

Encouraging Women in Computer Science

Eric S. Roberts, Marina Kassianidou, Lilly Irani

Department of Computer Science

Stanford University

Stanford, CA 94305-9015

{eroberts,marinaek,lirani}@cs.stanford.edu

Abstract

At a cost to both their own opportunities and society's ability to produce people with much-needed technical skills, women continue to be underrepresented in computer science degree programs at both the undergraduate and graduate level. Although some of the barriers that women face have their foundations in cultural expectations established well before the college level, we believe that departments can take effective steps to increase recruitment and retention of women students. This paper describes several strategies we have adopted at Stanford over the past decade.

1. Introduction

This paper describes the strategies that we have put in place at Stanford University over the past ten years in an effort to increase recruitment and retention of women in computer science at the undergraduate level. The principal components of that effort are as follows:

- We have focused our effort on increasing the *number* of women enrolled in computer science, as opposed to the *percentage*.
- We have redesigned the introductory sequence to make it accessible to a much wider audience.
- We have sought to provide role models for undergraduate women at every level of the educational process, including those who are only one or two years more advanced in age and experience.
- We have established several bridge programs that target students, both women and minorities, who are at greater risk of leaving technical fields.
- We have instituted a program to engage undergraduates in faculty research.

While progress towards achieving equal participation of men and women at the undergraduate level has been slow, the number of women graduating with BS degrees in computer science has increased significantly over the last five years. These women have, for the most part, gone on to take positions in the computing industry. Their very presence in that industry—coupled with the expertise, creativity, leadership, initiative, and confidence they bring to those positions—underscores the enormous value that women bring to this discipline.

2. Barriers to Women in Computer Science

Existing barriers to women in undergraduate computer

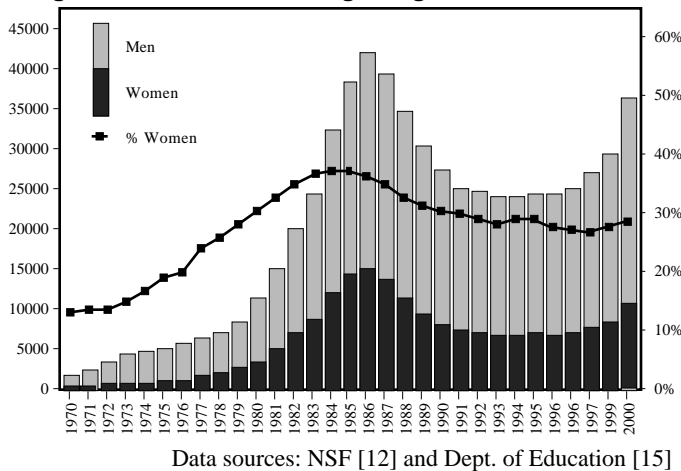
This paper appears in the June 2002 issue of *Inroads*, the quarterly bulletin of the ACM Special Interest Group on Computer Science Education (SIGCSE).

science programs have been detailed in many previous reports, several of which are listed in the reference section or appear as reprints in this issue of *Inroads*. Reports that we have found particularly useful include the pioneering MIT “Barriers” report [14]; the first special issue of *Communications of the ACM* devoted to women in computer science [16]; Ellen Spertus’ report on the scarcity of women in computer science [19]; the study of female undergraduate enrollment in electrical engineering and computer science at MIT [2]; the Computing Research Association study of recruitment and retention of women graduate students [4], which is reprinted in this special issue; and the recent book *Unlocking the Clubhouse* by Jane Margolis and Allan Fisher [13], which is summarized in this special issue in the article on page ???. The barriers themselves are not the main focus of this paper, which is concerned with assessing the effectiveness of various strategies to increase the number of women undergraduates in computer science. Even so, designing effective solutions requires understanding the underlying problems.

To a large extent, computer science departments face the same recruitment and retention problems that affect other engineering disciplines. These common problems—patterns of discriminatory behavior that create an unsupportive classroom environment [11], gender-correlated differences in how students assess their own performance [20], the scarcity of role models, and the lack of a sufficient critical mass to sustain supportive peer communities—are all critically important in computer science. There are, however, additional, more specific problems that seem unique to or particularly pronounced in computer science, including the following:

- The level of computing experience that students have prior to college differs markedly with gender.
- The extraordinary flexibility of software makes it easier to incorporate social biases in the design of computing systems [9].

