WOMEN IN COMPUTER SCIENCE:

A Report for the NSF CISE Cross-Disciplinary Activities Advisory Committee

Prof. Nancy Leveson

Information & Computer Science Department
University of California, Irvine
Irvine, California 92717

Email: leveson@ics.uci.edu
Tel: (714) 856-5517

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EXECUTIVE SUMMARY

This is a report written for the NSF Cross-Directorate Activities (CDA) Advisory Committee on ways to increase participation in computer science research by women. A preliminary draft of ideas was circulated on an electronic mailing list of approximately 100 female computer science graduate students and researchers and printed in the Newsletter of the Computer Research Board which is sent to the faculty members of 161 Ph.D. granting institutions in computer science and computer engineering. A total of 50 people responded with comments including men and women from academia, industrial research labs, and NSF. This report contains a summary of those comments.

The little data available shows that there are problems for women all along the pipeline. Girls are dropping out of science and math in their early years even though they do well in it. Societal, familial, and educational factors appear to be the culprit here. When women do enter college math and science programs, they drop out at the lower levels. For the few that manage to get through a Ph.D. program, they are much less likely to reach the higher-level academic positions than their numbers warrant. Very few role models exist to provide encouragement for younger women: There are only 33 female full professors (out of a total of 1189) in computer science and computer engineering in the 158 Ph.D.-granting institutions included in the Taulbee Survey and only 74 female associate professors (out of 909). One third of the universities included in the Taulbee Survey have no female faculty at all. What is most disturbing is that the trend is not positive. Although there was a slight increase this year, the percentage of female Ph.D. recipients in computer science has basically remained constant for the past 15 years. And there is some evidence that the numbers may start to decrease. Although the total number of students interested in studying science is decreasing, the decrease for women is even steeper than for men. Computer science is not an exception to this trend. The Boston Globe (March 13, 1989) reports:

> *Nationally, fewer women are expected to pursue degrees in mathematics and computer science, according to the National Science Foundation, which estimates that only 9,600 will graduate compared to 22,400 women in 1986.*

Based upon the comments received, there appear to be many things that NSF and others can do to attack the problem. It also appears that no easy solution exists. For most of the suggested activities to be effective, dedicated men and women are needed to execute them. NSF can provide the funding and support to help them accomplish their goals.

Multi-university and extramural programs can be effective in optimizing contact of women with role models. A nationwide group to coordinate and publicize activities might be patterned after those in other scientific fields, such as the Committee on the Status of Women in the American Physical Society. Regional workshops can provide career guidance and role models for graduate students and beginning faculty members. Networking activities are also important to combat isolation and might be implemented through electronic communication and interaction at professional functions.

Because girls are dropping out of science and math at an early age, it is important that programs for pre-college women be established and supported. Although the CISE directorate may not be directly involved in such programs, it can provide support to those parts of NSF that are involved in early education.

Activities undertaken by departments and individuals can have a profound effect on the careers of undergraduate and graduate students. Such activities as providing women speakers can focus both male and female attention on successful women. Mentoring of both students and faculty is important and can be done by men or by women. Given the small number of women in university positions, it will be necessary to enlist the aid of men to help support women and minority students. Women in industrial positions can provide mentoring for female students at local universities. Funding is important both to bring in speakers and role models and also to provide release time from other activities. Most women (and men) are already so overloaded with administrative, teaching, and research activities that taking on an additional burden is impossible.

One of the most effective ways to get more women into research is to provide them with opportunities to participate on research projects. This can start with high school summer projects and continue through undergraduate study. Funding summer research jobs and female undergraduate participation on research projects would be a highly effective use of resources. Research paper competitions and other such activities to get women interested and participating in research are important. Special mentoring programs where a female graduate student writes a research proposal with a faculty member have been found to be very successful at several universities. Reentry programs provide opportunities for women to return to science and math and to prepare for Ph.D. programs.

The most effective funding is that which is tied to research. Funding is important starting at the undergraduate level and continuing through graduate fellowships. Because of the changing employment patterns in computer science, post docs may assume increasing importance. Special chairs would help get more women into faculty positions, and more flexibility such as release time from research and teaching could provide the flexibility necesssary to juggle career and family obligations. Finally, the small number of senior women in academic positions implies a need to help women advance to the upper ranks of their profession.

A female graduate student stated very eloquently the reason why these types of activities should be undertaken:

> *Science's ability to build on itself and positively influence society is hindered by the exclusion of important sectors of the society. A woman has the right to educate herself, to know first-hand the beauty of science, and to attempt to make a contribution to the body of knowledge of her choice.*

By not providing the opportunity for women to contribute to scientific activity, everyone loses.

INTRODUCTION

Because of the current concern within NSF about human resource issues and a desire (in fact, a mandate) to implement programs or policies that will help to increase participation in research by underrepresented groups, at a June 1989 meeting I suggested forming a subcommittee of the NSF CISE Cross-Directorate Activities Advisory Committee (of which I am a member) to investigate and suggest possible programs to increase the number of women in computer science research. This report contains the preliminary results of my investigation. Minority issues are currently being addressed by several new NSF programs and, therefore, are not included directly in this report. However, many of the issues and solutions are similar.

In order to get input, I wrote a brief description of the problem and a list of possible activities (NSF and otherwise) and asked for feedback on these particular suggestions and for additional ideas and comments. This was circulated through an electronic mailing list of approximately 100 women computer science students and researchers and also reprinted in the Newsletter of the Computing Research Board. A few people passed the electronic message along to others or told them of my activities. A total of 50 people responded with comments including men and women from academia, industrial research labs, and NSF. It should be noted that NSF employees are speaking for themselves and not for the agency. To preserve anonymity, I have included (with a few exceptions) only a designation of the sex and professional classification of the respondents in this report. I want to sincerely thank everyone who took the time to provide input.

This was in no way a scientifically-conducted survey; everything in the report should be taken as either my opinion or as anecdotal comments from a non-random sample of people. I have tried to include all of the opinions of the respondents, but it should be kept in mind that it is difficult to be totally unbiased when preparing such a report. Finally, this has been a part-time activity and in no way should be taken as a deep or thorough study of the problem. However, the feedback that I received (from both men and women) was overwhelming in its agreement that there is a problem and that something must be done about it. Hopefully, the information that this report provides will help in formulating NSF programs and in providing ideas for individuals and groups to take action.

The first section of the report contains background data to help understand the scope of the problem. This is followed by a list of activities (either for individuals or institutions) that have been tried or suggested along with personal comments received concerning them. These activities are divided into multi-university and extramural programs, single-university and department activities, funding for students and faculty, and miscellaneous comments that did not fit into any of the previous topics. Appendix A lists the contributors to the report. Excerpts from two relevant Boston Globe newspaper articles can be found in Appendix B. Finally, Appendix C contains a term paper written by a Ph.D. student at UCI for a graduate class on social aspects of technology that provides information about the factors affecting the decision of women to enter doctoral programs in computer science.

BACKGROUND DATA

The data I have been able to gather is sparse, but disturbing. If you have not already seen it, I highly recommend reading the AAAS Presidential Lecture by Dr. Sheila Widnall (a professor at MIT) called "Voices from the Pipeline" (*Science*, 241: 1740-1745, September 30, 1988). Unless noted otherwise, the following data was obtained from NSF publications.

Although governments should be moved by inequities and by the desire to allow all their citizens to realize their greatest potential, they are much more likely to act when a national crisis looms. The basic problem as seen by the government is this. The changing demographics in the U.S. will not produce enough scientists and engineers in the future if present circumstances continue. Blacks and Hispanics will make up almost half the school-age population by the year 2000, but the two groups historically do not choose science or engineering as professions. These two groups comprise only 2% of the Ph.D.s in science and engineering. Women, who are half of the population, are only 11% of the science and engineering workforce. Michael Heylin, editor of *Chemical and Engineering News* (vol. 8, p.3), comments:

> *Chemistry and much of the rest of science in this country have been working for far too long under an implicit assumption that scientific competence is disproportionately concentrated in roughly 40% of the population represented by white males. It is a handicap that neither science nor the U.S. can any longer tolerate on economic, competitive, moral, or any other grounds.*

There is a shortage of faculty in technical fields in universities. For example, 1,400 engineering faculty positions are vacant. In addition, the percentage of new physical science and engineering Ph.D. recipients who have remained to teach and do research at universities has fallen 20% over the past 20 years. Currently, much of the shortfall is being made up by foreign graduate students, but an increasing number are returning home to their native countries. Dr. Walter Massey, current president of the AAAS, warns (*Science*, 246:915-921, September 1, 1989):

> *One must consider that only about half of the foreign nationals remain in the United States after obtaining their degrees. It is argued by many who study the problem that this percentage is likely to decline as growth in the labor markets and the need for scientific and technical personnel increases in the home countries of these individuals.*

There are consistent reports that the increase of foreign faculty and TAs has a negative effect on women students as many of these faculty come from countries where it is not regarded as appropriate for women to get advanced degrees in science. Foreign students account for 26% of all science Ph.D.s awarded in 1988 and 54% of all Ph.D.s awarded in engineering. 1988 was the first year in the last five that the number of U.S. citizens earning a Ph.D. in science showed any increase. That increase was due entirely to an increasing number of women earning doctorates in those fields that showed an increase.

The number of 30 year olds in the population peaked in 1988; in that year, there were a total of 9,189 natural science and engineering Ph.D.s awarded to Americans. That age group will decrease steadily and bottom out in 2004, when demand for natural science and engineering Ph.D.s is expected to be about 18,000. The action plan of the recent Federal High Performance Computing Program calls for an increase to attain a level of 1000 computer science Ph.D.s per year by 1995 and laments:

> *the severe undersupply of computer scientists and computer engineers at advanced degree levels. Computational scientists and engineers are in even shorter supply. Addressing the Grand Challenge applications requires large-scale collaborative effort involving diverse groups of scientists, engineers, and mathematicians. The manpower shortage in computing technology and in computational science and engineering is hindering progress in these areas.*

White American males are not going to be able to fill the demand; the only hope is in increasing the number of women and minorities.

But the number of women interested in science, and especially engineering, is decreasing. "Societal stereotyping denies girls the encouragement given to boys to try science and math" (Christian Science Monitor, May 9, 1989). Girls are being turned off to science even by elementary school. Researchers believe that the problem is not that girls have less aptitude in math and science as boys, but that they do not even try. All the social cues discourage them from taking math courses and tell them that they are not qualified to be scientists. Jacquelynne Eccles at the University of Colorado has done some studies showing how student, teacher, and parental attitudes discourage girls from pursuing science and math despite the fact that females, in general, get better grades in math and science than males. She says:

> *the role that parents and teachers seem to play is underestimating girls potential in math and science [...] and being less likely to encourage girls who have talent in math and science to go on to develop those talents and skills, and consider occupations in those fields.*

She has videotaped a large number of classrooms and demonstrated the different treatment that girls receive even though the teachers believe they are acting fairly and no differently toward girls than boys.

I personally am disturbed by the studies suggesting that women are genetically inferior to men in math. Directly after some of the more prominent ones appeared in the popular press, the number of girls in advanced math classes in high schools dropped drastically.

One result of these societal and parental pressures is that women are indicating a declining interest in majoring in science and engineering. This is not surprising when considering that:

1) Women have a lack of support from teachers and parents;
2) As science graduate students they are less likely than men (including foreign men in the same field) to have either institutional or federal support during their graduate study and are more likely than men to be self-supporting;
3) When they do have support, it is more likely (compared to male students) to be in the form of a teaching assistantship which leaves less time for research than in the form of a research assistantship which often involves work that leads to a dissertation;

4) After completing a doctoral degree, women find more difficulty in attaining a first position than do the men with whom they graduate;

5) Once they find a job, women are less likely than their male peers to find an academic job in a tenure track (this is not a function of their more recent entry into the labor force, since at least twice as high a proportion of women as of men employed in academic institutions are neither tenured nor on a tenure track, and this difference has not changed in the past decade);

6) When employed, women continue to be paid less than comparable men. The gap in salaries which is present even in the first job, widens with age — women earn less than men in every field of science, regardless of degree or experience level, and as experience increases, the gap actually widens. This is true for computer science as well as the other sciences.

The percentage of Ph.D.s in computer science awarded to women since 1978 has ranged each year from 10-12% although there was a slight increase last year.

