Unlocking the Clubhouse: The Carnegie Mellon Experience

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Invited Papers

1. Introduction

In the fall of 1995, just seven of 95 students entering the undergraduate program in computer science at Carnegie Mellon University were women. In 2000, 54 of 130, or 42%, were women. What happened? This article presents a brief history of the transformation at Carnegie Mellon's School of Computer Science, and the research project that lay behind it. A fuller discussion, set in an analysis of gender issues in computing from childhood through college, is found in our book, *Unlocking the Clubhouse: Women in Computing* [2].

The story begins with a research study designed specifically to diagnose and find remedies for the gender gap in Carnegie Mellon's undergraduate computer science program. Female enrollment had hovered below 10% for a number of years, and the fraction of women leaving the program was approximately twice that for men. In 1995, the Alfred P. Sloan Foundation funded our proposal for a two-year program, which was followed up two years later with a two-year extension. The goal was to understand the experiences and choices of both men and women with respect to studying computer science, and to design interventions that would involve more women.

1.1 Carnegie Mellon University: The Site of the Research

Carnegie Mellon's School of Computer Science is perennially ranked among the top few computer science departments in the nation for both research and education. Founded in 1965, it was among the first computer science programs created, and has been the source of seminal advances in artificial intelligence, computer design, robotics and many other areas. Beside the Department of Computer Science, the School includes institutes devoted to research and graduate education in robotics, language technologies, human computer interaction, entertainment technologies, machine learning, software engineering, and other facets of computing. As in most computer science departments, faculty members are mostly male, with the women making up less than 10% of the group during our study.

Admission to the undergraduate computer science program is highly competitive: It accepts one in six applicants and average combined SAT scores of entering students have been between 1460 and 1480 during our study. This elite student body may raise the question whether the findings from CMU are representative of how women fare in less competitive settings. While there are always specific dynamics particular to each local setting, our review of other research shows how common these dynamics are in other institutions.

1.2 The Research Project

The research project benefited from a unique insider-outsider interdisciplinary research collaboration. Allan Fisher is a computer scientist, and was the Associate Dean for Undergraduate Education in Carnegie Mellon's School of Computer Science during the term of the project. Jane Margolis holds a doctorate in Education, is a specialist in gender issues, and has a primarily non-technical background (despite a ten-year stint as a telephone installer).

Our collaboration has allowed us to make vital connections: "insider" knowledge of computing and its culture to an outsider's ability to see the unseen; an emphasis on rigor to an ear for nuance; quantitative knowledge to qualitative; academic understanding of gender in our society to its daily experience. It is often tempting for technologists, in particular, to assume that "soft" issues of culture and psychology are simple matters of common sense; we believe the integration of insider commonsense knowledge with outsider expertise and technique is critical.

We grounded our research on interviews with students:

men and women, majors and non-majors. Our intention was to understand students' decisions to study (or not study) computer science. For this we needed to gather their experiences, their perceptions of the field, their attachments and detachments from computer science, their sense of their own abilities, and follow them over time. The computer science student participants consisted of 51 female and 48 male undergraduates. By the end of the fourth year, we had conducted over 230 interviews with computer science majors. We followed the 1995 incoming class through their entire four years, the 1996 class through three years, and the 1997 class for two years. We interviewed students multiple times during their college years. This longitudinal approach has allowed us to see more than just still snapshots of students' lives at single points in time; it let us observe the evolution of their relationship with the field of computing, over time and through many layers of experience. In addition to interviews with computer science majors, we also collected information using classroom observations, surveys of incoming classes, informal interviews with computer science faculty and graduate students, online discussion groups, journals, and a focus group.

2. Summary of Findings

We summarize here the findings reported in more detail in our book.

Different Motivations and Interests in Studying Computer Science

- Rather than finding satisfaction in "hacking for hacking's sake," as do many men students, the context of computing is often very important for many women students. Among our sample, more women than men link their interest in computer science to other arenas such as medicine, the arts, space exploration, etc.