Figure 1. CS Bachelor's degrees granted



- The culture that develops around computer science departments is often unattractive to women [1].

These factors all have a negative impact on recruitment and retention of women.

3. The importance of numbers

Many of the analyses of academic computer science programs focus on the disproportionately small percentage of women graduating with computer science degrees. While low percentages are ultimately a matter of concern, it is often more useful to focus on the *number* of women enrolled in computer science programs. As outlined in the preceding section, one of the major barriers to women's participation in computer science is the difficulty of creating a critical mass of women within an institution. To a large extent, the ability to develop such a critical mass is a function of the number of women available to become part of that community. Producing more women with computer science degrees is also important over the longer term, because it increases the pool of qualified women who can serve as mentors for future generations.

On a national level, statistics about the production of undergraduate degrees suggest that increasing the total number of students has a correlated effect not only on the number of women, but on their percentage as well. Figure 1, for example, illustrates the number of undergraduate degrees given to men and women from 1970 to 1995 to 2000. The pattern of the overall curve from 1970 to 1995 is familiar to most computer science educators. After rising sharply in the 1970s and early 1980s, the number of undergraduate degrees in computer science—for both women and men—declined sharply for several years before beginning to level out in the mid-1990s. However, as the line superimposed on the bar graph indicates, the downward trend was sharper for women. The percentage of degrees awarded to women tends to track the total number of computer science degrees.

The dramatic decline in majors that occurred during the late 1980s has been the subject of considerable speculation. A surprising number of writers attribute the decline to a downturn in industrial demand, despite the fact that the

recession that led to such a downturn occurred several years *after* the number of computer science graduates began to decrease. In fact, the decline in the number of computer science degrees was largely the result of explicit steps taken by academic institutions to reduce computer science enrollments when it became impossible to hire sufficient faculty to meet the demand [5, 18]. These steps included, for example, imposing more stringent requirements for admission to the major, adding new required courses in mathematics, and transforming introductory courses into filters designed to limit entry into the field. Such strategies have a disproportionately negative effect on enrollment by women and minorities.

This historical pattern has become increasingly relevant in the last few years, when the numbers of computer science graduates has again begun to increase sharply. Although the data from 1997 and 1998 show a declining percentage of women in the face of increasing enrollments, both the numbers and percentage of women have risen in 1999 and 2000. The fact that the growth in participation by women lags somewhat behind the increase in enrollment is particularly interesting when you take it together with the fact that is a corresponding lag in the growth pattern during the enormous enrollment boom in the mid-1980s, when the percentage of women started to decline a couple of years before the overall enrollments had hit their peak. These statistics suggest that women were affected earlier by the efforts taken by institutions to reduce the number of computer science students and that they respond more cautiously to changes in enrollment patterns.

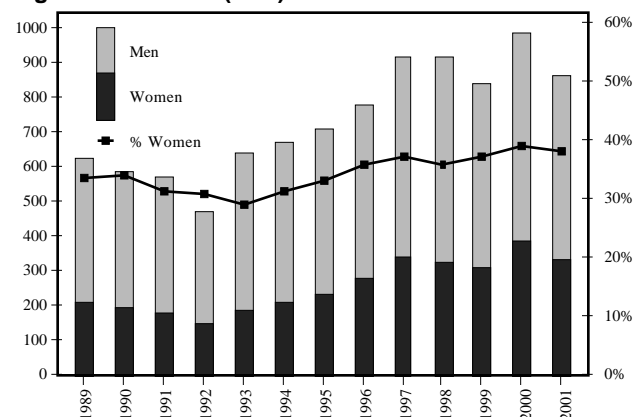
4. Efforts to increase numbers at Stanford

The subsections that follow outline the major initiatives we have undertaken at Stanford to recruitment and retention of women in computer science.

4.1 Creation of a wide-audience introductory course

Much of our work over the last decade has focused on the introductory computer science courses, which serve as feeders for the major. Enrollment in CS106A—the principal introductory course that follows the structure of the ACM CS1 curriculum [3]—has risen significantly. As Figure 2 makes clear, both the number and the percentage of women involved have risen during that time.

