

Expanding the Pipeline

Transforming the Culture of Computing at Carnegie Mellon

By Lenore Blum

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In 1995, the Computer Science Department at Carnegie Mellon University (CMU) began an effort to bring more women into its undergraduate computer science (CS) program. At that time, just 7 percent (7 out of 96) of entering freshman computer science majors at Carnegie Mellon were women. Five years later, in 1999, the percentage of women in the entering class had increased fivefold to about 38 percent (50 out of 130).

careers in the United States has declined precipitously during the past decade, and suggest this is unlikely to change. Whether or not this conclusion is valid, it is the view of many observers in the field, and indeed was cited by Rita Colwell, Director of the National Science Foundation, in her keynote address at the 2001 Grace Hopper Celebration of Women in Computing.

We hope the Carnegie Mellon experience may offer inspiration, ideas, and concrete suggestions to others who wish to reverse this perceived trend.

Why (and How) the Increase?

It may be helpful first to say a few words about the history and structure of computer science at Carnegie Mellon. The Computer Science Department (CSD) and its Ph.D.

then Associate Dean for the undergraduate program, spearheaded an intensive effort to understand and change the representation of women. He collaborated with Jane Margolis, a social scientist and expert in gender equity in education, on a research study aimed at acquiring a deeper understanding of the nature of the problem and establishing a sound basis from which to develop interventions.

Funded by the Sloan Foundation, the project consisted of hundreds of interviews with both male and female CS students about their histories with computing, interests, motivations and aspirations, reasons for majoring in CS, and their experiences in the undergraduate program. Conducted over a four-year period, the project was able to track many students throughout their time at CMU. By interviewing students once a semester, the researchers witnessed the ups and downs of their experiences and changes in attitudes over time. Most importantly, they were able to identify crucial periods in the students' attachments to the field, and factors that contributed to, or inhibited, their ability to succeed.

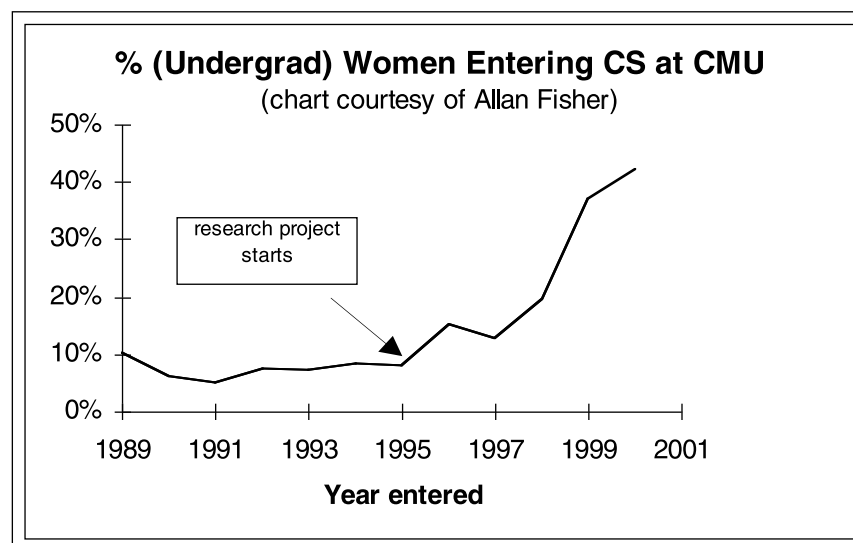
The study yielded significant insights into the many layers of the problem, not only in terms of bringing women into computer science, but also of retaining them. Four problem areas were identified: 1) experience gaps, 2) confidence doubts, 3) the curriculum and pedagogy, and 4) peer culture.

The findings of this study have been well documented elsewhere,⁵ and we will not go into details here. Suffice it to say that the project set the stage for further efforts, including developing a blueprint for action, confirming hunches, and serving as an informational resource for faculty and other potentially supportive parties.

Summer Institute for AP CS Teachers

Clearly the problem of few women entering the field of computer science is inherited. For example, in 1997 only 17 percent of Advanced Placement (AP) CS test-takers were female, the lowest of any AP exam that year.⁶ This amounted to a gain of only 1 percent in 10 years.

In 1995, prompted by impending revisions in the AP CS exam, the NSF issued a call for proposals to prepare high school teachers for the change. Allan Fisher saw this as a fortuitous opportunity to work with teachers to address gender-gap issues while they were motivated to gain new expertise. Thus the Summer Institute for CS Advanced Placement Teachers (6APT) was conceived. With a grant from the NSF, Fisher—together with Jane Margolis, computer equity expert Jo Sanders, and Assistant Dean Mark



Rather than an endpoint, the increasing number of women in the program signifies the beginning of a crucial period of transition for women in computer science at CMU. We are now faced with the challenge of ensuring that women and men in the program thrive. Starting in the academic year 1999-2000, there has been a concerted effort to foster a community committed to this process.