Pre-College Computing Experience

- Before entering college, women have significantly less hands-on experience with computing than most men.
- However, prior computing experience level is not a predictor of success in the program.
- Women and men tend to come to computing at a different pace and time in their lives. While more males experience an intense fascination with computing while they are quite young, more females have their interest piqued later, such as in a high school programming class, and regard computing as one interest among several.
- Significant gender differences in attitudes and experiences with computers appear at the earliest ages. These differences are crucial to understanding the roots of the gender gap in undergraduate computer science and for devising effective interventions.

Culture of Computing and "Geek Mythology"

- There is a stereotype of computer science majors as myopically obsessed with computing. Although many male students, as well as female students, feel that the image is "not me," this stereotype is more damaging for women than for men. This is due largely to a computing culture that promulgates a typically male orientation towards computing, expectations of male success, and continual questioning of women's abilities.

The Nexus of Confidence and Interest: As one drops so does the other

- More women than men transfer out of computer science before the third year, expressing a loss of interest. We have found women's exit statements that they are "just not interested" to be a misleading endpoint to a complex process we've seen over time, often involving a drop of confidence *preceding* a drop in interest. This drop in confidence is usually driven not by low academic performance, but by students comparing themselves unfavorably with others in the light of the dominant image of what constitutes success.

3. Changing the Curriculum and the Culture

While there is a large inherited component to the gender gap in higher education computer science, we believe that there is much higher education can do to engage and protect the interest of women students in computing. Our understanding of the problem, some initial intervention experiences and other research suggest key areas for institutional change: culture, curriculum, and support for women students. An important theme in each case is that women must not expect to model themselves after the stereotypical male computer science student.

3.1 Culture: Multiple Ways to Be a Computer Scientist

Many students and faculty picture computer science students as narrowly focused, intense hackers. For students for whom this is not an appealing work style, and whose career aspirations extend beyond narrowly technical work, this image can be repellent or discouraging. One of the aims of higher education must be to provide students with a broader picture of the possibilities, and to create an environment where alternate models are valued and respected. Faculty must be mindful of ways that the hacker culture becomes an ideal that they promote consciously and unconsciously.

In light of these observations, we made some modest efforts to broaden perceptions of the field. Among faculty, this took the form of discussing the results of our research and that of others, and introducing diversity considerations into discussions of curriculum and programming. Among students, in addition to stressing to entering students that prior experience is not a critical issue, we have begun to talk about the fact that achievement in computer science is more multi-dimensional than the standard "boy hacker" icon. We need to establish the sense that there are multiple valid ways to "be in" computer science. Our research confirms results from other research, as well, that women are more likely than men are to seek a balance in their lives and have multiple interests that are important to them.

3.2 Curriculum: Computing in Context

Our findings on the broader context that women bring to their interest in computing echoes a theme widely found in the literature. Sue Rosser, in her book *Female Friendly Science*, argues that "insuring science and technology are considered in their social context may be the most important change that can be made in science teaching for all people, both male and female" [3, p.72].

Some of the elements of a more contextual approach include early experiences that situate the technology in realistic settings; curricula that exploit the connections between computer science and other disciplines; and diverse problems and teaching methods that appeal to a broad variety of preferences and styles. At Carnegie Mellon, some of the approaches that we have adopted include:

- Interdisciplinary courses that bring students of diverse backgrounds together to work on multifaceted problems;
- An undergraduate concentration in human computer interaction;
- A course that engages students with non-profit groups in the local community and applies student skills to community issues.

All of these efforts provide additional paths for students to pursue in addition to the traditional, technically focused path. More remains to be done, especially in terms of early experience with integrated problems.

3.3 Curriculum: Closing the Experience Gap

Our findings regarding the disparity between the average levels of computing experience of men and women, and its effect on their confidence, echo observations by Janet Schofield. She concludes in her ethnographic study of computer usage in a Midwestern high school that course offerings "must effectively compensate for the likely initial disparity in prior experience between male and female students...that tend to reinforce pre-existing differences in interest and expertise by discouraging many girls from seeking out opportunities to use computers." [4, p.163] Accordingly, we designed multiple points of entry into the Carnegie Mellon computer science curriculum that allow students with widely varying levels of experience to enter courses with appropriate prerequisites, and to end up "in the same place" with only small variations in schedule, and ample time to complete graduation requirements. These changes increased levels of satisfaction among both more and less experienced students of both genders, and indeed seem to result in the smooth integration of the less experienced into the remainder of the curriculum.