Figure 2. CS106A (CS1) enrollment



The following factors contribute to the growth in the number of women enrolling in the introductory course:

- *The course is attractive to a wide audience.* The introductory computer science courses at Stanford are designed to appeal to a wide audience and not just to majors.
- *The course is designed to encourage all students rather than to select the best.* At all too many institutions, the introductory computer science course is run as a filter course designed to weed out all but the best students. At Stanford, our goal in the introductory course is to get as many people as possible through it [17].
- *The course offers many positive role models for women.* Women are involved at many different levels of the introductory course. Two out of the seven lecturers who teach in the introductory program are women, as are many of the teaching assistants. More importantly, individual sections of the course are led by advanced undergraduates, where women have historically comprised approximately a quarter of the group.

4.2 Stepping-stone role models

In our experience, role models are most effective if they exist at many different levels within the university. Relying on faculty role models, for example, runs the risk of discouraging introductory students who cannot see themselves as reaching so high a level of achievement. By involving undergraduates, graduate students, lecturers, and faculty together in the teaching process, we create a structure in which the path to that goal is more clear. Women who are just starting on the path can look ahead, not twenty years to the point at which they might themselves be a professor, but one year to the point at which they might become a section leader. We call this structure a *stepping-stone model*, and believe it is critical to the success of the program.

4.3 Bridge Programs

Many of the factors that lead to the low enrollment of women in technical disciplines begin well before they enter college. To counteract the years of social conditioning, many universities have introduced “bridge programs” that prepare students to work in these fields at the college level [8]. Stanford offers three such programs: a general program to introduce students to engineering before their first year, a program to help at-risk students with introductory mathematics, and an intensive introduction to a discipline for students just beginning their sophomore year. These programs are described in more detail in the three subsections that follow.

4.3.1 Stanford Summer Engineering Academy (SSEA)

The Stanford Summer Engineering Academy (SSEA) is a traditional pre-college bridge program that seeks to prepare entering students for majors in engineering. Students in the program come to campus for a month in the summer before their first year and take an intensive set of short courses that cover both calculus and a basic introduction to the

major engineering disciplines, including computer science. The material overlaps to some extent with traditional first-year courses, but does so in a way that encourages students to experience the process of engineering in a vivid, hands-on way.

The SSEA program enrolls approximately 40 students per year and is targeted toward those students at the greatest risk of leaving engineering. The percentage of women in the program has grown in recent years, to the point at which women represented 51 percent of the class in 2001.

4.3.2 Accelerated Calculus for Engineers (ACE)

For many prospective majors in engineering, the biggest barriers to continuing in their chosen discipline do not lie in the courses they take in their own department, but instead in the large introductory mathematics and science courses that are required of all engineering students. In an effort to reduce the level of attrition associated with introductory calculus, the School of Engineering established a program called Accelerated Calculus for Engineers (ACE). ACE is associated with the introductory calculus series and offers additional assignments and problem sections in exchange for an additional unit of course credit. In all other respects, students in the ACE program are simply part of the regular calculus sequence, completing the same assignments and taking the same exams.

4.3.3 Sophomore College

The Computer Science Department offers an intensive two-and-a-half week summer seminar titled “The Intellectual Excitement of Computer Science,” which is taught by Eric Roberts as part of the university’s Sophomore College program. The goal of the course is to offer sophomores intellectually challenging material, an introduction to the department, and a close association with a faculty mentor to provide a bridge into their sophomore year.

The course consists of guest lectures, lab tours, field trips, and a research project, all of which introduce students to exciting questions in subfields such as artificial intelligence, robotics, graphics, computer architecture, automata theory, and human-computer interaction. The broad range of topics and introduction to research actively dispel the myth that computer science is only about computer programming.

In each of the five years since the program began, the class has enrolled six women and six men, with one male and one female course assistant. The women involved in the program overwhelmingly choose to major in computer science. Of the 22 women who have since declared a major, 17 have chosen to major in computer science with one of the remaining five deciding to major in another engineering discipline. This level of retention (74 percent) is marginally higher than the corresponding rate for men (72 percent).

4.4 The CURIS Honors Program

In the past year, the Computer Science Department has sought to encourage deeper involvement in research by establishing the Computer Science Undergraduate Research Internship (CURIS), a program designed to match

motivated CS majors with research faculty mentors. Students apply for projects that match their interests and are then assigned to mentors based on experience and academic record.

As part of CURIS, students receive a stipend, along with room and board as part of the university-wide Summer Research College. All CURIS interns are expected to conduct full-time research (40 hours a week) for a ten-week period over the summer.

In its pilot year, the program attracted 65 applicants, of whom 33 were assigned and completed the program. Of these students, 24% were women—a rate slightly above that for women who have declared a computer science major. Of the 15 faculty mentors, three were women, including Professor Daphne Koller, who initiated and directs the program.