Percentage Women CS Ph.D.s since 1975 (from the Taulbee Report)

Year	Percent	Year	Percent	Year	Percent
75	8	80	12	84-85	10
76	6	81	11	85-86	12
77	7	82	11	86-87	11
78	9	83	12	87-88	10
79	10	84	10	88-89	14

These low numbers are not a result of few women starting out in computer science. In 1986, for example, 36.9% of bachelors degrees in computer science went to women, 28.7% of master's degrees, and 12% of doctorates. Women are dropping out in the pipeline at a much higher rate than men. These computer science figures compare to 30% of all the doctorates awarded in the sciences going to women (although this includes the social sciences and psychology where the percentage of women ranges from 32-50%). For some other comparisons, women earn 16.4% of the physical sciences Ph.D.s and 16.6% of the math Ph.D.s. Computer science is not the worst, however; engineering is worse with a range from 0.8% (in aeronautical engineering) to 13.9% (in industrial engineering). The percentage in electrical engineering is 4.9%.

The percentage of women faculty holding doctorates who teach computer science in 4-year colleges/universities is 9.4%. This figure does not truly reflect the problem since a large number of women are concentrated in schools without Ph.D. programs and thus are less likely to be engaged in research.

For the 158 CS and CE departments included in the Taulbee Survey, 6.5% of the faculty are female. This is a little more than half of the percentage of women getting Ph.D.s in computer science and reflects that either women are not getting or taking faculty positions or they are dropping out of the faculty ranks. Breaking down the figures by faculty rank, 9% of the assistant professors, 8% of the associate professors, and 2.7% of the full professors are women. One third of the departments included in the Taulbee survey do not have any female faculty members at any rank, another third have one female faculty member, and the final third have 2 or more.

1988-89 Taulbee Survey Data for Faculty
[This survey includes 129 CS departments and 29 CE departments]

	CS faculties			CE faculties			CS+CE		
	Total	**Women**	**%**	**Total**	**Women**	**%**	**Total**	**Women**	**%**
Asst.	938	92	10	204	11	5	1142	103	9
Assoc.	718	66	9	191	8	4	909	74	8
Full	894	30	3	295	3	1	1189	33	2.7
Total	2550	189	7	690	22	3	3240	211	6.5

Distribution of Female Professors (1988-89 Taulbee Survey)

	Asst.	**Assoc.**	**Full**	**All Ranks**
# females	**# depts**	**# depts**	**# depts**	**# depts**
4+	1	2	0	9
3	3	1	1	17
2	20	10	4	31
1	50	40	22	54
0	84	105	131	47

For comparison purposes, the 7% women faculty puts CS departments third from the bottom, below all the sciences except engineering (2.3%) and physics (4.2%). The proportion of women faculty with doctorates in all sciences is 18.2%. The figures for computer engineering alone, where the percentage of women faculty is about half that of computer science departments, are truly abysmal. A female professor wrote:

> *As a women who has served for many years as a computer scientist within a college of engineering framework, I have either been the single women, or one of two women, within the entire college. As a graduate student, I never had a woman professor. As a young assistant professor, I occasionally encountered real hostility from engineering students who felt that I did not fit their image of the professor. Twenty years later, I am one of at most two women that my students will encounter in their undergraduate (and sometimes graduate) careers. Yet there are many more women students in my classes. I know, and have known of a number of law suits involving sex discrimination in matters involving hiring, promotion, tenure, and advancement into administrative ranks. There is still a considerable reserve on the part of many of my male colleagues toward the hiring of women in general. And in some cases, there is overt hostility.*

The underrepresentation of women in computer science and computer engineering faculty positions is a serious problem. It is not necessarily all a result of bias or lack of opportunity; as one concerned male faculty member pointed out:

> *The problem is having enough women to go around. If only 10% of the PhDs are women, say 50, and if only 40% of them stay in academia, that means only 20 women to be spread around the 150 PhD-granting departments.*

Furthermore, I have noticed that although many female graduate students with whom I have come into contact want to become professors, they aspire only to jobs at teaching colleges rather than research universities. The lack of female and minority role models in research positions at top-ranked schools tends to enforce stereotypes and to work against efforts to increase participation.

ACTIVITIES TO ADDRESS THE PROBLEM

What can be done about all this? There are some things that can be done on an individual level, and there are others that must be implemented at an institutional, state, or federal level. The activities described below are divided into those that are limited to a single school and those that have a broader scope. Both current and proposed activities are included. Almost all of these activities would benefit from NSF support and guidance.

Multi-University or Extramural Programs

There are some existing programs that are attempting to help women along the pipeline. The following list demonstrates the range of such activities; it is by no means complete.

- **Leadership Texas Options Project**: This women's leadership organization is looking for strategies to encourage an early and lifelong interest in science and math by girls. More specifically, they are researching model programs to keep girls in science and math courses through high school. "After that, the choices are theirs, but at least they will have the OPTION to choose." They have produced a videotape for high school students and are experimenting with slide shows and other media.

- **Math/Science Network**: The purpose of this organization, which is run out of Mills College, is to encourage high school girls to consider careers in math and science and to keep their options open by taking the basic courses before they reach college. To reach this goal, they sponsor various projects, most notably summer math and science programs and a serious of "Expanding Your Horizons" conferences that expose girls to career opportunities. They also have a pilot project called "Expanding More Horizons," which is targeted at minority girls and women. In addition, they have been involved in the compilation of a databse of women's centers, support groups, and foundations, which is now being used by the AAAS.

- **Conferences on women in science**: Conferences have been held concerning Women in Linguistics (June 1988) and Women in Mathematics and the Sciences (November 1989). There was also a conference on the status of women in computer science held in Great Britain in 1988. There is some interest in arranging such a conference for computer science in the U.S.

- **COSEN (Carolinas-Ohio Science Education Network)**: This is "a consortium of higher-education institutions committed to encouraging and supporting black and women students in the study of science." The schools involved are Duke, Davidson, Denison, Furman, Kenyon, Oberlin, Ohio Wesleyan, and the College of Wooster. It is supported by a grant from the Pew Charitable Trusts. They are starting an undergraduate women's support group and also support undergraduate research. The COSEN program encourages women and minorities to try science research as undergraduates. This research program started this summer so there is no information on success rates or on the reaction from the faculty or students.

Other types of activities might also be useful including a national committee for coordination of activities, regional workshops, networking activities, and programs for pre-college women. Each of these is discussed below.

Committee on Status of Women in Computer Science

There is no such thing yet, but a model for this might be the Committee on the Status of Women within the American Physical Society. This rotating group of male and female physicists publishes a Gazette to combat isolation; gathers a database of women for employers; asks for volunteers (via the Gazette) and compiles a speaker's list in order to get more women invited for colloquia and public talks (there is still an old boy's club in most fields in terms of men being much more likely to be invited to give talks); promotes women for prizes, fellowships, editorships, and important committees; and lobbies for programs to promote flexibility such as career interruption, part time work, and recognition of family priorities. This group might also act as a "Finder's Bureau" to match qualified women with opportunities — both full-time and advisory. The American Council on Education does this already for female academic administrators.

One graduate student suggested another activity that might be appropriate for such a committee:

> *[...] establishing some kind of national clearinghouse, to gather and disperse information on the different programs (both long and short term) that DO exist for girls/women. This could include info on junior high level 'science career days' to special programs for women in graduate school. I myself found out about a summer camp for girls in Vermont and a new program for women graduate students in Boston completely by accident. It would be good to have a central "bulletin- board" for such things — not only for people who might want to attend, but also for those who wish to learn how such events might be organized.*

Regional Workshops

It may be possible to establish a pattern of local (regional) short events. One advantage of this is that it provides optimal exposure to the few role models that exist without causing unreasonable travel expenses for students.

These workshops can be either guidance-oriented or research-oriented. The objectives of a guidance-oriented workshop are to help women understand the politics of scientific research, to give advice on getting tenure, and to provide networking opportunities. One female graduate student commented on the possible content for such workshops:

> *I feel pretty strongly that meetings like this should NOT focus on traditional women's problems such as child care, male chauvinism, etc. Rather a major portion of such get togethers should be focused on sharing information that men in science have been sharing (quietly) for years such as how to network in your field, how to make friends (contacts) and influence people (colleagues), what counts for tenure, etc. I have coped with the traditional problems in various ways and so have lots of other women (and men). We can of course share such information, but don't need a large meeting to do so. Individual tastes are too different.*

An NSF staff member suggested that proposal writing skills are important to teach. Classes for such skills might be held at regional meetings or in conjunction with professional meetings.

> *There is a skill to proposal writing, which increases chances of success. (Most repeat grantees, by the way, send many more proposals than they get funded). Your notion of proposal seminars ought to be easy to follow-up. The easiest way is to have a seminar at every professional meeting: NSF staff should be quite willing to participate. I will, if asked, for instance!*

Dr. Barbara Simons described a workshop of this type that she helped to organize:

> *In 1978, when I was a grad student at Berkeley, a small group of women graduate students (we called ourselves Women in Computer Science) decided to organize a conference aimed at getting more women to enter computer science and engineering. Fortunately for us — since we really didn't have much of an idea of what we were getting ourselves into — Sheila Humphreys had just joined the Women's Center at Berkeley. Working with us, she organized the conference in only 3 months, and it was a tremendous success. We had about 400 attendees, almost all of them women. Some of my male fellow graduate students attended the opening session. Afterwards one said to me that for the first time he understood how I felt being the only woman in my classes. With the exception of a couple of male deans, all the panelists and speakers were women scientists or engineers.*
>
> *The conference was attended by Berkeley undergrads, women from surrounding colleges and junior colleges, women considering returning to school, and women currently in cs and engineering. It was a wonderful experience, and there was a lot of comraderie. Also, I think (hope) that it encouraged a number of younger women to either enter the field, to remain in the field, or to aim for higher goals.*

A female professor commented on her experiences at such a workshop:

> *In 1978 I participated in a symposium on Women in Science right after receiving my Ph.D., and it was extremely helpful. If this kind of activity is done well, it is excellent. The symposium I attended was held in Indiana, and senior women were brought in from Michigan and other nearby states. Some very successful female academics came to the symposium, and during the lunches they were spread among the tables, thus providing the younger women a chance to get acquainted. Since very successful women are so spread out in the sciences, this kind of networking opportunity is rare.*
>
> *I also felt the seminars themselves were very helpful. We broke into small groups to discuss*

various issues, and the discussion became quite lively. I got a perspective on the struggle for tenure, grants, etc., which (not having a real mentor) I never received during graduate school. Like many women, I made it through a Ph.D. with a very "cold" advisor who did the absolute minimum. So this symposium gave me some very valuable perspectives on academic careers and what it takes to be successful. Many attendees were graduate students (I was already an Assistant Professor) and it was obvious that they also learned a lot.

I should add that the organizers of the symposium had to call me up and convince me to come. I would not have attended just based on a mailing. So, to have a successful symposium requires real work and dedication.

Another model for such workshops is that they would showcase role models and encourage women to pursue research careers. Such a workshop is planned for Southern California in spring, 1990. Graduate and undergraduate students from universities in the Southern California area will be invited. The speakers will be primarily academic and industry researchers presenting information about their particular research, but there will be a panel in the afternoon about general career opportunities. As one NSF employee commented:

My view, for what it's worth, has always been that the area on which to focus is providing and showcasing role models (successful women who are successful as scientists and engineers), with particular attention to ages 3 to grad school.

Networking Activities

Networking is an important aspect of successful entry to the scientific research community. One male professor wrote:

From my perspective, what has generally worked the best for men or women is networking — early, intensively, and continually. [Women need to] participate; not as a woman, but as a professional. Mechanisms that help women network are great — but the danger is that they will only network with other women, which is a dead-end (in general).

A female professor noted:

I personally benefited from being able to attend conferences in my area, and meeting established researchers. To be perfectly honest that was my entry into the old boys' network; indirectly it helped me get a good job, and it still helps with grants and awards. Those students who don't happen to be on a rich research project don't have this advantage.

Finally, a female graduate student commented:

I think contact with other, more advanced women, would have been a very beneficial thing for me. I am very inclined towards mentor programs, and the establishing of an e-mail penpal system, so that women who cannot participate in a mentor program can establish contact at least through e-mail. I think the regional meetings are also a very good idea, as is funding to get to conferences. One of my biggest gripes is my relative isolation, and so anything that breaks that looks very good to me.

Providing funding for women to travel to conferences and workshops would be useful in these kinds of networking activities (discussed further below). Recently, conference lunches for women have been tried. All it takes is scheduling a room, posting announcements, and a nearby place for people to get take-out lunches. Some women at workshops that include meals have reserved tables for women to converse. One such luncheon resulted in the establishment of an electronic mailing list for women in computer science research. Other types of formal and informal networks of female faculty in the sciences, either single university or multi-university, currently exist or could be established.

