RECRUITMENT AND RETENTION OF WOMEN GRADUATE STUDENTS IN COMPUTER SCIENCE AND ENGINEERING

Report of a Workshop June 20-21, 2000

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ORGANIZED BY THE COMPUTING RESEARCH ASSOCIATION'S COMMITTEE ON THE STATUS OF WOMEN IN COMPUTING RESEARCH

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1. INTRODUCTION

> *If we want a different outcome, we're going to have to do things differently. We're making too little progress doing more of the same thing.*
>
> — John White, Dean of Engineering, Georgia Institute of Technology [42]

This document is the report of a workshop that convened a group of experts to discuss the recruitment and retention of women in Computer Science and Engineering (CSE) Graduate Programs.[1] Participants included long-time members of the CSE academic and research communities, social scientists engaged in relevant research, and directors of successful retention efforts.[2] The report is a compendium of the experience and expertise of workshop participants, rather than the result of a full-scale, scholarly study into the range of issues. Its goal is to provide departments with practical advice on recruitment and retention in the form of a set of specific recommendations.

Women are significantly underrepresented in CSE academic departments [5][40]. As computing technology becomes increasingly pervasive, this underrepresentation translates into a loss of opportunity for individuals, a loss of talent to the workforce, and a loss of creativity in shaping the future of society. While there are many causes of this underrepresentation—some rooted in early socialization and primary educational experiences—academic departments at the university level nevertheless can have an effect [6][7]. In particular, an improvement at the graduate level in recruitment and retention (and thus in graduation rates) would enable more women to move into visible and influential positions in the CSE community. The increasing presence of these women would provide positive role models and mentors.

[1] The workshop and this report were supported in part by the National Science Foundation Award EIA-9812240.
[2] See inside cover for a roster of workshop participants.

In order to treat all students fairly, educators must pay attention to gender-based traits. Although in characterizing behaviors one must be careful to acknowledge the existence of individual differences and to avoid stereotyping, there is a large body of information on gender traits. There is strong evidence, for example, that women, even though they perform at the same levels, have less confidence in their abilities and individual accomplishments than men [2][17][36][39][43]. Women are often less aggressive than male students in promoting themselves, attempting new or challenging activities, and pursuing awards or fellowships. There is evidence that females come to computing as only one interest among many, and are thus less single-minded than their male counterparts [27]. Often women report feeling "out of place" in the male-dominated, hacker culture [3][22][28]. In light of such differences, some of our recommendations are gender-specific. Most, however, are not. The adoption of our recommendations would improve the educational environment for *all* students.

The recommendations are given in two sections, the first on recruitment and the second on retention. Without undertaking a complete bibliographic review, the report cites some useful studies that speak to the relevant issues. Implementation mechanisms are sketched out rather than elaborated; any department wanting further information is welcome to contact the authors.[3]

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2. RECRUITING WOMEN TO GRADUATE CSE PROGRAMS

Many departments are interested in improving their ability to compete for the limited number of women applying to graduate school. It would be short-sighted, however, to focus on what would merely amount to a redistribution of women among departments. What is needed is an effort by all departments to increase the total number of women in computing-related graduate programs nationally. Our recruitment recommendations are thus divided into two parts: recruiting women to individual departments and increasing the number of women nationally.

A. INCREASING THE NUMBER OF WOMEN ENROLLING IN A GIVEN DEPARTMENT

Recommendation 1: Broaden the recruitment pool beyond students with undergraduate CSE majors.

Men are more likely than women to become interested in computing at an early age—often describing "epiphany moments" that occurred even before the age of 10—and they are more likely to be interested in computing for its own sake [26][27], whereas women tend to become interested in CS as an "acquired taste" that emerges over time [17]. Frequently, women are interested in computing for its potential applications to societal concerns [33][41] or other areas of interest such as education, medicine, art, and music [26][27]. As a result, they may come to computing at a later stage in their education, perhaps after having majored in some other discipline. Thus their CS backgrounds may not be as strong as most undergraduate CSE majors, leaving them out of the principal recruitment pool for many departments.