In its first year, CURIS was viewed very positively by the women who participated. As a female senior explained, CURIS “made it easier to get in contact with faculty members. It provided a channel.” Another female senior felt that CURIS “exposed me to what the Ph.D. process is, which I didn’t know before. . . It brought [the faculty] down to earth.”

The community fostered by CURIS’ structure and residential component also allayed the fears of isolation that are often cited as a reason women choose not to pursue research careers. As one female participant reported, “I was more worried about being isolated in the lab. . . And I think the experience is a lot better because I was able to do CS research with a bunch of peers.”

5. Future Directions

The task of seeking to improve recruitment and retention of women is an ongoing challenge. We recognize that the initiatives described earlier in this paper address only parts of the underlying problem and therefore meet with only partial success. We are therefore seeking to develop new strategies to improve the climate for women in computer science at Stanford.

To this end, the department is making an active effort to encourage discussion and research issues about computer science education and gender. The undergraduate representatives in the Computer Science Department have already initiated discussions among undergraduates. In November, the undergraduate representatives organized a small meeting that included both undergraduate and graduate women students as well as a computer science lecturer. At that meeting, students discussed their common experiences as women in computer science at Stanford and talked about the need to attract and retain more women in the field. Subsequent meetings have explored several ideas for future actions, including several ideas outlined later in this section.

In addition to these discussions, the department is also encouraging student research into the problems women face in computer science education. The student co-authors of this paper are each writing undergraduate honors theses in this area. Such work can potentially yield valuable results that will help us to improve the climate for women

at Stanford. It could also lead to further suggestions for future modifications in the department and curriculum so as to attract and retain more women to computer science departments across the globe.

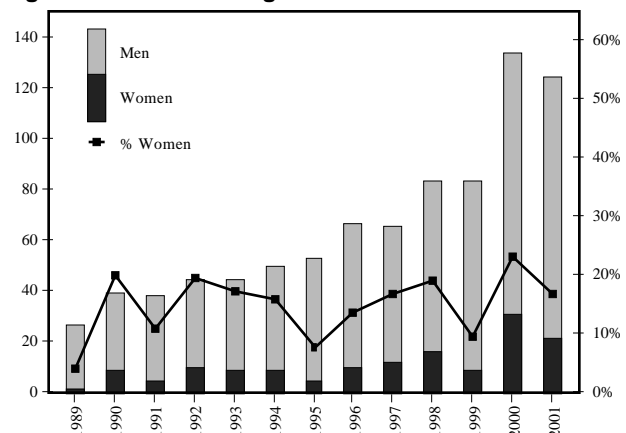
While these new initiatives are as yet at an early stage, it may be helpful to describe some of the ideas:

- *Provide entering students with a better sense of the range of opportunities in computer science.* To make computer science more attractive to women, it is important to counter the myth that computer science is merely programming.
- *Organize a lecture series by women in computer science.* Inviting women—from both on and off campus—who have become established in computer science will make positive contributions to the campus climate on several levels. The presence of these women would also provide role models from outside of Stanford and from industry. The visible presence of women in the field will provide encouragement for women considering majoring in computer science as well as broaden student perceptions about the options they can pursue with a degree in computer science.
- *Develop a “big sister” program.* Carnegie Mellon has had significant success with its “big sister” program, which provides role models for women entering the field (see [6] and [10], which is reprinted in this special issue). We are working to develop a similar program here.
- *Organize larger events to help promote the community of women.* Although individual mentoring is key, larger events also play a role in helping to promote community. Holding get-together programs for women from different years enable recently declared women to get to know each other as well as those women who are already in the program. Such events not only nurture a friendly and supportive environment but allow students to recognize faces when walking into a big computer science lecture.

6. Conclusions

In our experience, the increased participation of women in the introductory course has translated into a somewhat smaller increase in the percentage of women graduating in computer science. The numbers, however, are sufficiently small that the annual variation can be quite large. This

Figure 3. Stanford BS graduates in CS



phenomenon is illustrated in Figure 3, which shows a great deal of variation in both the number and percentage of women graduating with computer science degrees. While the instability in the data makes it impossible to draw firm conclusions, we are pleased that both the number and percentage of women graduating from the program are up significantly in the last two years.