Programs for Pre-College Women

I received a lot of comments about the problem of getting young women interested in science and mathematics at an early age. The number of comments reflect both the fact that it is viewed as important by many people and also the fact that I left it off my original list which encouraged people to write, "*I like all your ideas; in addition, what about ...*" Industrial researchers seemed particularly concerned about programs for young girls.

Several women who commented on the early draft of this report participated in university summer math programs for women that were instrumental in their pursuing science and math degrees. Others who had not participated in such programs thought they sounded like a good idea. From a woman working in industrial research:

> *If the problem is partly that women are not attracted to math and science and are not even applying to major in math and science in college and grad school, then perhaps NSF should focus on programs in grade school and high school. I, too, participated in special programs before college, including some at City College on Saturdays (where I first learned to program) and at Cornell University during the summer (where college-level courses were offered to high school students). These programs exposed me to people who were doing real research in math and science, and they were exciting and fun. Programs such as these, coupled with role models in school who encouraged me in math and science, led me to choose math as a college major.*
>
> *At the same time, I received lots of social and familial signals to stay away from math and science because they weren't feminine. Nevertheless, I ended up in math, so the stimulation in high school must have worked.*

A female professor commented:

> *I was at [a summer program for high school students] in math, and taught at it for a number of years. I think they're great. Mine has at least five women PhDs that I am aware of. Since math is so important for CS, how about also encouraging some of the math programs to have a CS component? I think the math programs might attract more women students.*

Finally, a male professor responded to my suggestion for such programs:

> *YES!! I strongly feel that by the time women get to the university, it is almost too late to encourage them to enter the sciences. Summer programs such as this would be an excellent idea, and I would be happy to encourage our lab to help support one.*

There were suggestions for other types of programs that might be effective. From a graduate student:

I once participated in a program where local jr. high girls came to the university to see "women in science in action." We presented workshops and gave them some hands-on experience too. I have no idea if this has "good results" and I don't know if anyone has tried to track that. My own empirical observation was that it was a good experience for everyone, and reaches a fair number of girls. So another suggestion is funding such events.

From a male professor:

There is a local program supported jointly by the museum of natural history and the local school district called the after school science academy. They have mentors who are generally retired engineers who help 1-3 students with projects of the students' choosing. This works wonders in helping the kids gain mechanical skills and in learning about doing projects.

Do you think that there would be any way that this sort of thing could be fostered? Do you think that there would be any way that it could be adapted to encourage girls to be interested in science?

From a female industrial researcher:

I remember being told in high school not to pursue my interest in chemistry because women didn't make good chemists (this was from the head of the chemistry department at the local university who was visiting the school on a recruiting trip).

I wonder whether some programs could be set up with high schools to show interested young women what a researcher does all day. For example, pair a high-school age woman interested in some area of engineering with a woman working in research in that field. They would spend some significant amount of time (e.g. a week) going to seminars or working on something together. This would take a lot of work to set up but might have a significant impact at an early enough stage to make a difference. A less intensive program of exposure (through lab tours or outreach to schools) would also be a possibility.

Several people expressed concern about the general state of education in math, science, and computing at the pre-college level. A female professor responded:

I am quite disturbed by what appears to be a drop in the relative number of women entering CS as undergraduates. My hunch (several people I've spoken with including one person involved in pre-college education) is that there's a problem with the ways in which computing is taught in the high schools.

A male university researcher wrote:

I've just read a copy of your letter, and have several thoughts. As a co-author of a popular intro-programming text that is frequently used for high-school AP courses, one of my concerns has been the problem of simply getting women started into the discipline. We see the inequities starting at the junior-high level and even earlier. It's not unusual to see a CAI class where the boys keep jumping in and taking over from the girls. This may simply be related to the fact that girls seem to develop social skills earlier than boys, and are not as likely to be rude. Whatever the cause, however, the problem must be addressed much earlier than college. I would suggest a program to add incentives to young women, and their teachers, to enter computer science. Perhaps this could be an extension of the AP exams, or something like the Math Olympiad, but specifically for women (and possibly minorities), with national recognition of both the student and her teacher through articles in both *computer society magazines and teaching magazines. In addition, universities should set up scholarships specifically for women (and minorities) who achieve high scores in the exams, with some adjustment for financial need. Some of the scholarships might have to be funded by state or federal sources, while private schools could probably afford them without outside assistance. Perhaps equipment manufacturers could contribute to the student's schools, although that is likely to lead to fraud if the prizes are valuable. The idea, however, would be to create a structure similar to the National Merit Scholarships, but for women in computer science.*

If we could get an extra 2000 women seriously interested in computer science prior to entering college, especially through a program that is tied to professional organizations and academics, it would be much easier to increase the number who go on to graduate school. I think that many of your proposals for what to do once women are in college are very good. There is indeed a lack of mentoring, and encouragement for women to seek advanced degrees. But, we can't hope to right the inequities at that level until the number of female undergraduates approaches that of males. Whatever program is eventually developed, it has to address the problems at all levels of education, and not just in the classroom.

For example, intro textbooks are frequently sexist. Sometimes blatantly (referring to programmers with male pronouns), but often more subtly (using male-oriented examples, male names in data sets, etc.). Just the fact that most are written by males sends a negative message to women. My experience with my textbook has really opened my eyes to the pervasiveness of sexism in our discipline. I hope that your committee's work will help to open the eyes of others to these problems.

A female from industry was also concerned about the sexism in textbooks:

Work on publishers of math/science books to eliminate sexism. There are still books called things like "A Boy's First Book of Electricity Experiments."

Rid textbooks and other work materials of things that boys are more familiar with than girls. In school it annoyed me that descriptions of distance were given in terms of "football fields" and weight in terms of "golf balls."

And another woman working in industry commented:

Most of the action items seem to me to be symptomatic cures for problems that are often quite deep-seated. As a parent of a four-year old girl who abhors any book on science or math (the same books that my seven-year old son read when he was four), I am very distressed by this culture that indoctrinates its women starting at the pre-school level.

I would like to see in your list of action items not only some steps to re-train pre-school and primary school teachers, but also efforts to rewrite text books (the kind that show girls dressed in pink and boys dressed in blue) in a non-sexist manner, as well as a non-sexist curriculum for primary and middle schools. Because by the time women students reach the graduate level (and that's where almost all your action items are directed) the indoctrination has long been cast in concrete....

A female graduate student commented:

I would love to see a program involving teachers. Since studies have shown that teachers are (consciously or otherwise) much more likely to encourage boys, I have wished that a program could be developed to demonstrate these problems to teachers, so they have a *chance to develop greater awareness of this issue. For example, some studies actually video-taped classes, and apparently this behavior was quite visible on the tape. This same tape could potentially be used as a tool to demonstrate the problem.*

I also have thought about developing films, or videos, addressing specific problems that could be shown in classrooms — not necessarily to girls only. For example, I recently read that a woman astronaut had, even has? math anxiety. Obviously, this didn't stop her! I thought how wonderful it would have been for me to hear about such things when I was going through my problems with math anxiety. Then I dreamt of having a national library of tapes like this that could be shown to children.

A male faculty member also expressed concern about teachers:

I believe that the really critical population to be attended to right now are our high school teachers — even more so than the high school students. I am not even sure that we need to go back much further than high school (9th grade) to begin to make a dent in the problem you discussed in your paper.

But with all of the special programs that we may establish, it would seem to me that it is the math and science teachers that our students have in the classroom, especially the women (if we are going to attract more women) that have the greatest potential to address the issues you presented. [...] I think the primary point of attack should be the high schools — with at LEAST as much attention given to the teachers as the students.

Although there was agreement that pipeline programs are important, there was not agreement on which parts of the pipeline were most important. One woman in industry wrote:

I noticed though that you only target women who are already in science and engineering graduate programs. In my opinion those have already crossed the main barrier. If we want to see the number of women increase in those areas I believe we should start at an earlier stage, namely high school and early college years. This is when young girls are drifted away from hard sciences due to social pressures. If we can give them enough support then to counteract the pressure from their peers and families (sometimes), I believe this is the most important role and they will be able to take care of themselves from there on (with maybe less support later). From my experience as an undergrad/grad student in engineering/ computer science the hard decisions are made in the undergrad years, the support from my family was the main thing that made all other social pressures completely frivolous (all women in my family have university degrees). I like the idea of women speaker series, I believe they would be more effective if given to high schoolers and undergrads.

The importance of the earlier years was stressed by a female researcher:

I believe that most attitudes (intellectual inquisitiveness, self-worth, etc.) are pretty well developed by the age of 5 or so, and the unfortunate discouragement that girls receive in schools only exacerbates beliefs and attitudes developed in the home, in child care, and in pre-schools or kindergartens. All those programs addressed at female grad students assume that you have the female students in the first place. If we REALLY want to make a difference we have to get them early. We have to change the attitudes of the children and those who influence them at such a tender age. This means that we have to get into the home. We have to reach the parents & teachers of these children, and the children themselves. It seems to me that this means that efforts must go into reaching NON-technical, NON-scientific people. [...] Perhaps putting some emphasis on programs to reach the future elementary- and pre-

> *school teachers would be more helpful. Support for girls in sciences in the lower grades (whenever they start to teach sciences) might help. Even paper dolls that have females dressed as doctors, civil engineers and airline pilots would help. Saturday morning cartoons, kids' learning-to-read books, anything that gets the message across early- is it possible for the feds to support such things?*

Single University or Department Programs

Besides these extramural programs, there are many possible activities on a smaller scale that can be undertaken by single universities and departments and by a few individuals. One example of such a university program has been started recently at Douglass College, one of the Rutger's University colleges and the largest women's college in the United States. This program is attempting to encourage women students to enter fields of mathematics and science that have been traditionally male-dominated. There are several special programs in the Douglass Project for Rutger's Women in Mathematics and Science including:

- A residence hall for women mathematics and science students at both the undergraduate and graduate level.
- A residential summer institute for girls in their junior year of high school.
- Career workshops.
- Information on research and internship opportunities.
- Study groups.

It is interesting that the majority of women mathematicians and scientists in the past have come from women's colleges. As noted earlier, Mills College has been very active in providing such programs. But smaller scale efforts can be established at any university.

Women Speakers Series.

This has been very successful in other fields such as physics and biology and relatively low-cost. It not only provides role models for women students, but it focuses both male and female attention on successful women. Female graduate students have especially enjoyed the opportunity to interact with the speaker informally after the talk (e.g., at dinner). Female professors who have organized such activities in fields other than CS have personally reported to me tremendous enthusiasm for these activities by the female graduate students.

Several people commented on this proposal. From a male faculty member:

> *YES!! This would be a great idea. We have an active speaker program, but we probably have only had 4 women speak in as many years. NSF funding of women speakers would be an excellent idea. Where can we sign up?*

And from a female graduate student:

I am especially enthusiastic about [...] women speakers.

Another male faculty member noted:

I saw your article about ways to encourage more women in computing. I liked the ideas — particularly about having a Women's Speaker Series. I doubt that anyone here has the energy to organize another series of talks, but we are always looking for more speakers for the research colloquium and for the IEEE student chapter. If you ever do get a list of women speakers (particularly speakers from the [...] area), we would be delighted to invite some to come here.

Finally, a female professor commented:

I personally had planned to organize a role models' speaker series here at the University of [...], coupled with a panel at the end of the series that covered very pragmatic topics, such as how to interview well, how to apply for grants, how to get tenure, how to pick a mentor, what qualities are important in a mentor and so forth. Money to fly in the role models would obviously be crucial to such a program.

Mentoring Activities

With the current small number of women in faculty positions, mentoring and providing role models assumes great importance. Lack of role models is an important aspect of the reason why women do not enter certain fields. There is, of course, a lot of informal mentoring that is always going on. A female professor reports:

Within our department, there are more roadblocks for female graduate students than there should be. (i.e. there are several key male faculty members who are not very enlightened, even though some of them would like to believe they are.) Again, I haven't had time to really work on the problem. I've provided some informal mentoring to a few of the grad students; since it doesn't solve the problems, it isn't generally very effective.

Another female university researcher noted:

Unfortunately, I don't feel that a great deal is done for women explicitly (or for that matter for anyone else either), in terms of being supportive through difficult times. There is no real mentoring. There is no effort to recognize that different groups of people (women or other minorities) might approach CS research differently from white males. [...]

I would like there to have been more mentoring or advising by women of women, but that was not available. I believe that a regular meeting of women, led by a faculty member who had an interest in cultivating and currying the women students would have made a huge difference to me.