Students without traditional backgrounds can succeed—and indeed flourish—in CSE graduate programs. Departments should go beyond the traditional applicant

pool to recruit and admit strong students without undergraduate degrees in CSE. The potential of such students can be judged on academic records, difficulty of electives, successful research experiences, leadership roles, involvement in computing-like activities in their work or volunteer efforts, and internship experiences. Women who have taken a number of courses in computer science, mathematics, or other engineering disciplines are generally better prepared to make the transition, but women with other undergraduate backgrounds should not be summarily discounted. Bridging experiences may be needed to prepare these students for graduate courses (see Recommendation 4).

Recommendation 2: Broaden the criteria used in admissions and be flexible in their application.

"Broaden the criteria" here does not mean "lower the standards." Traditional criteria used for graduate school admissions are not always the best predictors of success. GRE scores, for example, may function much like SAT scores, which are only "mildly" predictive: above a low threshold, higher scores do not translate into significantly higher probabilities of academic success [4]. The GRE Computer Science Exam scores, in particular, may measure the breadth of a candidate's undergraduate program more reliably than her potential for success in graduate school.

Do not focus solely on technical skills. Include such factors as intellectual accomplishment in other disciplines, leadership, motivation, communication skills, breadth of ability and experience, and social commitment. These factors contribute to innovation and a broader application of technology, and they are valued by employers [1][15]. Assess the skills of your department's most successful students. How do they compare to the attributes identified by your admissions criteria? Modify application materials and internal review processes to reflect any changes.

Recommendation 3. Encourage reentry students.

Because women are more likely to be late adopters of computing and because they are more likely to interrupt their education for family reasons, women are dis-

proportionately represented among reentry students. Reentry students can be very successful. They often have a greater level of maturity, focus, independence, and commitment than traditional students. They are more likely to bring a range of experiences to their work.

Develop admissions criteria that take work experience into consideration. Give special weight in these applications to self-statements of motivation and intention, demonstrated capability based on work or volunteer experience, and sense of maturity. Accept recommendations from nonacademics who might be qualified to evaluate the applicant's potential for research. Advertise your willingness to work with reentry students.

Recommendation 4: Provide bridging opportunities to entering graduate students.

Students entering graduate CSE programs who do not have, or do not perceive that they have, strong undergraduate degrees in computing will be at a disadvantage unless they have positive and supportive ways to confirm their ability and fill in any background needed to succeed in their graduate courses.

A bridging program would provide assessment or self-assessment exams for all entering students, along with suggested mechanisms for filling gaps in their educational background. Possible remedies might include attendance at upper-level undergraduate courses for credit or non-credit, introductory summer courses for new graduate students, sanctioned reading lists, and mentors assigned from senior graduate students or faculty. The program should enable students to be part of the graduate community from the beginning and rapidly transition into regular graduate coursework. Departments should advertise the availability of bridging services to prospective students.

Recommendation 5: Explicitly include diversity considerations in your admissions process.

Admissions procedures are often informal, ad hoc, and lacking in continuity. There is a natural tendency, often subconscious, for faculty to want to recruit

students much like themselves, putting a premium on white males with strong technical backgrounds.

Codify the admissions procedures and criteria of your department and incorporate diversity considerations. Ensure that your committee members are educated in diversity issues, understanding, for example, that highly qualified women may well have backgrounds that look quite different from those of their male counterparts. Make sure that your admissions committee recognizes that there are many different acceptable paths to graduate study in CSE and many different kinds of careers that can be launched from this education.

Recommendation 6: Be proactive in making recruiting contacts.

The number of applications from women is unlikely to increase unless your department takes positive action to recruit women. Advertise your department as a women-friendly place. Make it clear that you apply broad admissions standards, and that you welcome students with non-CSE degrees. Enhance the feeder network for your department by including women's colleges and strong, coeducational liberal arts colleges. Establish relations with these schools, either formally between departments or informally between faculty members. This will help you to identify potential applicants and—because both the undergraduate program and the faculty who write letters of recommendation become known through this process—to better evaluate those applicants. In addition, faculty members at an undergraduate institution are more likely to encourage their students to matriculate in a graduate program that they know. Where possible, personalize contacts with prospective students. Have your faculty meet informally with undergraduate women when they give lectures at another institution. Be sure that potential recruits visiting your department have an opportunity to meet female graduate students and faculty.