3.4 Support: More Attention to Good Teaching

Even though issues of women's confidence have a significant impact on women's interest in majoring in computer science, the issue of confidence is often regarded as beyond the purview of faculty, who are focused on curriculum and research. Yet, confidence is closely linked with pedagogy and relations with faculty.

Researchers Seymour and Hewitt [5] have found that the relationship between teachers and students is particularly significant for female students. They observe "more women than men arrived in college with the expectation of establishing a personal relationship with faculty." In their multi-institutional study of students who leave math and science, they found that male and female students had different objections to large classes: men objected because they have "negative effect on grades," encourage more competition for grades, are usually taught by less qualified faculty. Women objected because "you don't get to know the professor," faculty are "too impersonal," and "the professor doesn't care about you." They conclude that the lack of faculty relationships and mentoring relationships is one of the most common causes of women's drop in confidence:

> *To be faced with the prospect of four years of isolation and male hostility on the one hand, and the abrupt withdrawal of familiar sources of praise, encouragement, and reassurance by faculty on the other is, in our view, the most common reason for the loss of self-confidence that makes women particularly vulnerable to switching* (p. 271).

3.5 Support: Building Student Awareness of Confidence Issues

A more difficult feature of the confidence problem is the role played by students' self-evaluations. A partly intellectual, partly cultural, agenda that we have considered pursuing is to raise awareness of the issues that affect women students' self-assessment and confidence. One approach would be to provide students with some information on cognitive psychology, hoping this will help dispel some of the myths about effortless learning and innate ability that seem to have a corrosive effect on self-confidence. We also need to find ways to reduce the occurrence and remove the sting of comments such as, "You are only here because you are a girl." Students must be educated about admissions policies that show that this is not so, and also understand that the institution considers taunting such as this to be unfriendly and hostile to students' learning environment.

4. Results at Carnegie Mellon

Most significantly, the numbers of women entering computer science at CMU have dramatically increased since we began this project. When we began the study in 1995, women made up just 7% of the incoming class. We are pleased to report that the percentage of women among computer science majors in the entering 2000 class is now 42%

– putting Carnegie Mellon above the national average, and well above the rate for comparable research universities. Figure 1 shows this trend.

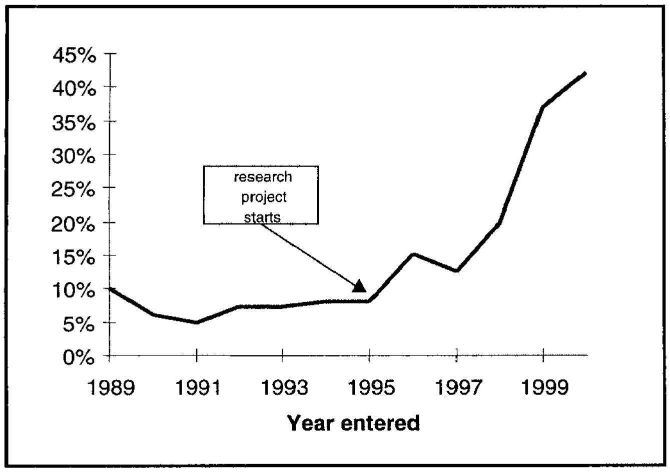

Figure 1. Female Percentage of Students Entering the Program

While a substantial part of our success in increasing the presence of women clearly has to do with recruiting them to apply, enroll and persist, it is clear that admissions standards, too, have shifted. Part of the shift is explained by the observation that experience is not a prerequisite for success; the admissions office attributes the rest of the shift to a search for character and leadership qualities among admitted students. Especially given the recent divergence in admission rates between men and women, careful scrutiny of results over the next few years is called for.