The importance of mentoring and role models cannot be stressed too much. One female student, a senior at MIT who is planning to go on for a Ph.D., wrote about her experience in a summer job working for a female manager who she described as:

one of the most respected people in the company. I had never expected that having a female role model would change the way I felt about myself, but it did.

Mentoring can involve providing help for students or for beginning faculty members. With respect to providing mentoring for faculty, some universities formally or informally provide mentors for junior faculty women. One female faculty member suggested having meetings for junior faculty women on arrival (and perhaps throughout) that explicitly address how to "play the game" (e.g., get papers published, research funded, colleagues to listen). Some universities have formal assignments of mentors to junior faculty. Programs can also be established to provide mentoring for undergraduate and graduate students. A female professor suggested that ways be provided

> *for women science students to interact closely with the people who have gone before; e.g., provide a 'database' of students who have taken certain courses (especially the ones that tend to be discouraging) who are willing to talk about how they managed.*

This might be broadened to providing mentors to new students from the pool of experienced and successful students and faculty members. Both student and faculty mentors for new women students are useful; they can provide different types of information and support. One female graduate student suggested:

> *In the military, when you are reassigned to a new base, you are "assigned" to another military member who is your sponsor for the first several months until you get acclimated to the new base, surrounding area, etc. I think the graduate students should have a similar program. Not so much to handle the housing transition, but to provide the "who to ask what questions" information. It would be nice to be in close contact with someone who has already successfully completed some of the tasks you are facing with great apprehension. I think this might also provide an opportunity for males who are willing to participate to develop an appreciation for different but acceptable needs that women graduate students (and future colleagues) are facing.*

A woman from industry commented:

> *I think all the proposals are good ideas. Although I do think we need to increase the pool or pipeline of women coming from high schools, I think we could do a lot to increase the numbers of women and minorities who decide to stay in technical fields after say the freshman year and who decide to stay for MS's and PhD's. I think the mentoring and networking proposals are particularly important. It is so common for us "affected group" members to feel like maybe we AREN'T really good enough. I think we forget our own roles as mentors and don't get enough positive reinforcement by potential mentors.*

Given that the latest Taulbee survey shows a very small number of women in CS faculty positions at research universities and one third of the universities without a single female CS faculty member, the problem of how to provide enough mentors becomes important. A female faculty member comments:

> *One problem I've found [...] is that the most precious resource in addressing this problem is the few women in the field. Hence I think it is essential that our male colleagues join in helping to solve this problem. How to enlist their aid is not so clear (aside from the few who already are willing).*

I believe that there are many men who would be interested in helping provide support and opportunities for women and minorities if we, in turn, provide them with ideas and information about how to do this. Some evidence of this assertion is the support expressed by male faculty members who responded to my request for comments and ideas. One man wrote:

Our current faculty ratio seems about typical (1 computer science and 2 computer engineering women out of a total of about 24). Our student ratios also seem to agree with what you report (about 30% female undergrad, falling off rapidly in the MS and PhD programs, with more women in CIS than CE).

If you think of anything we can do to improve the situation here, let us know. (We're almost all assistant professors, which means that we don't have the time for really labor-intensive activities, but we'd all like the ratios to improve.)

A female graduate student responded:

About the mentor and tutor programs: I would like to see significant participation on the part of men as mentors and tutors. My experience in [... area of computer science], which is tremendously male-dominated, is that the men have not explicitly thought about sexism in science and what to do about it, but when it is brought to their attention, they do not have any inherent objection to being involved in the fixing. They do have a hard time imagining a way to fit themselves in; and they take no initiative in finding a way. So I think the NSF should outline to them in a simple way the nature of the problem and exactly what they can do to help.

One female industrial researcher noted some of the problems female students and male faculty members sometimes have in finding appropriate ways of interacting:

Sexist attitudes, where they are pervasive, are as elusive as the air we breath and very hard to change. Perhaps the NSF could fund studies on group dynamics that could be applied to teaching faculty non-sexist methods of mentoring, and ways of intervening in group behavior where sexism is expressed by others. Sometimes just intellectual bullying can turn women off, even when practiced uniformly toward men and women. Changing the social atmosphere is very important and can have very large effects. Sometimes it only takes one person to speak up or to challenge someone else's bullyism (sexism) in order to change things in a big way. Also, NSF could fund ethical workshops and/or seminars on what constitutes sexual harassment. The distinction between harassment and desire for personal involvements are sometimes difficult to track. It's not surprising that men are sometimes confused. Sometimes WE are too.

Another important way to provide more mentors is to take advantage of female researchers who are not at universities. One woman from industry reports:

As head of recruiting for the SUNY-Binghamton alumni association in the DC area, I have set up a tutoring/mentoring program with local high schools. Alums from SUNY-B are working with students to help them in whatever the school perceives as the greatest need: tutoring, helping them decide whether to go to college or what college to choose, helping prepare for the SATs, for example. The high schools we have targeted are those with large percentages of minorities.

Another female industrial researcher reported:

Recently a group of women post-PhDs have held a meeting for all the women PhD students at [...] in CS. [...]

Anyway, the idea was to give "advice" — how to get through the PhD program, words of wisdom, etc. The goal: to encourage women to stick it through and finish the PhD. The motivation came from reading that report about women in the sciences and how a major attrition point was between the MS and PhD levels.

I think we plan on holding this as a yearly event. It was very successful too. We had about 10 students and 6 post-PhDs. It was informal but organized. Lots of heart to heart....

One male faculty member noted the importance of providing mentors to faculty in high schools and in universities with less well-developed research programs.

We need to find a way not just to accomodate students, but to give faculty (principally high school faculty) a chance at having a mentor perhaps every five years or so.

I am aware of several informal and formal mentoring relationships between faculty at small, primarily women's colleges and nearby research universities that appear to be very successful.

Another way to solve the problem of a shortage of mentors is to plan group activities where one or several women and men can provide support to many students. Regional activities and meetings were discussed above. Similar types of activities could be held at a single university. We hold monthly luncheons at UCI for female CS graduate students where visitors and the local female faculty members discuss topics such as how to be successful in graduate school, recruiting, how to get tenure, tips on writing research papers, tips on giving conference presentations, grantsmanship, etc. There are some strictly women's issues discussed, but more emphasis is placed on the general information needed to be successful in a research career.

A female professor described some activities at her university:

- A couple of times a semester the technical women in the School of Computer Science at [...] get together in the evening. Sometimes we order in, sometimes it's pot luck. Usually there's no formal agenda but some professional topic becomes the center of conversation. Even more informally, some of the women at [...] get together for lunch every couple of months. This sounds like a pretty small deal — but it seems to generate a lot of good feeling.

- Reading groups. [...] also has a reading group on gender issues. It meets roughly monthly and the participation cuts across science and engineering.

- [...] has an associate provost who holds meetings of students with the ability to go to graduate school; in many cases it hasn't occurred to them that this is an option. This clearly benefits women. She also held a get-acquainted meeting this fall in conjunction with the Society of Women Engineers.

Another female faculty member described an interesting way to provide a graphic point about the possibility of combining career and family:

We have a group called Society for Women Engineers at [... University]. These are mostly undergraduates. Each year they hold an orientation meeting for accepted incoming students to encourage them to attend [...]. I usually speak at this meeting. I find that this meeting introduces them to women in the school (and faculty) before they arrive and thus, when they arrive they already have some link to other women for help. For example, I always take this opportunity to let them know they can come talk to me once they are here and I find that many students do remember this meeting and do come talk to me. I *sometimes bring my children to this meeting so that students can see that they can be engineers and humans too. They always remember this when they talk to me later. This meeting primarily discusses what it is like to be a woman in the engineering field.*

Prof. Lori Clarke, at the University of Massachusetts, Amherst, recently set up a panel during their "Civility Week." These are her observations about that forum:

Immediately after I announced that I would be holding a forum on "Why Mostly White Males Go Into Computer Science" my e-mail was humming. MANY students sent me mail with their thoughts on the subject and one of our minority students agreed to speak on minority concerns. I was told by several graduate students that the announcement alone increased awareness and started people talking about the problems.

The actual forum was packed and discussion went for over two hours. Faculty and students came from Smith and Amherst College as well. I started by presenting statistics, describing the national situation and comparing it to what is happening in mathematics and business. This provoked a lot of discussion about why the statistics were the way they are. I also gave the statistics about our department, which although better than the national statistics, are still not great. I then discussed some of my observations and some of the problems that had been reported to me.

The minority student spoke about his observations. He pointed out that computer science is not a hospitable field for someone who is poor and must work, and perhaps maintain a minimum number of credits to be eligible for financial support. Our courses are very demanding time-wise and there is no lab credit given for the long hours that must be spent at a machine. This is in contrast to engineering or the sciences, which give lab credit, or business, which does not require laboratory time. He also noted that poor students can not buy pc's and thus must often wait to get terminal/workstation access, which can be difficult to arrange around a work schedule.

Another problem that he pointed out was that black organizations on campuses did not encourage students to pursue a career in science. Many felt that business was the best route for providing a strong economic base for the black community in the future. Another problem is that minority students more frequently come from urban areas with poor high schools and thus are not prepared to pursue a career in mathematics or science.

Our discussion about possible improvements included the following:

-faculty should be aware of the strong cultural bias against women and minorities pursuing a career in science. To counteract this bias they should:

> *Be sure to take the time to encourage women and minorities who are doing well in their classes,*
>
> *Avoid using male pronouns for all figures of authority or intelligence,*
>
> *Realize that aggressively challenging a student may have a negative effect if they lack self confidence,*
>
> *Choose scenarios that will be relevant to minorities and women. Although much of computer science funding comes from the DOD, many find military oriented scenarios*

> *(e.g., mobile robots) offensive or uninspiring and would prefer scenarios that indicate more humanitarian applications(e.g., assistance to the handicapped),*

-To encourage women and minorities to enter or remain in the field:

> *our female graduate students have formed a support group to meet with and mentor undergraduate women in computer science,*
>
> *the female faculty have set up a few informal meetings with the female undergraduates and graduate students to discuss issues and provide support and guidance. Our first meeting with undergraduate women is next week to discuss career options in computer science,*
>
> *a group, of mostly graduate students, is looking into a summer mentor program to help attract minority students to the department.*

There have also been some other suggestions, such as requesting industrial support for fellowships for minorities and women and meeting with the minority organizations on campus, that are still being pursued. We also need to look at restructuring our laboratory courses so our courses can be more accessible to the poor.

The enthusiasm and participation in this forum demonstrates that there is a wellspring of concern and interest in these problems that can and should be tapped.

Another activity I heard about recently was an informal class on writing papers for publication given by a female professor for women graduate students. At the end of the class, several of the papers were good enough to be published. Other women have held seminars and classes on Women in Science that usually span all the sciences. One female faculty member started a ‘‘Women in Science and Technology Program’’ in which female faculty in the sciences went to visit dormitories after dinner and discussed things like how to get into summer research and how to orchestrate a graduate career. One person reported about a science mentoring group at a university that meets weekly and includes local industrial researchers.

There are obviously a large number of activities that one could come up with of this type. Funding support in the form of release time from other activities will most likely be required. Most women (and men) are already so overloaded with administrative, teaching, and research activities that taking on an additional load is impossible. By allowing mentoring activities to replace other types of administrative and teaching activities, more men and women would be able to participate.

Research Opportunities for Students

One of the most important ways to get women interested in pursuing research careers is to provide opportunities for them to work on real research projects. A female professor recalled:

Working on a research project is one of the things that convinced me, as an undergraduate, that I wanted to be involved in computing research.

Another female faculty member remarked:

From my observations of women students I'd say getting them actively involved in all aspects of research (participating in research seminars, giving talks locally and then at conferences, working on projects) and teaching (being TFs) earlier (as undergraduates, no later than their junior years) is very important.

One way to provide such opportunities is by funding summer research jobs for students — starting with high school students. A female graduate student suggests:

I would like to see a massive summer research program set up for women at all levels. Stipends should be provided to the participants.

One university provides special incentives for female students to write research papers. A student reported on this:

I would like to see the NSF provide funds to be used as prize money for competitions. We had a competition here recently in which women from engineering, math and physical and natural sciences gave 20 minute talks about their original research. It was great.

A female professor described the same program:

There is a group on campus that sponsors a "colloquium" for female graduate students in the sciences, approximately once per year, at which the students present their research, and 1-2 awards are given for the best talks.

