expressed an interest in retraining and reentry. Finally, the SCF projects that provided this retraining were quite successful: in total, 65% of the participants were reemployed in science while another 10% became full-time graduate students [15].

Conclusions

We have presented some of the problems facing women who are in the process of becoming computer scientists, as well as the women who are training them, and we have made recommendations for change (see sidebar). There appear to be clear and relatively easily implemented solutions for some problems, while for others, such as the apparent conflict between childrearing and gaining tenure, the issues are more complex and further study is required to develop effective solutions. Indeed, complete resolution of some of these problems will depend upon significant societal changes. Ultimately, everything hinges on increasing the number of women in the field. We must make sure that increased representation of women is not stalled because of policies or practices of computer science educators or employers.

Obviously, this article is not comprehensive. We have not, for example, addressed problems unique to women in industrial computer science, nor have we considered how the problems we have described are exacerbated for women of color or disabled women. We believe it is important that these issues be examined, but we leave them for other articles.

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Endnote

(1) Statistics were also acquired from the U.S. Bureau of Labor Statistics in a telephone conversation.

Recommendations for Change

- Ensure equal access to computers for young girls and boys and develop educational software appealing for both.
- Establish programs to encourage high school girls to continue with math and science – for example, science fairs, scouting programs and conferences in which women speak about their careers in science and engineering.
- Develop programs to pair undergraduate women with women graduate students or faculty members who serve as role models, providing encouragement and advice.
- Provide women with opportunities for successful professional experiences such as involvement in research projects, beginning as early as the undergraduate years.
- Establish programs that make women computer scientists visible to undergraduates and graduate students—-for example, invite women to campuses to give talks or to serve as visiting faculty members (e.g.: the NSF's visiting Professorships for Women).
- Encourage men, as well as women, to serve as mentors for younger women in the field.
- Establish more re-entry programs that enable women who have stopped their scientific training prematurely to retrain as computer scientists.
- Develop and enforce safety procedures on campus. Provide safe access at all hours to public terminal areas. Well-lit routes from offices to parking lots, and services to escort those walking on campus after dark.
- Award small grants to female professors for the purchase of terminals or workstations, printers, and modems for home use for safety reasons.
- Educate all computer science faculty about self-esteem issues that women computer scientists face.
- Increase awareness of, and sensitivity to, the use of a variety of communication styles, especially less-aggressive styles.