Before outlining the factors that have been crucial to the success of our efforts thus far, it is worth noting that such dramatic increases in the number of women in computer science do not appear to be widespread. In fact, the widely cited statistics from the articles "The Incredible Shrinking Pipeline"¹ and "The Incredible Shrinking Pipeline Unlikely to Reverse"² indicate that the percentage of women entering computer science programs and

program were inaugurated in 1965; the undergraduate major was not instituted until 1988 (first as a Math/CS major and then in 1992 as a CS major). Typically, students enter the computer science major as freshmen. In 1988, the department evolved into the School of Computer Science (SCS), which now comprises seven departments (including the CSD), centers, and institutes of education and research.³ Each of the divisions offers graduate programs; undergraduate students major in CS, but can also dual major in another program.

Research Basis to Support Change

During its first several years, the undergraduate CS program was plagued by very low numbers of women—a trend common to most comparable Ph.D.-granting CS departments.⁴ In 1995, Allan Fisher,

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Stehlik—ran two weeklong sessions in the summers of 1996, 1997, and 1998. The goal of the program was two-fold: 1) to prepare high school CS teachers to teach C++, a major component of the revised AP CS exam, and 2) to talk to teachers about the computing gender gap and what they could do about it.

During the course of the three summers, 240 teachers (approximately 16 percent of all AP CS high school teachers in the United States) participated in the program at CMU. Thus, it is likely that, both directly and indirectly, 6APT has played a significant role in the increased numbers of high school women considering majors in computer science at Carnegie Mellon. Indeed, preliminary data support this claim. The percentage of women from the 6APT high schools entering our undergraduate program increased from 0 in 1995 to 18 percent in 1999.

Admissions

Around 1995, Raj Reddy, then Dean of Computer Science, articulated to the Director of Admissions his desire to attract students to Carnegie Mellon who demonstrate the potential to be world leaders and visionaries in computer science. The CMU Admissions Office responded to Reddy's vision by expanding the range of qualities they looked for in CS applicants. In addition to demonstrated academic competence, the Admissions Office began giving more weight to non-academic factors, looking for applicants with leadership potential and a commitment to "give back to the community." These broadened criteria also became important in awarding financial aid.

About the same time, Allan Fisher also conveyed to the Admissions Office his goal of a gender-balanced program. He felt it was important to get the message out that "no prior programming experience is necessary" to enter the CMU computer science program. The image of a CS student as someone (usually male) who has played with computers since early childhood is widespread. This often discourages many otherwise talented students from applying to a CS program.

Admissions statistics (summarized in Table 1) indicate several important

trends at different stages in the admissions process:

- A steady rise in the numbers of both male and female applicants to the undergraduate program over the past five years, somewhat steeper for women than for men.
- A significantly higher proportion of women applicants being accepted each year.
- An increased yield among female applicants (now about 33%).

According to the CMU Office of Admissions, standardized scores have remained high (e.g., in 2001, the average math SAT score for entering students was 760), while measures of outside achievement and personal attributes are now at an all-time high.

Issues of retention must also be addressed, and efforts have been made to ensure a positive learning environment for women in the School of Computer Science.

A Supportive Community: The Women@SCS Advisory Council

The Women@SCS Advisory Council was created in fall 1999, and has since met weekly during the academic year. Membership includes undergraduates representing all four years and graduate students representing the various departments within SCS.⁷ Council meetings, and ensuing conversations, whether in person or virtual (the Council logs voluminous email correspondence), determine the Council's priorities and evolving agenda for action. A top priority is community building.

Community Building and Networking

The most extensive single activity of the Women@SCS Advisory Council has been the Big Sister/Little Sister program, which pairs upper-class and graduate students with first-year and sophomore CS majors. It was formed to strengthen the bonds of women in SCS and encourage a forum for discussion, advice, and support. Thirty-four students participated in the Big Sister/Little Sister program during its first year, 48 during the second year.

Other community-building activities have included: student-faculty dinners, undergraduate-graduate

student dinners, dessert socials during exam periods, and group outings (e.g., to the Carnegie International Art Exhibit and the Pittsburgh Symphony). The Council also sponsors panels with visiting women computer scientists on topics such as "Women's Career Choices: Costs and Benefits Along the Way," "Grad School or Industry—What Should I Do?" and "The Joys of Undergraduate Research." A tradition begun at the end of the first year is the "Passing the Torch" dinner where seniors share their *pearls of wisdom*.

Consulting and the Curriculum

The Council also acts as a resource and sounding board for the faculty and administration about issues affecting undergraduates. These issues can be quite specific. For example, the Council has reviewed TA training videos and provided feedback to Associate Dean Peter Lee about recruitment presentations.

Even more, insights provided by the Council are likely to have a profound impact on the curriculum. In her "green paper" circulated at a meeting with faculty, senior Ting-Chih Shih clearly pointed out that the current CS undergraduate curriculum serves male students far better than females. For one, the entry programming courses favor students with more experience (usually men) who seem to get better scores effortlessly. As a result, many women "begin thinking that learning computer science takes innate talent and no amount of hard work will pay off... They start to lose confidence and forget their initial interest in computer science..." Moreover, the "way lectures are presented seems to appeal to men more. In general, females feel that the birds-eye view of a problem, and the end result, are more relevant than the coding details in between..."