Recommendation 7: Review all departmental publications for both text and images containing overt or subtle messages that might discourage women from applying.

Materials should be inclusive, depicting both men and women in a variety of activities. They should portray women as the integral members of the department

that they are and avoid images and messages that reinforce negative stereotypes (see Recommendation 11). Materials should focus on the broad range of opportunities available to students.

B. INCREASING THE NUMBER OF WOMEN IN CSE GRADUATE PROGRAMS NATIONALLY

Recommendation 8: Inform your undergraduates about the opportunities and rewards of a research career, giving them timely information about appropriate preparation for such a career.

While all students benefit from such information, it can have a disproportionately large impact on women who, because they may be less sure of their abilities and may have seen fewer role models, are less likely to consider research as a career option.

Make sure that students see practical examples of the exciting, groundbreaking research that is going on in your department. Let them know that they can become a part of it. Hold an annual meeting that shows undergraduates the wide range of career opportunities open to researchers in CSE. Inform them of the benefits of an advanced degree. Let them know that an advanced degree provides higher initial and long-term salaries, for example, as well as greater independence in the workplace, more interesting assignments, job security, and greater opportunities for career advancement. Discuss the preparation needed for graduate school: how it might affect their course selection, how important it is for them to develop working relationships with faculty who might be able to write letters of recommendation, how to apply, and what financial aid is typically available. Let them know what it is like to be a graduate student. Let them know that graduate school is not just five more years of taking classes, but a time of unusual freedom to independently explore ideas. Involve current and recent graduate students in these informational programs.

Recommendation 9: Provide undergraduate women with exposure to computing research.

Students who have had hands-on experience with computing research as undergraduates are more likely to apply to graduate school.

Incorporate research into the standard undergraduate curriculum in the form of research credits or theses, or by making it a requirement of an honors degree[4]. Set aside a modest budget from departmental discretionary funds to pay for research grants for undergraduates. Encourage your faculty to apply for supplements to their research grants that enable them to involve undergraduates in their research activities. In the United States, apply to NSF for a site Research Experiences for Undergraduates (REU) [30] supplement for your institution; in Canada, supervise a student as part of NSERC USRA [31]. Offer summer research experiences to your undergraduates, and make these opportunities available to undergraduate women from other colleges, especially schools where research opportunities are less available. Encourage your students to participate in summer research programs at other institutions. Advertise these opportunities rather than relying on person-to-person contacts.

Monitor the participation rates of men and women in research opportunities within your department to ensure that women are not underrepresented. Women may not be as likely as men to aggressively pursue research opportunities. They may feel more comfortable with programs specifically designed for women, such as the CRA-W Distributed Mentor Program [10], the CRA-W Collaborative Research Experiences for Women [11], or the Lucent summer internship programs [25]. Make sure that your students are aware of these programs. Give them copies of the CRA-W Graduate Student Information Guide [12].

Recommendation 10: Give individual encouragement to your women undergraduates.

Women who major in the sciences often report that they have been influenced by the personal encouragement of high-school teachers [16][27], and thus they

[4] The EPICS program at Purdue University is a particularly good example of an undergraduate research program[23]. It brings together interdisciplinary teams of students to design products for the community and has attracted a large number of female participants.

expect more individual attention from faculty members. Women may be more sensitive than men to social feedback and more responsive to encouragement, personal recognition, and individual invitations from faculty [16][20][22][34][37].

Seek out your department's academically strong women. Give them advice about their education and careers. Encourage them to pursue opportunities for scholarships and awards, as well as research experiences.

Recommendation 11: Actively counter negative stereotypes and misperceptions of computer science and engineering.

Ensure that department literature and departmental visitors include women whose lives and careers do not reinforce the standard clichés. Some of the common misperceptions include:

- All computer scientists are nerd hackers.
- All computer scientists work 24-7-365.
- You cannot be successful in graduate school unless you are highly competitive.
- Women are not good at computing.
- All successful CSE students have a single-minded focus on computing.
- Graduate school is very expensive.
- Graduate education is not worth the salary loss.
- There is no time for a life outside of graduate school.
- The academic culture is incompatible with many ethnic and personal values.
- Working with people and working with computers are mutually exclusive.
- Going to graduate school cannot match the excitement of working in a start-up company or a beginning industry job.
- All applications of computing are in science or engineering.