We are also witnessing an increase in *retention* of women in computer science at Carnegie Mellon. Attrition of women from computer science has been significant problem at CMU and nationwide. Women in the computer science program have transferred to other majors or left CMU at more than twice the rate of male students over the past several years. This gender difference in attrition rates is found

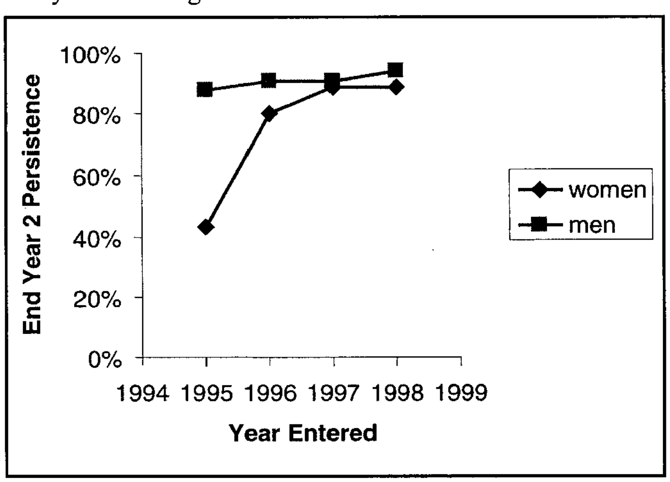

Figure 2. Early Persistence Data

in other sciences, as well. However, the drop-out rate for both men and women has decreased over the past several years at the CMU School of Computer Science. See Figure 2 below. Note that this chart does not account for students who transfer in to computer science. Women who transfer out of computer science tend to be replaced by equal numbers of women transferring in, so the class tends to maintain a consistent proportion of women.

A timely development as the research project wound down was the arrival at Carnegie Mellon of Lenore Blum, a longtime advocate for women in the mathematical sciences, on the Carnegie Mellon faculty. Dr. Blum is coordinating efforts to enhance the social and educational experiences of women in computer science at CMU throughout the pipeline. She has created and is advising the Women in School of Computer Science Advisory Committee (Women@SCS) (see [1] in this issue), a group of articulate and motivated undergraduate and graduate students. The Committee has the ear of the administration—the dean, the associate deans, and department heads—and plays an important part in the life of the department. Through Dr. Blum's individual efforts and the work of the advisory committee, a number of important initiatives spoken to in our research have been introduced:

- Continued monitoring and identification of pedagogical trouble spots such as the transition from the introductory courses to the upper-level courses
- Peer tutoring for students in 15-211, a course that has historically been problematic for women and novice computer science students
- A variety of events for women in the program, to encourage cohesion and lessen social isolation (see [1] in this issue)

The accounts of Women@SCS participants suggest that the group helps to build the perception of "critical mass," breaking down the sense of isolation felt by some female students.

5. Concluding Remarks

From the beginning, we had intended our research to be not just an exercise in knowledge gathering, but also a guide to action. Far from being a passive object of study, the CMU School of Computer Science responded to our findings and other research with a variety of interventions, starting soon after the research began. A variety of formal and informal changes have been made, ranging from the design of the curriculum to the education of teaching assistants to the way the university thinks about admissions. We believe that the research project and its findings have been central to what promises to become lasting institutional change.

We believe that our results can serve as a reference for understanding a wide range of situations. Although we focused on one specific university, we constantly triangulated our research with the observations of others. While intervention programs must be tailored to local problems and conditions, we are confident in making a few general recommendations:

- Take differences in experience into account. Admit inexperienced students who show promise, and provide them with appropriate curriculum tailored to their levels of experiences.
- Take differences in motivation into account. Revise assignments, courses, and curricula to ensure that they serve the interests and orientations of students who are studying computing because of what it can do, as well as those studying computing just because they like it.
- Remember that everything bad that happens is even worse for "outsiders." Weed-out courses in which many students receive low grades or fail are virtually guaranteed to drive out differentially female and minority students, regardless of their talent. Indifferent teaching, untrained TAs, and carelessly administered labs will have similar effects.
- Measure. Know who is applying, who is coming, who is staying, and who is leaving. Find out why, and measure the results of programmatic changes.
- Persist. Lasting systemic change happens slowly, through the accumulation of many small changes.

References

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