Designing a program that is more attractive to all students has a positive effect on the number of women

enrolling in the program. By designing an introductory course that is widely seen as relevant and supportive of its students, we have increased the number of women in both the introductory course and in the program as a whole. Moreover, by ensuring that women entering the program see other women at every stage within, we can highlight a path that encourages their enthusiasm and fosters new excitement for the field.

References

- [1] American Association of University Women. *Tech-Savvy: Educating Girls in the New Computer Age*. Washington, DC: AAUW, 2000.
- [2] Hal Abelson, Tracy Adams, Lou Braid, Anne Hunter, Bette Johnson, Marilee Jones, Naved Khan, Marilyn Pierce, Lynn Stein, Lisa Tucker-Kellogg, Susan Yeh. Women undergraduate enrollment in electrical engineering and computer science at MIT. Final report of the EECS Women Undergraduate Enrollment Committee, January 1995.
- [3] Richard Austing, Bruce Barnes, Della Bonnette, Gerald Engel, and Gordon Stokes. Curriculum '78: Recommendations for the undergraduate program in computer science. *Communications of the ACM*, March 1979.
- [4] Janice Cuny and William Aspray. *Recruitment and Retention of Women Graduate Students in Computer Science and Engineering*. Washington, DC: Computing Research Association, 2001.
- [5] Kent K. Curtis. Computer manpower: Is there a crisis? Washington, DC: National Science Foundation, 1983. <http://www.acm.org/sigcse/papers/curtis83/>.
- [6] Allan Fisher, Jane Margolis, and Faye Miller. Undergraduate women in computer science: Experience, motivation, and culture. *SIGCSE Bulletin*, March 1997.
- [7] Allan Fisher and Jane Margolis. Unlocking the clubhouse: The Carnegie Mellon experience. women in computer science: Experience, motivation, and culture. *Inroads* (the SIGCSE Bulletin), June 2002 (this issue).
- [8] Shawna L. Fletcher, Dana C. Newell, Mary R. Anderson-Rowland, and Leyla D. Newton. The women in applied science and engineering summer bridge program: Easing the transition for first-time female engineering students. *Proceedings of the 2001 Frontiers in Education Conference*. Reno, NV, October 2001.
- [9] Batya Friedman and Helen Nissenbaum. Bias in Computer Systems. Center for the Study of Language and Information, Stanford University, 1994 (report number CSLI-94-188).
- [10] Carol Frieze and Lenore Blum. Building an effective computer science student organization: The Carnegie Mellon women@SCS action plan. *Inroads* (the SIGCSE Bulletin), June 2002 (this issue).
- [11] Roberta Hall and Bernice Sandler. *The Classroom Climate: A Chilly One for Women?* Washington, DC: Association of American Colleges, Project on the Status and Education of Women, 1982.
- [12] Susan T. Hill. Science and Engineering Degrees: 1966-96. Report number NSF 99-330. Arlington, VA: National Science Foundation, Division of Science Resources Studies, 1999.
- [13] Jane Margolis and Allan Fisher. *Unlocking the Clubhouse: Women Studying Computer Science*. Cambridge, MA: MIT Press, 2002.
- [14] Massachusetts Institute of Technology Laboratory for Computer Science. *Barriers to equality in academia: women in computer science at MIT*. Report prepared by female graduate students and research staff in the Laboratory for Computer Science and the Artificial Intelligence Laboratory at MIT. Cambridge, MA: MIT, February 1983.
- [15] National Center for Education Statistics. *Digest of Education Statistics, 2001*. Office of Educational Research and Improvement, Dept. of Education, March 2002. <http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2002130>
- [16] Amy Pearl, Martha Pollack, Eve Riskin, Becky Thomas, Elizabeth Wolf, and Alice Wu. Becoming a computer scientist. *Communications of the ACM*, November 1990.
- [17] Eric S. Roberts, John Lilly, and Bryan Rollins. Using undergraduates as teaching assistants in introductory programming courses: An update on the Stanford experience. *SIGCSE Bulletin*, March 1995.
- [18] Eric S. Roberts. Conserving the seed corn: Reflections on the academic hiring crisis. *SIGCSE Bulletin*, December 1999.
- [19] Ellen Spertus. Why are there so few female computer scientists? MIT technical report, August 1991.
- [20] Laraine Zappert and Kendyll Stansbury. In the pipeline: A comparative analysis of men and women in graduate programs in science, engineering, and medicine at Stanford University. Stanford University: Institute for Research on Women and Gender, 1984.