Just as the current NSF Research Opportunities for Undergraduates Program encourages the participation of undergrads in research by adding extra money onto grants for them, extra money might be added to grants for hiring female RAs. A male faculty member commented on the current program:

I am pushing this program with several undergraduates right now. It seems to be an excellent idea, and a great motivator. One wrinkle that I am trying is to try to get the undergraduates to write most of the justification (with LOTS of support), so that when the add-on comes in, they feel like they did it. This sense of accomplishment is a tremendous encouragement.

Some universities have mentoring programs where female and minority graduate students write a research proposal with a faculty member (male or female). If selected for funding, the student receives RA support for a year and the faculty member may get a small amount for expenses. A female graduate student who participated in one of these programs had some illuminating comments about it:

I have some ideas about this, having participated in it first hand. It is far from perfect. While money (support) is important to female graduate students (indeed to all graduate students), the goals of the mentor program can't be met by merely providing monetary support. Once the award has been made, what IS the incentive to the mentor to do anything beyond what he/she was going to do anyway? A survey was conducted near the end of the award period to check on progress; its contents might have encouraged some action, but March was much to late to give suggestions that could have made a difference. I think sometimes *mentors don't realize special needs/weaknesses that female graduate students may have. Or they focus on allowances for family needs and aren't aware of the need to break the social barrier put up by the good ol' boy club. (Male graduate students, by the way, are the worst offenders in the good ol' boy club. Do they get this from role models, or are they selected by some process that also selects this trait?)*

What might help?

- *I would have liked to have had a series of small group sessions with women who had successfully completed PhD programs in science. In groups of 5-7 they could have helped me know what to do to "demand" the mentoring I needed. This would have also provided the success stories and role models I needed at that point. As an award recipient, I would have been willing to commit to participate after successful program completion. This could have been part of the terms of the award.*
- *The graduate school made the awards, and they were very good about seeing that I got my money and fee waivers on time. Beyond that, however, I felt ignored for the year. I had some expectation of interest in my progress at the beginning, but soon found out that there was no one really following that or caring how things were going.*
- *Similar small group sessions for the mentors who have agreed to participate in the program would have helped. As most of the mentors involved were men and certainly were not accustomed to female graduate students, I think they would have welcomed some guidance beyond the original "write a three page proposal" handout they were given.*

One final way to get women involved in research activities is to hire them to work on research projects as programmers or other non-research personnel. At UCI, the software engineering faculty have hired several graduating senior women who had excellent grades but who did not want to go to graduate school — instead they wanted to go out and get jobs. Each of these women went on to Ph.D. programs at top universities after 2-3 years of programming for our research projects. This leads naturally to the next topic — reentry programs for women.

Reentry Programs

Several women noted the importance of encouraging women to return to school. As one female faculty member wrote:

> *One thing I would like to see is more encouragement for girls who have "dropped out" of math and/or science at some point during junior high or high school to return. There is all this discussion of girls dropping out early that unfortunately implies that they can never return, and are lost to math, science and engineering forever. This is extremely counterproductive.*

A few college programs have targeted re-entering women. For example, one female industrial researcher describes such a program at Mills College:

> *There also used to be a Master's degree program at Mills College which was a cross-disciplinary program in computer science and another topic of the student's choosing. There were a lot of reentry women in that program, as well as some men. (The undergraduate program at Mills is all female, and there are quite a number of older women students). I*

don't know what the current status of the Master's degree program is.

The best known program of this type is at the University of California, Berkeley where the Computer Science Division runs a program to prepare women and underrepresented minorities for graduate study in computer science. The program was established in 1983, and its first students were enrolled in Spring 1984. The program mission is to increase the pool of competitive women and minority candidates for university professorial and research positions by enabling them to take undergraduate technical and math courses required for graduate work in computer science. Additionally, the program provides faculty advising, access to other Berkeley faculty and graduate students, and support services such as tutoring, study groups, discussion groups, technical and career-oriented seminars, strategies for applying for graduate programs and scholarships, and facilitation of discussion and exploration of topics related to the reentry experience. Financial support of the program comes from the university and from the industrial community.

The program has been small but quite successful, with graduates at many major universities including MIT, Stanford, CMU, Illinois, Berkeley, Texas, Wisconsin, UCLA, Michigan, NYU, Brown, Dartmouth, Rutgers, and the University of Washington. Of the 36 students who have completed the Reentry Program and applied to graduate school, 30 have been admitted with a total of 91 admission offers received. Of the 27 who entered graduate programs, ten have completed masters degrees: three at Berkeley, one at MIT, one from the University of Massachusetts, three from Stanford, one from Santa Barbara, and one from the Oregon Graduate Center. Several students have advanced to candidacy in Ph.D. programs.

Several women wrote to me to tell me of this program. An industrial researcher described it as follows:

> *The students in the program take the regular Berkeley c.s. courses, and compete with the standard students there. One of the advantages of the program is that it allows students with non-standard backgrounds or with a degree in another subject an opportunity to do coursework at a major university. There is also a supportive environment to which the students themselves, female grad students, and some interested faculty especially contribute. And, finally, there has been in the past (and I assume the same is true today) some financial support.*

Another female professor, who was a student at Berkeley, also described her impression of the program:

> *The women were bright, had often worked in industry for several years, and had academic training in a field other then CS. And often a less employable field, like a BS in Math. They took 5 quarters of basic computer science, electrical engineering or math, whatever was needed. I.e., each person's curriculum was based on where her academic holes were. Most students worked half time on the outside (no support was available), which made the program quite rigorous. I believe that most of the money was raised from industry, with the university contributing some — but you should check that.*
>
> *[...] I also have first hand knowledge of the success of the reentry program at Berkeley. (I am a recent graduate of Berkeley, not the reentry program, but the graduate program). It has provided several topnotch graduate students here at [...] University. And it addresses a*

segment of the population that would otherwise be locked out of a scientific career — women in a related but deadend or unemployable field who are years beyond college. I would strongly suggest starting similar programs at other universities, particularly ones in the vicinity of large scientific or engineering employeers. The program at Berkeley could use more RA-type funding. Typically the reentry students must work halftime outside of school to support themselves; that time could be put to better use taking classes.

When non-traditional programs of this sort are tried, it is important that the system be flexible enough to accomodate the unusual educational patterns. For example, some students who have gone through the Berkeley reentry program have had subsequent problems in getting NSF fellowships. A female professor writes:

NSF will allow up to n (n=?20 semester hours, 30? quarter hours) of courses past the baccalaureate degree for students applying for the fellowship. Although the reentry program students are taking undergraduate courses (data structures, intro programming, etc.), they are not registered for a degree; thus if they take too many courses they are overqualified for the NSF fellowships. This can happen at the same time that they have not yet taken quite enough to be strong candidates for graduate school. It is a catch-22 situation. Berkeley will not allow them to be registered for an undergraduate degree (which would get them off the hook, since NSF does not count courses taken towards an undergraduate degree, even if the degree is not attained). This is because then they would have to compete against the normal Berkeley applicant pool, and they are not strong enough. NSF is unwilling (unable?) to grant special dispensation for the reentry program. Although the particular catch-22 I am describing catches very few people, if there are to be more reentry programs like this (what is Berkeley's success rate?), it should be fixed.

Funding for Female Students and Faculty

Although funding may be extramural or within the university, I am separating this topic because of its importance and scope. All reports have shown that women are less likely to get support as graduate students. Funding is also important at the undergraduate level.

Designing funding programs can be tricky. Sheila Widnall, in her AAAS presidential lecture, warns that providing scholarships to female graduate students may actually be harmful because it is likely to keep women out of RA-ships that get them involved in research with a faculty member. On the other hand, two female graduate students and a female industrial researcher sent a joint response to this assertion:

At this point in time, funding for graduate students is very tight. A number of graduate students go through graduate school on fellowships all the way through because of the lack of funding. The fellowship students must still do research in order to write a dissertation; having a fellowship does not change this. In addition, having a fellowship allows the student the luxury of picking the professor with whom she most wants to work, regardless of the professor's funding situation. Thus, we recommend that a fellowship program for women should be established.

To add to this, I would suspect that a woman who is at all insecure would find it very difficult to approach a professor and ask for funding. Having a fellowship would allow her to at least avoid this obstacle.

A female industrial researcher notes:

> *I think funding is important, but should be tied to research. I know that [... University] makes some grants that require the recipient to find a research advisor to get the money. So the faculty gets a "free" RA and the student is not so isolated as with Fellowships.*

A second problem in designing funding programs is to avoid setting up programs that are easily stigmatized ("she got it only because she is a woman"), although we should not let this concern paralyze us either. One female graduate student responded to these concerns:

> *I think we do need to be careful not to encourage the separate but equal route followed unsuccessfully by the civil rights movement.*

One way to avoid the impression of second-class awards is to stress the competitiveness and importance of the award as NSF has successfully done for the Visiting Professorships for Women program. This program includes special letters to the Chancellor of the recipient's university from Erich Bloch along with press releases. An NSF employee wrote:

> *The strength of the VPW program (as you note) has been in its not being viewed as a "second-class" program. You're absolutely correct in the concerns regarding stigmatization; there have always been concerns within NSF (and in the larger community as well) regarding "losers" programs. On the other hand, I find your targetted suggestions for undergrads, RAs and others eminently sensible.*

Funding programs can be divided into those for students, post docs, beginning faculty, and more senior faculty. One female professor had a suggestion for funding that could apply at all levels:

> *I thought of one thing to suggest to NSF in terms of special programs for women — equipment. In particular in many places it is a real problem to do work at night for security reasons, but it is a necessity for professional reasons. How about suggesting relatively small grants so women can buy a terminal, workstation, printer so it is possible to work at home when it is not possible to go into school? Also, many women have family obligations that prohibit working at school at night, even if security is not a real factor.*

Student Funding

Student funding programs can be implemented by individual universities or by government agencies such as NSF. Some of these types of programs were described in the section on research opportunities for students and include summer research programs, research mentoring programs for undergraduates and graduates, and various types of special funding programs. A female professor wrote:

> *Another thing I'd like to see is more financial support for undergraduate women majoring in math, science and engineering. Many schools have very high work-study and summer-job savings requirements as part of their financial aid packages, but I think it is much harder for women than for men to find suitable jobs to make the required income. And minorities are often unlikely to enjoy the assumed financial contribution from home, since even poverty-level parents are expected to pay a large percentage of their income.*

For graduate students, regular fellowship programs can be implemented. A female professor reported:

> *Apparently a couple of years ago an NSF advisory panel recommended that both CS and engineering institute a special NSF graduate fellowships for women (because of the strikingly low numbers of women in those fields compared with other sciences). The NSF director agreed to the one in engineering, perhaps in part because the directorate in engineering came up with 50% of the funds. (The rest of the funds come from the education part of NSF, which is supposed to double the number of NSF graduate fellowships over the next five years. Diverting some of the money to special programs for women etc. diverts it from the others, obviously.) I just spoke with [...] at NSF. [...] He said that the idea of special graduate fellowships for women in CS is not dead, but neither is it anticipated that it will be funded soon.*

Other types of funding programs mentioned earlier for students are (1) programs that add to existing research grants to include female RAs as is now done for undergraduates and (2) programs to provide funding for special research mentoring. Another potentially worthwhile program is to provide travel funds for female graduate students to attend conferences and workshops. An NSF employee commented:

> *There have been arguments for providing small travel-only supplements for PhD researchers who couldn't quite make it in the research grant competitions, but it seems that there is a crystal-clear need for such awards to women graduate students in areas of science and engineering in which women are historically underrepresented.*

Several female faculty members stressed the importance of this type of travel in providing incentive to continue their studies and in establishing networking activities that helped them throughout their careers. I have found this type of experience especially stimulating for my students: they get a chance to meet other researchers and students, they see that everyone is pretty human and that the papers are not any better than they could write, they establish contacts for the future, and they usually come back eager to write a paper for the next such meeting. Two female graduate students wrote:

> *Just about our favorite proposal you had was having travel funds for women graduate students to go to conferences. Do this if at all possible!!! It is extremely important to meet the field for both getting jobs and for getting research funds if one decides to enter academia.*
>
> *From my own experience, my advisor has been wonderful about sending me to lots of conferences and meetings. As a result, I have a number of people to contact when I start looking for an academic position this fall and when I start looking for funding. Finally, I usually return from each conference with either a new idea for research or a way to improve my existing talk or research.*

Post Docs

Post docs have not been very common or needed in CS. For the most part, faculty jobs have been so plentiful that new Ph.D.s did not want or need to take such positions. But the situation may now be changing. One university researcher wrote:

> *It is clear that the academic market for CS graduates will continue to get tighter and it seems likely that CS will move towards the model used by most scientific fields where new Ph.D.'s do a postdoc before accepting a tenure track job. This transition won't be smooth and if we aren't going to lose all the new women Ph.D.'s in CS to industry (where they won't*

be quite as useful as role models) we need to establish more postdoctoral programs and professorships for women.