The myth that "women are not as good at computer science" is prevalent and particularly destructive. It affects peer attitudes and can thus be a significant, negative climate issue for women [17]. A recent study found that departments where the faculty express strong appreciation for their female students' abilities and work styles had lower gender-related attrition [7].

Also on a positive note, take time as a faculty member to tell your students about your satisfaction with your career choice. Share your passion for the intellectual life. Emphasize the potential of a computing research career for social impact, creativity, and interdisciplinary activity.

Recommendation 12: Provide women role models for your undergraduates.

Make sure that there are women faculty, graduate students, and visitors, and that the undergraduates get to meet them. Make sure that the professional contributions of women are discussed in classrooms and lectures.

3. RETAINING WOMEN THROUGH GRADUATION

It is important to create a women-friendly environment that supports your students through graduation. We divide our recommendations on retention into those that improve student relations (and thus support within the department) and those that foster a more inclusive research environment.

A. IMPROVING STUDENT-STUDENT AND STUDENT-FACULTY RELATIONS

Recommendation 13: Be diligent at mentoring women graduate students.

The relationship between the advisor and the graduate student is often the most influential relationship in the student's career. All faculty members need to take this duty seriously. Mentoring is important to persistence and success in graduate school [24]. Both quality and quantity of contact matters. Anecdotal evidence suggests that there may be differences between men and women students in what works best to motivate them. For example, when told that their time for completion of studies is running out, males may respond by working harder while females, feeling that their insecurities have been validated, may feel the situation is hopeless. Each student must be treated individually, and women may need more encouragement.

Make good mentoring a high priority in your department. Make sure that incoming students have mentors as they enter the department, even before they choose a research advisor. Determine which faculty members have been more successful at attracting and advising women graduate students, and try to find patterns in their successes. Make sure that your faculty is aware of some of the excellent literature on effective mentoring [8].

Recommendation 14: Help to create a peer community for your women students.

Peer support has a significant impact on persistence in CSE education [7]. Women graduate students may well have close professional relationships with men in the department, but there is a special value to having a critical mass of female colleagues as well [16]. If your department does not have such a critical mass, you can compensate by encouraging the development of self-sustaining peer organizations for your women students. If there currently are too few women in your department to do this, create a virtual peer group by moving beyond the department to women in other science and engineering departments at your school or women at nearby colleges and universities. Inform your students about national and international organizations, such as CRA-W[5] and ACM-Women, and online communities that provide peer support to women in CSE. Promote the formation of short-term peer support groups, for example, for cooperative classroom activities or study groups for qualifiers. Create social opportunities, including modest funding, for your students to interact with one another and with the faculty. Make sure that these activities offer sufficient variety that everyone will find something of interest at least some of the time.

Recommendation 15: Broaden the institutional culture of the department to accept a range of personal choices in balancing work and life.

The default culture in an institution is often defined by its majority constituents. To broaden access to your department, broaden that culture. Understand as valuable a variety of attitudes and approaches to academic life. CSE graduate programs have accepted, and indeed promoted, certain kinds of behavior and attitudes as highly desirable, such as a fierce single-mindedness of purpose, competitiveness, and aggressive assertiveness in technical discussions. Many women are uncomfortable with these behaviors. Faculty should show, by words and action, that it is acceptable for students to have a life outside academics. They should recognize the individuality of students and the fact that many different kinds of behavior and attitudes can lead to success.

Be sensitive to family and other external responsibilities. Support campus child-

[5] CRA-W is the Computing Research Association's Committee on the Status of Women in Computing Research, http://www.cra.org/craw.

care options. Have a departmental, family-friendly parent policy for both male and female students. Be flexible with timetables for progress through your degree program. Accommodate students who need to take a leave during their graduate study for financial, family, or other personal reasons. Be generous in treating students who are reentering their formal education.

B. FOSTERING A RESEARCH LIFE

Recommendation 16: Provide women role models.