Outreach

There is a large niche for educational activities geared towards engaging girls in science and technology. Council members have designed a workshop for middle school girls ("Is There a Robot in Your Future?") and have sponsored a national forum on "Girls, Technology and Education."

The Council has been, and continues to be, a source of information about women in computer science for the campus community and the community-at-large. The Women@SCS web site (<http://www.cs.cmu.edu/~women>) is a "must see" to get a feel for the enormous scope of our activities.

Evaluation and Impact

We believe the following features have been crucial to the success of our efforts so far:

- A vision articulated by key faculty and administrators stressing that a more diverse student body is not only good for potential students, but is crucial to the intellectual health and future of CMU's computer science program as well as the entire field.
- A solid base of research from which to make change and educate faculty and students, and a commitment to act.
- Respected and experienced researchers, faculty, and administrators at the helm of the effort, working to bring others on board.
- An articulate and committed group of women undergraduate and graduate students who have gained the recognition and respect of the faculty and administration.
- The growing reputation of CMU as a place that wants women and values their presence.
- Support from the President of the university that has enabled us to bring speakers to campus; organize events, workshops, and outreach activities; and send students to professional meetings.⁸

There is a growing perception among the faculty and administration that the student body is "more interesting than ever before." The awareness of pressing issues—such as the curriculum, advising, and climate—appears to be increasing, particularly among core faculty involved in undergraduate teaching and key administrators. We are witnessing a major transformation in the culture of computing.

In Conclusion

Increasing and maintaining the presence of women in computer science at levels equal to men necessitates taking a hard look at, and changing, business as usual. In the past, the culture, environment, and expectations of the undergraduate CS program have served male students better than female students, although it has not been optimal for many male students either. Many of the changes we have been advocating—particularly regarding curriculum, advising, pedagogy, and community—are not gender-specific. Many are applicable in other educational settings, for example in high

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Table 1. Computer Science Undergraduate Admissions Carnegie Mellon University 1995-2001

Year	Applied		Admitted		Enrolled	
	Total	Women (% of all applicants)	Total (% of applied)	Women (% of female applicants)	Total	Women (% of total enrolled)
1995	1484	160 (11%)	382 (26%)	54 (34%)	96	7 (7%)
1996	2182	231 (11%)	479 (22%)	87 (37%)	142	23 (16%)
1997	2222	248 (11%)	481 (21%)	87 (35%)	136	18 (13%)
1998	2364	274 (12%)	462 (19%)	96 (35%)	140	27 (19%)
1999	2680	342 (13%)	454 (17%)	122 (36%)	130	50 (38%)
2000	2876	404 (14%)	386 (13%)	158 (39%)	132	51 (39%)
2001	3237	435 (15%)	402 (12%)	157 (36%)	132	49 (37%)

Source: CMU Office of Admissions (May 18, 2000); updated (September 10, 2001).

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schools and in graduate programs. We believe they can benefit all students and the field as well.

Lenore Blum is Distinguished Career Professor of Computer Science at Carnegie Mellon where she is faculty advisor to Women@SCS (lblum@cs.cmu.edu).

Notes

1. http://www.mines.edu/fs_home/tcamp/cacm/paper.html "The Incredible Shrinking Pipeline," Tracy Camp, Colorado School of Mines. An edited version of this paper appears in *Communications of the ACM*, vol. 40, no. 10, pp. 103-110, Oct. 1997.
2. http://www.mines.edu/fs_home/tcamp/new-study/new-study.html "The Incredible Shrinking Pipeline Unlikely to Reverse," Tracy Camp, Colorado School of Mines; Keith Miller, University of Illinois at Springfield; and Vanessa Davies, Colorado School of Mines.
3. These are: the Center for Automated Learning and Discovery; Computer Science Department, which houses the undergraduate program; Entertainment Technology Center; Human-Computer Interaction Institute; Institute for Software

Research, International; Language Technologies Institute; and the Robotics Institute.

4. <http://cra.org/statistics> The Computing Research Association "Taulbee Survey."
5. <http://www.cs.cmu.edu/~gendergap/> *Women in Computer Sciences: Closing the Gender Gap in Higher Education*, Allan Fisher and Jane Margolis, School of Computer Science, Carnegie Mellon University.
6. <http://www.collegeboard.org/press/senior97/table14.html>
7. During its first year, eight undergraduate women, four graduate women, one faculty advisor, and one staff member served on the Advisory Council. Four additional students comprised the Women@SCS web team. Starting its third year, the Council had 14 undergraduate and 22 graduate student representatives.
8. In her article, "Toward Improving Female Retention in the Computer Science Major," *Communications of the ACM*, May 2001, J. McGrath Cohoon argues that, based on her investigation of Virginia's CS departments, "the characteristics and practices of computer science departments affect female retention at the undergraduate level" and that "inherent female characteristics are an insufficient explanation of women's underrepresentation in computer science." ■