A few programs exist such as the University of California President's Fellowship Program, which provides postdoctoral fellowships to minorities and women for use at any of the University of California campuses, and the American Association of University Women which provides eight postdoctoral fellowships for women in all areas. Although some of the latter fellowships are earmarked for minorities or women in particular areas (i.e., not CS), four are open to women in any area.

If the current trends in employment continue, new postdoctoral programs for women in CS will be needed. One female professor commented:

Post-docs for women at top Universities would be an excellent way to help new Ph.D.'s get into the mainstream. These post-docs could be given as an add-on to an existing grant — PI's who are interested could submit descriptions of their research, which could be distributed and then women could contact the PI. Then the PI and the candidate could submit a joint proposal. This would motivate PI's by giving them an extra person for their group, and effectively a bigger grant. And the woman would get exposure to a first class research department.

Another female professor described an unusual use of a postdoctoral opportunity:

A year ago I received an NSF Postdoc in Math. (I do theory.) It was an odd time to do it (five years out), but good for me, because I have young children. It's two years of full-time support, or four years of half-time, generally supplemented by half-time teaching, or any combination thereof. As one of my senior colleagues commented, the teaching will always be there. The theorems might not be. I'm not sure exactly what I am suggesting here, but juggling kids, beginning a research program, tenure is crazy. Despite whatever sharing goes on, women are still the ones that get pregnant. Some early career fellowships might be nice. How to construct them so that they don't backfire is not so clear.

Junior Faculty

The current NSF Research Opportunities for Women program funds women who have not previously had NSF research support. There are rumors that this program may be phased out. One female graduate student commented on this:

Do not phase out the Research Opportunities for Women program. Getting NSF and NIH grants is very difficult. This could make a difference in keeping women in academia. Getting one of these grants certainly does not preclude getting grants from other sources, but instead ensures that you have some money to work with.

Two female graduate students also commented:

A final suggestion we would like to add would be to start a grant program specifically for new women professors. Not everyone can get a PYI. Getting research funds is one of the keys to being a successful professor. Knowing that there are some funds set aside to get started with might make the difference for a young woman deciding to go into academia or not. If we are trying to increase the number of women professors, attention should be paid to new Ph.D.'s.

> *From my point of view, if I knew that there were some funds set aside for new women professors, that would make ALL the difference in my job decision. I would definitely accept an academic position if one were offered. With the current situation, though, industry is appearing a lot more attractive than it used to.*

A female professor had an idea for augmenting the effectiveness of startup research funds:

> *[It is] best if these could be augmented by mentors who would help with finding appropriate funding sources, including contacts, and initial proposals.*

Another way to help junior faculty is to provide them with release time from obligations other than research. UCI has a program called Career Development Awards. These awards are based on a submitted proposal. If selected, the recipient is given time ranging from a quarter to a year to devote solely to research activities. The program is open to all junior faculty members, but females and minorities are given high priority in the selection process. This type of program can be implemented at a relatively low cost by a university.

A female professor wrote:

> *The most valuable time for career building to new Ph.D.s is the years which immediately follow the receipt of the degree. That is the time for building upon one's dissertation research, expanding research interests, networking to establish valuable contacts with colleagues, etc. Yet for most women, those are also the years when one has the best opportunity — and sometimes the only opportunity — to have children.... I suggest the type of awards that are often targeted toward new Ph.D.s, such as those that are only available within a certain time frame (e.g., five years) after receipt of degree, are often of little use to women, whose careers do not always follow the same track as those of their male counterparts.*

Often women find themselves in non-tenure track research positions and face an additional stumbling block. A female university researcher reported:

> *As in other fields, many female computer scientists (including myself) find themselves in non-faculty positions within the university and, therefore, ineligible for many NSF programs. In some cases, NSF could fix this problem simply by changing its eligibility criteria. In others, it is a restriction made by the university — for example, [...] does not allow research associates to act as Principal Investigator on proposals to NSF or other agencies.*

But before women can apply for most grants, they need to get into faculty and research positions. A female professor commented on the importance of getting women into faculty positions:

> *I think the best thing that can be done to increase the number of women who are making significant contributions to science is to encourage the best universities in the country to hire new female PhDs as tenure-track faculty. In these universities it is EXPECTED that faculty will produce papers, write grant proposals, attend and give presentations at top conferences, supervise PhD thesis students and so forth. When I graduated with a PhD in*

> *mathematics in 1971, it was not possible for any woman in science to obtain a position in such a university. I have been fortunate to be in a university which has changed and improved, so that although the math department of [...] in 1971 could not be so characterized, the computer science college in 1989 can be so characterized. It is very important to get in an atmosphere where research is PUSHED. If it is just "allowed" it will be too difficult to do well.*

A more recent graduate wrote:

> *I graduated [in CS] with a Ph.D. last year and this is the first time in my career that I've felt that I needed help from a "women's program." Right now I wish that there were more programs to help women get started on an academic career. I've been having trouble finding an academic job, at least in finding the perfect job. Much of my problem is a reflection of the increasing tightness in the CS academic market. Another part of it is the peculiarity of my area.*

This is not an easy problem to fix, but one thing that might help would be to establish chairs for female professors. I know of such a chair for women at MIT and also a new one, funded by the Clare Boothe Luce Foundation, at Georgetown University. There are probably others. Alumni associations, private companies and charitable foundations might be willing to provide the funding for such positions. Rotating chairs might be used to get junior women into faculty positions and also to advance women to the upper ranks.

Advancing to the Upper Ranks

A previous section of this report presented the argument that emphasis should be put on the early years to encourage entry into scientific careers. There was also a great deal of support in my informal survey for placing the primary emphasis on the other end of the pipeline. These respondents all tended to be women in academic or university research positions or those who were planning to go into such positions. Despite the obvious self-interest involved, the statistics do seem to support the need. The fact that there are only 33 female full professors in CS and CE out of 158 departments and 74 associate professors indicates an extremely serious problem in getting women into senior positions. This is not a function of women not being in the pipeline long enough — 10-12% of the Ph.D.s have been awarded to women each year for the past 15 years, but only 8% of the associate professors and 2.7% of the full professors are women.

The following comment came from a female university researcher:

> *I have seen many studies showing that as women advance professionally they fall increasingly behind their male peers. Although I support the efforts of NSF, AAAI, and others to encourage entry into CS, I do feel that more attention should be given to capitalizing on the achievements of those women who have struggled partway up the ladder.*

And from a female university researcher:

> *Where in the pipeline should we strive to help women? We'd like to help everybody, but we have finite resources. I'm most concerned about programs that cost money, not projects like*

> *graduate student lunches or mentoring which require only time.*
>
> *I'd argue that we should help women further along in the pipeline than most of the programs that now exist. If we can dramatically increase the number of senior women in CS (and science and engineering in general) I believe the shortage of women in the earlier stages of the pipeline will disappear. Everyone needs to see someone they admire doing the things that they want to do. Women in CS see only men in those roles — it's no wonder they decide that CS isn't the area for them. By helping just one junior woman become a senior woman we ought to be able to create a role model for hundreds of women in the early stages of the pipeline.*

Another female professor wrote:

> *[...] the highest priority should be to help more women move from junior to senior positions.*

And finally, a female professor commented:

> *I think that promoting women into senior positions (and making sure they get grant money) is one of the most effective ways to combat the problem. One of the reasons we all have had more help from men than women during our careers is that the men are able to provide more help from their more powerful positions!*

As mentioned earlier, the NSF Visiting Professorships for Women program has been very successful. Unfortunately, it is limited in size. Very few CS women have received these awards. The program might be expanded, perhaps with this type of program within each directorate. One female faculty member also suggested that universities might support such programs:

> *These could be modelled on the NSF Visiting Professorship for Women program (which cannot fund all of the proposals it finds worthy). Several constraints to consider: area should be close to that of some faculty member(s) so visitor is not isolated; teaching responsibilities limited to seminar in area of expertise; possibly schedule explicit activities with women. Note that women from industrial research labs as well as professors at other universities could be attracted. These should be clearly marked as distinguished positions, and not viewed or used as low-status temporary positions.*

An NSF task force on programs for women has produced a draft recommendation with the stated purpose of increasing the number of senior women faculty in the sciences. Under this program, NSF would initiate 5-year Career Recognition Awards of approximately $50,000 per year. Candidates would be nominated by their institutions. It is hoped that a 5-year program of this type will produce 500 full professors (these programs are for all the sciences). Support among the respondents to my initial draft report for this type of program was very positive.

Miscellaneous Comments

Some comments were received that suggested problems for which there do not seem to be easy and obvious fixes or programs. One female industrial researcher thought that parental leave is an important issue:

> *I think that current parental leave policies, and the lack thereof, are seriously hampering young female faculty. (And indeed, I think, are also hampering an important group of young male faculty).*

The two-body problem was the focus of a comment from a female faculty member:

> *Many women faculty are married to faculty, often a few years older. I probably don't need to tell you what the consequences are. Michigan had one imaginative solution: the University has "affirmative action" money, in which half of the two-body problem is funded for n years (n<=5, I believe), then the department takes over. One can see problems in this type of solution; it seems better than no solution ...*

Several people noted the lack of representation of women in the "power positions" of the field. It is interesting that several of these commenters were men. A male professor wrote:

> *I finally got around to your article in the CRBs Summer Issue of Computing Research News. Aside from three NSF program directors (and several staff associates here and there), the only names of women that I found from a quick scan of the entire paper were yours, and those of Mary Shaw and Grace Ostenso. Perhaps we have not given sufficient recognition even to those women who have established themselves in Computing Science.*

A female professor also commented on the CRB newsletter:

> *I'm delighted to see the headway you are making ... concerning the CRB report, I found it most disturbing that they have no women on the editorial board, which is my impression from reading the first page of the bulletin. They do have a woman on their committee, I believe Mary Shaw, which is great, but another few would help the image problem of what happens after women enter the field. [...] Perhaps you can use this as an example of lack of on-going perspective about women that the CRB should have.*

In all fairness to the CRB, they invited my original article that prompted these comments, and several of their leaders are very concerned about the problems of women in CS research.

If one examines the two major professional societies in our field, the ACM and the IEEE Computer Society, two different patterns emerge. The ACM appears to have a large amount of participation by women in important positions. For example, at least 6 out of the 25 current ACM Council members are women. Women are also well represented among the elected executive committees of the ACM special interest groups (SIGS). Of the 31 SIGS, there are three women chairs (one position is vacant). In addition, of the nine ACM journals, two of the editors-in-chief are women (22%) as are approximately 12% of the editorial board members.

In contrast to the democratic structure of the ACM which stresses elections, the IEEE Computer Society officers are, for the most part, selected by the previous officers, i.e., an "old boy's" setup. In general, the representation of women as chairs and members of the

Technical Committees is much lower than the equivalent ACM SIGS. Out of the 10 IEEE CS journals, none have a female editor-in-chief and approximately 7.5% of the editorial board members are women. IFIP, and especially the IFIP Working Groups, appears to be even worse than the IEEE Computer Society.

The problem of getting greater representation of women in situations where there is not a democratic process working is a difficult one to solve. One senior female professor suggested:

> *I get more requests to serve on study panels, program committees, visiting committees, etc. than I can handle. When you turn down such an invitation you usually have the opportunity to nominate an alternate. A couple of years ago I realized that it's awfully easy to name the first two or three people who come to mind — who are likely to be men. Now I make a conscious attempt to propose women, both in this situation and when the initial lists for various activities are drawn up.*

One final comment came from a female industrial researcher:

> *It's clearly a tough problem and it starts early. I don't have any magic bullets. But I've thought about one thing that NSF could do directly. Assuming that a woman makes it as far as an entry academic job, the next step is to get research funding, do research, and get tenure. There seems to be a lot of evidence that women's writing styles differ from men's, in particular women hedge more; they are less self confident. One question I've wondered about but don't know the answer to is whether such style differences have any affect on women's chances for successfully getting research proposals funded. ... If they do (and maybe even if they don't — there are clearly lots of factors at work here) then one thing NSF could do is to help to assure that their reviewers react as little as possible to the tone of a proposal and instead react to its contents. I don't know if they can do that with some instructions to reviewers. They can do it when they have review panel meetings. Of course this same issue may affect women at other stages in their careers (for example, essays that are written to get into graduate school or to apply for fellowships, e.g., NSF). Some of this is hard for NSF to have any direct effect on, but they could watch for this bias in fellowship applications as well.*

RECOMMENDATIONS FOR NSF

The original purpose of this report was to generate ideas for NSF programs to increase the number of women in computer science research. For various reasons, this report seems to have taken on a life of its own and grown beyond the original intention. In this section, I return to the original purpose. It should be remembered, however, that NSF is not the only source of funding for these types of programs. Other possibilities include state and local governments, charitable foundations, industry, universities, and alumni associations.