The lack of role models remains an issue at the graduate level [16][18]. Bring women into the department as visiting faculty and distinguished speakers. Arrange for these visitors to meet with the women students during their visit. Increase the number of women on the faculty and professional staff; recruit and promote women at the highest levels. Place women in positions of authority within the department. Treat your current women faculty equitably in terms of salary, promotion, research opportunities, workloads, committee assignments, and so on [29].

Recommendation 17: Integrate students into the research culture of the department as early as possible.

Early involvement in research has a strong positive correlation to success and persistence in graduate school.

Decisions about funding for first- and second-year students often have implications for research involvement: students who hold research assistantships are, not surprisingly, among the first students to become involved in departmental research activities. Students holding fellowships or teaching assistantships may be marginalized in the research life of the department. At some institutions, for example, fellowship holders do not have offices and, consequently, have less interaction with other members of the department. Teaching assistants are often placed in offices with other teaching assistants and, thus, gain less exposure to the depart-

ment's research groups. Anecdotal evidence suggests that women are more often given teaching rather than research positions. Take steps to assure that women have equal access to research assistantships, and that teaching assistants participate in the research life of the department.

All students should be made aware of the research projects within the department, and they should be taught about the importance of getting involved and the mechanisms for doing so. An "Immigration Course" or faculty research seminar could provide this information.

Recommendation 18: Help women graduate students become involved in the professional community as well as the departmental community.

This gives them a chance to meet other women, find women role models, experience a wider range of research, make contacts, and become known. Bring women graduate students to technical conferences, and take time to prepare them to get the most out of the meeting. Introduce them to other professionals. Encourage them to apply for scholarship support to attend technical conferences when it is available. Send your female students to the Grace Murray Hopper conferences and your more advanced graduate students to the CRA-W Career Mentoring Workshops [13] or the CRA Academic Careers Workshop [9]. Encourage the doctoral students to join the online discussion of women computer professionals on Systers Academia [14].

Recommendation 19: Standardize the methods your department uses for delivering information, so that students do not have to be part of an informal social network to receive it.

All students should receive information in a systematic and structured way. They should be told about how to succeed in graduate school, how to get involved in a research project, how to select a research advisor, how to give a talk, and how to write a paper. They should all be informed of career options and strategies for job hunting. The information can be provided through formal talks, question-and-answer sessions with faculty panels, or the distribution of literature or web-based

communications. Students should not have to rely solely on a close working relationship with their advisor or the student grapevine for this information.

Recommendation 20: Change the departmental infrastructure to better promote the equal participation of women.

- Assure that all students have a safe physical environment in which to work.

- Be proactive in avoiding sexual harassment by faculty, staff, or students. Because many students come from backgrounds in which anti-harassment is not widely discussed and enforced, the department should take active steps to avoid harassment, including a well-formulated policy statement that is discussed with faculty and staff each year.

- Offer diversity training to faculty, staff, and incoming students. Discrimination is rarely conscious and overt, but the cumulative effect of even subtle, unintended slights can be significant. Make sure that your faculty has information on gender equity in the classroom [19][21][32][35].

- Form a diversity committee at the department level or participate in one at the university level.

- Establish clear and widely known procedures for seeking informal advice and/or filing formal grievances related to gender-based issues.

- Develop structural mechanisms that ensure that all students have good advising. Do not leave students at the mercy of a single, randomly assigned person. Have the department provide more than one advisor, perhaps a mentor or academic advisor in addition to a thesis advisor. Have the faculty review each student's progress every year. Have the students confidentially review their advisors each year. Make it easy for students to switch advisors.

- Perform a self-assessment of your department's weaknesses in recruiting and retaining women, and prioritize needed improvements. Collect tracking data to

build self-awareness and use as a basis for change. It might be instructive, for example, to know your department's answers to several key questions: What percentage of applicants are female? What percentage of admissions? Are women more likely to be supported by teaching assistantships than research assistantships? Are they more likely to be unsupported? Do women take longer to progress through the department? Are they less likely to persist through graduation? What reasons do students give in exit interviews for leaving the department before graduation?

- Publicize your successes at recruiting and retaining women. Highlight awards your women students and faculty receive. Circulate information about the successful careers of your women graduate students.

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