Because girls are dropping out of science and math at an early age, it is important that programs for pre-college women be established and supported. Although the CISE directorate may not be directly involved in such programs, it can provide support to those parts of NSF that are involved in early education. Programs are needed both to encourage girls' interest in science and math and to improve computer science education. Special summer and after-school programs have proven particularly effective in the past.

One of the most effective ways to get more women into graduate programs is to provide them with opportunities to participate on research projects. This can start with high school summer projects and continue through undergraduate study. Funding summer research jobs and female undergraduate participation on research projects would be a highly effective use of resources. These programs should allow and encourage women attending primarily teaching colleges to participate at research universities.

The most effective funding for graduate students is that which is tied to research. Fellowship programs combining research support with mentoring activities are needed. A graduate fellowship program for females in computer science and computer engineering could help women devote more time to their studies and keep them in school. Also, reentry programs allow women to return to school and to prepare for Ph.D. programs; the success of this program at Berkeley suggests that other programs of this type would be effective. Finally, there should be some type of program to provide travel funds for female graduate students (and junior faculty) to attend conferences and workshops.

In general, women in faculty positions are not doing poorly in the regular grant process. However, a program that provides flexibility would be useful. For example, NSF grants do not usually provide money for release time from teaching and administrative duties. Such support for a woman with small children might allow her to maintain a research career and momentum while starting a family. Also, a small equipment grant program to finance home computing needs should be considered. The small number of senior women in academic positions implies a need to help women advance to the upper ranks of their profession. The new Career Recognition Awards are one way to accomplish this. More opportunity for computer science and computer engineering women to participate in the Visiting Professorships for Women program might also be useful.

Mentoring and other activities undertaken by departments and individuals such as inviting women speakers and holding regional or local workshops can have a profound effect on the careers of undergraduate and graduate students and could benefit from small amounts of funding from NSF. Because individual needs and interests will differ, a program to fund such activities should allow general proposals without strict guidelines. After more experience with these types of programs is gained, it may be possible for NSF to provide more directed types of programs. A follow-up report to this one that provided information and feedback on such efforts would be very helpful in guiding and planning future activities. Funding for release time to plan and participate in such networking and mentoring activities would make it possible for already overburdened faculty to initiate and provide such activities.

A female graduate student stated very eloquently the reason why these of programs should be undertaken:

> *Science's ability to build on itself and positively influence society is hindered by the exclusion of important sectors of the society. A woman has the right to educate herself, to know first-hand the beauty of science, and to attempt to make a contribution to the body of knowledge of her choice.*

By not providing the opportunity for women to contribute to scientific activity, everyone loses.

APPENDIX 1

List of Contributors

Hala Abdalla, Sun
W. Richards Adrion, professor, University of Massachusetts, Amherst
Carrie Brownhill, graduate student, University of California, Irvine
Charles Brownstein, NSF
Vasudev Bhandarkar, Software Engineer, DEC
Lori Clarke, professor, University of Massachusetts, Amherst
Carolyn Crouch, professor, University of Minnesota
Ted Dunning, researcher, New Mexico State University
Susan Eggers, professor, University of Washington
Thelma Estrin, professor, UCLA
Peter Freeman, professor, University of California, Irvine
Frank Friedman, professor, Temple University
Susan Gerhart, researcher, MCC
David Gries, professor, Cornell University
Mary Grigolia, Computer Science Reentry Program Coordinator, University of California, Berkeley
Barbara Grosz, professor, Harvard University
Carole Hafner, professor, Northeastern University
Nancy Hall, researcher, University of Wisconsin-Madison
Barbara Hayes-Roth, researcher, Stanford University
Jessica Hodgins, researcher, MIT
Gail Kaiser, professor, Columbia University
Kevin Karplus, professor, University of California, Santa Cruz
Beth Katz, professor, Furman University
Susan Landau, professor, Wesleyan University (on leave at University of Massachusetts, Amherst)
Amy Lansky, researcher, NASA/Ames
Nancy Lynch, professor, MIT
Kathy McKeown, professor, Columbia University
Bonnie Melhart, graduate student, University of California, Irvine
Fanya Montalvo, researcher, DEC Cambridge Research Lab and MIT
Evan Morton, Apollo
Kathleen Nichols, Apple
Shari Lawrence Pfleeger, Contel Technology Center
Martha Pollack, researcher, SRI
Elaine Rich, researcher, MCC
Eve Riskin, graduate student, Stanford University
Betty Salzberg, professor, Northeastern University
Wendy Sarrett, student, University of California, Irvine
Mary Shaw, professor, Carnegie-Mellon University
Esther Shilcrat, graduate student, State University of New York, Stonybrook
Barbara Simons, researcher, IBM
Karen Sollins, researcher, MIT
Ellen Spertus, student, MIT
Melanie Stein, graduate student, University of Wisconsin-Madison

Al Thaler, NSF
Becky Thomas, graduate student, Stanford University
Mary Vernon, professor, University of Wisconsin-Madison
Jan Walker, researcher, DEC Cambridge Research Lab
Elaine Weyuker, professor, New York University
Meg Wilson, MCC
Chip Weems, researcher, University of Massachusetts, Amherst

APPENDIX 2

Boston Globe Articles

The following two articles appeared on the front page of the Boston Globe, Monday March 13, 1989.

Engineering losing its luster among students
by Ronald Rosenberg

Massachusetts' seven leading engineering colleges are experiencing serious declines in enrollment as more Bay State high school students turn to majors with less stringent mathematics and science requirements.

The drop in students studying such disciplines as electrical, civil, mechanical, and aeronautical engineering at the undergraduate level mirrors the national trend and is prompting renewed concern of an impending shortage of critical talent in the mid-1990s.

The National Science Foundation estimates that by 1996 there will be a shortfall of 45,000 baccalaureate degrees in science and engineering and that by the year 2010, there will be 700,000 fewer baccalaureate degrees than necessary to fill existing jobs.

These predictions come after the boom years of 1976 to 1985 when engineering, particularly electrical and computer engineering and computer science, were the hot fields. Schools were flooded with applicants and classrooms overflowed. College computer centers had waiting lines, women began entering the field, laboratory equipment was in short supply and engineering departments scrambled for facilities.

Today some engineering schools, such as the Massachusetts Institute of Technology, are thankful that the rush for engineering students is behind. But all institutions worry that the boom is turning into a bust.

At the same time, record numbers of foreign-born students are entering at the graduate level and aggressively pursuing teaching positions that were once the province of American-born students. At Northeastern University, nine out of 10 applicants for 5 teaching jobs in the engineering department are foreign-born.

And with the expected decline in college-age population, the National Research Council forecasts that such nontraditional sources of engineers as technicians or other nonregistered engineers, will be tapped. This will result "in a dimunition of quality that could threaten the long-term international competitiveness of the United States," according to the council.

Moreover, students who do decide to pursue an engineering degree are often weak in mathematics and science, according to several deans of engineering.

"We are concerned that the preparation engineering students get in math and science in the high school is just not as strong as it used to be,'' said John Proakis, chairman of Northeastern University's electrical engineering department.

''What we also see is that students are not as interested in working hard as students of 10 years ago. When I tell them they have to spend 10 hours of outside preparation for three hours of class per week, I hear students say, 'Gee, that is too much time.' At the same time, I see students coming from the Far East who are willing to work to achieve their goals, and that concerns me.''

Northeastern is a bellweather for local engineering schools since many of its students are from metropolitan Boston and the surrounding New England states. Disenchantment with engineering shows up in all disciplines, most notably electrical engineering, where 907 students are enrolled compared to 1,408 in 1985 — a 35.6 percent drop.

Still, Northeastern is not alone. Other major schools experiencing shortages are the Massachusetts Institute of Technology, the University of Lowell, Worcester Polytechnic, Boston University, Tufts University, and the University of Massachusetts at Amherst.

Several national studies bear out this regional trend. National surveys show that students prefer the less taxing curricula in business, teaching, and the humanities -- areas that do not require extensive high school mathematics and science courses.

''Teachers of mathematics and science need to instill in young people the thrill and adventure associated with engineering, not smother them in a blanket of complexity,'' said Edward Cohen, [...]

Cohen believes engineers should become more involved in improving math and science education in elementary and secondary schools as well as encourage students — particularly women and minorities, to pursue engineering careers.

[...]

What worries engineering school deans are the reasons that high school students give for shunning engineering despite a relatively strong economy, lots of jobs, and relatively good pay.

''Characteristically we have seen a sloshing back and forth between students in engineering and science but this year for the first time I didn't see this balance,'' said Richard B. Adler, associate head of the electrical engineering and computer science department at MIT.

Most disconcerting to the major engineering schools are the student preferences listed as part of the PSAT last October. Nationally, 9.4 percent of students taking the test indicated an interest in engineering compared to 10.5 percent in 1985. In Massachusetts, 7.7 percent of the high school juniors (2,931 of the 38,071 students who took the test) said they were planning to pursue an engineering career compared to 10 percent (4,284 of the 42,846 students) in 1985.

In computer science, the picture is even bleaker. Only 1.8 percent or 685 students expressed an interest in a software career, compared to 3.3 percent or 1,413 students four years ago. Nationally, fewer women are expected to pursue degrees in mathematics and computer science, according to the National Science Foundation, which estimates that only 9,600 will graduate compared to 22,400 women in 1986.

[...]

[Some numbers from an accompanying table showing total numbers of sophomores, juniors and seniors in engineering and computer science:]

MIT	**85-86**	**86-87**	**87-88**	**88-89**
electrical/computer science	1121	1040	940	850
mechanical	457	450	452	475
aeronautics/astronautics	301	334	330	332
chemical	166	158	132	128
materials	137	144	131	129
NORTHEASTERN				
electrical/computer eng.	1408	1312	1178	907
computer science	530	532	437	366
mechanical	567	518	365	356
civil	346	308	247	233
chemical	176	143	108	131
UNIVERSITY OF LOWELL				
electrical	794	683	589	549
mechanical	520	421	302	297
civil	252	243	189	231
plastics	175	177	141	153
chemical	125	97	66	59
computer science	406	335	209	193
BOSTON UNIVERSITY				
electrical	378	392	363	329
mechanical	126	99	116	110
aerospace	262	257	239	236
biomedical	219	247	251	239
manufacturing	50	68	64	105
computer engineering	245	207	173	136
computer science	204	175	145	159
UMASS-AMHERST				
electrical & computer	517	566	481	387
computer science	156	125	112	115
mechanical	390	406	402	367
civil	168	172	170	168

chemical	92	70	78	69

More Women Shun Engineering as Other Careers Beckon
by Ronald Rosenberg, Boston Globe, Monday Mar. 13

After nearly a decade of significant increases, fewer women are pursuing engineering and computer science careers, prompting concern in academia and industry that there will be a shortage of high-tech talent in the 1990s.

"The rate of women entering engineering schools nationwide is dropping slightly faster than men," said Betty M. Vetter, executive director of the Commission on Professionals in Science and Technology in Washington.

Vetter notes there are several reasons besides the overall decline in college-age population. Like men, women see alternatives to engineering, which is perceived today as less vibrant than five years ago.

"Women at this point have seen older sisters going into engineering who are often achieving at a far higher level academically than their brothers," she said.

"But out in the real world they wind up getting paid less, hit glass ceilings in advancement, and quickly realize that engineering is still a macho field, highly dominated by men, many of whom don't want women there in the first place."

Another factor inhibiting American women are the attitudes of foreign male students and faculty who dominate the graduate and teaching levels of most engineering schools. Often foreign males, particularly those from Asian countries, don't see female students as colleagues because of their own cultural upbringing.

"There are certain groups of students from certain countries who have never seen a professional woman and when they see one as a teacher it is a big shock and sometimes creates difficulties," said Richard Reis, associate dean of engineering at Stanford University.

"Occasionally we have foreign-born teaching assistants who simply discount women in a classroom. They don't call on women and often see them as just less important. Also, a woman professor may be challenged inappropriately by foreign students who will question her credentials."

Stanford is not alone in this problem, in part because the engineering profession continues to be male dominated. Negative attitudes remain, even when women match or exceed men in math and science.

Overcoming these prejudices and social barriers on top of a difficult study load has prompted women to question whether it is worth pursuing an engineering degree. Three years ago 17 percent of the nation's engineering students were women. Today they are about 15 percent, noted Vetter.

And yet women are viewed by academia and industry as a key to the future — to teach in colleges and universities and ultimately to provide role models to other women.

With fewer college-age students — particularly white males — there is a push to attract women and minorities to engineering. That means an emphasis on boosting mathematics and science in primary and secondary schools.

“There has to be an enormous shift in the participation of women in engineering — a new phenomenon — to meet the future talent needs of the area’s high-technology industries,” said Ray Stata, president of Analog Devices Inc. of Norwood and chairman of the educational committee of the Massachusetts High Technology Council.

APPENDIX 3

Factors Affecting the Decision of Women to Enter Doctoral Programs in Computer Science

Carrie Brownhill
University of California, Irvine
Revised: August 22, 1989

Introduction

As the baby boom continues to decline, the pool of college-age white males is expected to drop significantly in the future. The resulting vacancies in the scientific community, including those in computer science, could be filled by increasing numbers of women and other minorities. [Widn] However, the number of women earning doctorates in computer science is still smaller than it could be. This is due in part to the fact that women are less likely than men of equal ability to apply to graduate school. [HS83]

In 1983, 17.1% of first year college men and 19.4% of first year college women majoring in science and engineering, had aspirations of obtaining a doctoral degree. [Table 1] Contrary to these early expectations, only 4.8% of the women completing bachelor's degrees in 1979 went on to earn a doctorate. Approximately 56% more of the men went on to complete a Ph.D. [Table 2] Furthermore, in 1985, 36.9 percent of the bachelor's degrees in computer sciences were awarded to women. In the same year, only 28.7 percent of the master's degrees, and 10.6 percent of the doctorates were earned by women. [Table 3] These figures show that a lower percentage of women than men decide to enter graduate school. The difference in participation rates increases significantly after the master's degree is achieved.

Research has been done on the reasons women don't complete doctoral programs, but most of the attention has been directed at the factors causing women to drop out. That subject is outside of the scope of this paper. Also not included are the considerable gender-related factors that influence the choice of computer science as a field of study. In this paper, I will specifically identify some of the gender-related issues that may discourage women from applying to and entering a Ph.D. program in computer science. The topics addressed will include: lack of confidence, lack of role models and mentors, family considerations, unfriendly environments, self-image, expectations, and value systems.

Graduate Study as an Option

Continuing Students

Entry into a Ph.D. program is generally considered at two different times in life. The primary one is when a bachelor's or master's degree program is near completion. The student must decide whether to continue in the educational pipeline, or to whether to enter into the 'real-world'. For both men and women the appeal of getting

[Table 1] Degree Aspirations of First Year College Students in 1983 [NS86]

	Bachelor's	Master's	Doctorate
Men	27.1%	37.8%	17.1%
Women	23.0%	35.2%	19.4%

[Table 2] Higher Degree Attainment Rates of 1979 Science and Engineering Bachelor's Degree Recipients [NS88]

	Master's	Doctorate
Men	21.4%	7.5%
Women	14.7%	4.8%

[Table 3] Degrees in Computer Sciences in 1985 [NS88]

	Bachelor's	Master's	Doctorate
Total	39,121	7,101	310
Women	14,431	2,037	33
Percentage	36.9	28.7	10.6

out of school and becoming financially independent after years of study is strong. A clear idea of the resultant rewards may cause a student to consider a Ph.D. program as an option. The student also needs to feel reasonably confident of success, if the idea is to receive serious consideration.

Unfortunately, female students actually suffer a decline in self-esteem and academic ambitions during the college years. [Asti] [Widn] In addition, women tend to attribute their success to luck or hard work, rather than talent. They may also recognize the fact that a woman often needs to achieve more than a man would in order to receive equivalent recognition. [HS82] [SaHa] In short, by the end of her undergraduate career, a woman may feel she lacks the ability to succeed in graduate school.

The destructive effect of the college experience on a woman's confidence can be overcome with steady encouragement from a mentor. [Widn] [Boli] The mentor relationship is described in the following passage.

> In academe, the primary model for mentoring has been the sometimes lifelong relationship that can develop between an undergraduate or graduate student and

> a "special" professor. Ideally, the professor takes the novice under his or her wing; helps the person set goals and standards and develop skills; protects the novice from others in a way that allows room for risk and failure; facilitates the novice's successful entry into academic and professional circles; and ultimately passes on his or her work to the protege. [HS83] p. 3.

Unfortunately, the scarcity of female professors in computer science means that there is a serious lack of same-sex mentors for female students. In 1983, only 8% of tenure-track professors in computer science were women. It is quite possible for a student to complete an undergraduate degree without meeting a single female computer science professor. Females in senior positions are scarce indeed. [Table 4] This situation can lead a female student to the conclusion that if the brightest women can't make it to the top, then she certainly has no chance.

[Table 4] Doctoral Computer Specialists in Four-Year Colleges and Universities: 1985 [NS88]

	Total*	Tenured	Tenure Track/ Not Yet Tenured	Non-Tenure Track
Total	5,100	2,200	1,400	1,100
Women	500	100	200	100
Percentage	9.8	4.5	14.3	9.1

* Includes tenure status unknown and no report

Returning Students

The second time graduate study is considered is when some change in lifestyle is desired. This may be due to job or personal dissatisfaction. It may be because of a desire for emotional and intellectual growth. [Boli] For a woman, this desire for change often occurs when her children become old enough to leave with a baby-sitter or go to school. A woman in this position may have the advantage of spousal financial support. However, if she has been a housewife for any length of time, she may lack the self-confidence and courage necessary to apply to a Ph.D. program. Some women decide to ease into graduate school slowly, on a part time basis. In this way they test their qualifications, talent, and ability to cope with the increased demands. [Boli] However, many Universities require Ph.D. students to carry a full load, thus depriving women this chance to test their wings.

A woman with a family must also face the considerable burden of trying to balance family and school in an environment that demands single-minded attention. [Scot] This attitude is described in the following passage written by a female student trying to combine marriage, a family, and graduate school.

> Most graduate programs assume that their students come relatively unfettered. The student's time belongs to the graduate institution, and, like male faculty members, graduate students come either single or with wives who will

> take care of "real life" for the duration. When a married woman with children (especially young children) appears in this milieu there is consternation. A faculty member might suggest the woman wait until the children are older. One woman faculty member has refused to accept advisees with preschool children. Another invariably recites the divorce statistics. The most unnerving aspect of all this is the underlying assumptions about woman's career options and, ultimately, their seriousness in pursuing a Ph.D. [Levs] pp. 100-101

A person returning to school after working often faces a great, often impossible, loss of income. While this is true of both men and women, women more often are self-supporting. [NS88] If the woman has children, her child-care expenses may not even be covered by the usually meager support offered to graduate students. [Levs]

Motivations for Graduate Study

The Academic Environment

For some students, the desire to enter into graduate study stems from a love of the academic environment. For others, the acquisition of knowledge is a joy unto itself. Still others find the thought of regular work distasteful. These reasons for pursuing graduate study should apply equally to men and women. However some women, especially those in non-traditional fields, are implicitly or explicitly made unwelcome. [HS82] The college experience may even include sexual harassment. [SaHa] Instead of being socialized into academe, a female student may learn to think of school as an uncomfortable place.

Career Requirements

Another important motivation for earning a doctorate is the desire for career enhancement. Some careers even require a Ph.D. The most well-recognized of these is teaching at the college level, but there are others. For example, an executive in a technical field may view a Ph.D. as assisting his climb up the corporate ladder. Unfortunately, there are few female managers in a position to take advantage of such an investment.

However, women who want to do advanced research in industry nearly always need a doctoral degree. Although many women are choosing careers in science and engineering, there seems to be a lack of women wanting to do advanced research. Why is this? One reason may be the that the stereotype of the research scientist conflicts with many women's self-perceptions. A scientist is seen as devoting most of his time and energy working alone on his research. He is seen as having little time for outside interests or family. Women, consciously or not, realize that this model conflicts with their self-image as people and family oriented. [Eccl] There are few visible women scientists around to counteract this stereotype.

Some of the same stereotypical qualities of research scientists also pertain to college professors. These careers often overlap. Although teaching is a traditionally female career, women soon find that the emphasis on research at Ph.D. granting institutions overshadows the teaching and nurturing aspects of the job. Most people have little knowledge of the academic environment before going to college. Therefore, the undergraduate experience is a significant factor in identifying the possibility of an academic career. A student's exposure to faculty may give her the idea that professors spend most of their time struggling to publish papers, get grants, and achieve tenure. The impression is that academe is a competitive, aggressive, stressful and time-consuming environment, especially for junior staff members trying to get tenure. This is a very unappealing picture for many women. [KiSE]

The presence of a departmental role model may provide the "existence theorem" that a woman can be a successful professor. [Dres] Ideally, such a role model would be a senior department member and exemplify the ideal way to balance career and family. Unfortunately, such role models are few and far between.

Expectations

Many people decide on graduate study simply because significant people in their lives think they should. [King] These expectations are usually internalized so that the student expects to earn a Ph.D. Parents can have an especially strong impact on the aspirations of a child. For men, expectations of job and academic accomplishments are usually high. Sometimes, they are unreasonably high. Women, however, still receive the message that they should set moderate career goals. Emphasis is often placed on raising children and maintaining a happy home life. Thus, a woman may choose lower career and academic aspirations, reflecting society's expectations as a whole.

A spouse can have a significant effect on a woman considering graduate school. A supportive spouse will often assume some of the financial and familial responsibilities, in addition to offering moral support. However, jealousy can arise if a wife's achievements threaten to overtake her husband's credits. A husband may also resent the time and energy spent at school. A woman who is unsure of her (possibly future) husband's support may hesitate about taking a step which will be disastrous on her home life.

The Value of Achievement

Jacquelynne S. Eccles has recently suggested a new model for studying the academic and occupational choices of women. [Eccl] She feels that women have been socialized to have different goals from men. Therefore, the value a woman places on the achievement of a task is different than the value a man might place on the same task. She feels that ignoring this fact has lead to a negative bias when evaluating feminine choices.

> Too often scientists adopt a male standard of ideal achievement when judging the value of female accomplishments; they seek to understand why women do not "achieve" like men without considering that not engaging in some activity may reflect the choice of an alternate activity rather

> than avoidance....
>
> As a consequence, very little systematic information has been gathered regarding the more typical female achievement domains, such as the academic accomplishments of one's offspring and/or one's pupils, the satisfaction of one's clients, or one's contributions to local organizations. And until quite recently, even less information has been gathered regarding the meaning women and men attach to various achievement-related activities. As a result, we know very little about why women think they make the achievement-related choices they do. [Eccl] pp. 135-137.

It is easy to see how a woman facing the decision of entering a doctoral program may feel ambivalent. Not only does she have to weigh the benefits vs. opportunity costs of graduate study. She must also compromise between her academic and career goals and her more traditional female roles of mother and wife. For most women, all of these goals are important. [Boli]

Furthermore, to be successful in the traditionally male areas of academic and professional achievement, a woman must often appear to embrace the dictum that professional success requires the sacrifice of all else. [Eccl] To admit that she is not single-minded in her pursuit of "success" would mean inviting criticism from many men. If women's achievements are ever going to be fully recognized, then the definition of success is going to have to be changed.

Summary

For women, the decision to enter a doctoral program in computer science is affected by many gender-related issues. Lack of self-esteem and realistic role models can cause a woman to overlook graduate study as an option. She may feel that the burden on her family, both in terms of finances and time, is not justified by the rewards. Also, some of the motivations typically attributed to graduate students may be diminished for women. The academic experience may have been uncomfortable, even to the point of harassment. The types of careers which require a Ph.D., such as advanced research and college-level teaching, may be perceived as having qualities which conflict with basic psychological needs and self-concepts. Although some of these issues are relevant to graduate study in general, some are only evident when the field of study is a traditionally male-dominated one.

In order to judge the decisions and achievements of women, it is necessary to recognize that they may have a different definition of success than men. A woman may place a higher value on marriage, family, and outside achievements, than on professional or academic success. Whether a woman chooses to concentrate all her energies on her career, or to give other areas of her life equal time, her achievements should be recognized as equally valid.

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