



Tracy Camp

The Incredible Shrinking Pipeline

The ratio of women involved in computer science from high school to graduate school has been dwindling at a startling pace over the past decade. Is there hope in sight?

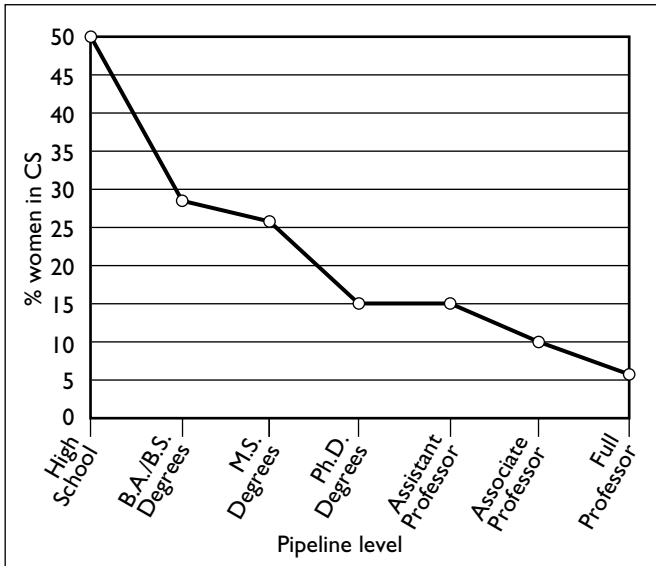


Figure 1. The shrinking pipeline: 1993-94

The pipeline shrinkage problem concerning women in computer science is a known phenomenon (see Figure 1). Although women make up 50% of high school computer science (CS) classes [10], the percentage of bachelor's degrees in CS awarded to women in the 1993-94 academic year was only 28.4% [7].¹ At the graduate level, for the academic year 1993-94, the percentages of degrees in CS awarded to women dropped even further: 25.8% at the M.S. level and 15.4% at the Ph.D. level. In addition, for women who become faculty members, the pipeline shrinks through the academic ranks. According to the Computing Research Association's Taulbee Survey, only 15.6% assistant professors, 9.4% associate professors, and 5.7% full professors were women in CS Ph.D.-granting departments during the academic year 1993-94 [1].

The title of this article, however, is the *incredible* shrinking pipeline: The percentage of bachelor's degrees awarded in CS to women decreased almost every year over the last decade. In other words, not only does the pipeline shrink from high school to graduate school, but it also shrinks at the bachelor's level (see

Figure 2). Furthermore, while the percentage of bachelor's degrees awarded in CS to women decreased, corresponding percentages of other science and engineering disciplines increased. Since the number of women at the bachelor's level affects the number of women at levels higher in the pipeline and in the job market, these facts are of great concern.

There are a number of reasons why we need to improve the percentage of degrees awarded in CS to women. In short, there is a critical labor shortage in CS and, although women are more than half the population, they are a significantly underrepresented percentage of the population earning CS degrees.

In this article, we look at the harsh facts concerning the percentage of degrees awarded in CS to women. We study the trend of degrees awarded in CS since 1980, and compare the trend in CS to other science and engineering disciplines. We consider the relationship between the percentage of degrees awarded to women by a CS department and the college the CS department is within. We find that CS departments in engineering colleges graduate, on average, proportionately fewer women than CS departments in non-engineering colleges. We request that the community respond to the facts and speculations presented in this article.

Degree Trends: 1980-81 Through 1993-94

We have already established that as women progress from high school to graduate school, they will be part of a smaller and smaller proportion of students. In addition, from 1983-84 to 1992-93, the percentage of B.A./B.S. degrees awarded in CS to women con-

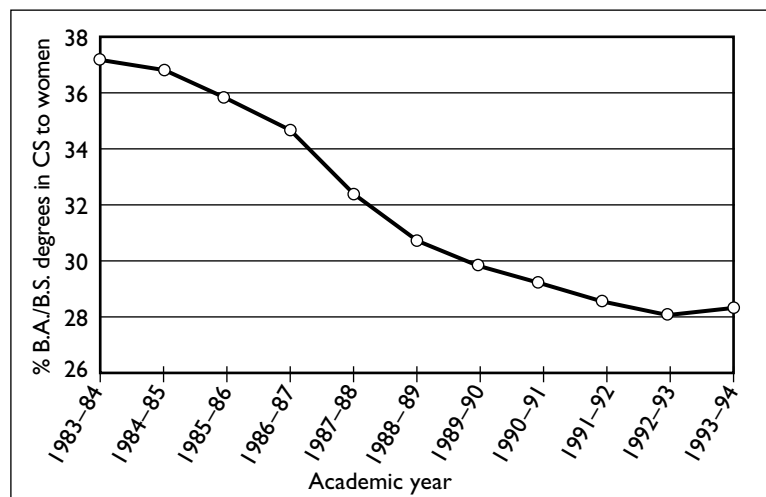


Figure 2. The incredible shrinking pipeline: 1983-84 to 1993-94

¹The number of degrees awarded for the academic years 1994-95 and beyond are not yet available from the National Center for Education Statistics at the U.S. Department of Education.

tently decreased. The percentages of M.S. degrees awarded in CS to women were more stable over this period, and the percentages of Ph.D. degrees awarded in CS to women (though still meager) increased.

The National Center for Education Statistics at the U.S. Department of Education classifies CS departments within the Computer and Information Sciences (CIS) category. Figure 3 illustrates the percentage of degrees awarded within different fields of study in CIS for B.A./B.S., M.S., and Ph.D. levels in 1993–94. As illustrated, the bulk of the degrees awarded are in the general computer science category, with information science and systems a distant second. We, therefore, use the acronym CS in this article to

Table 1. Degrees awarded in CS: 1980–81 to 1993–94

Academic Year	B.A./B.S. Degrees	% Women	M.S. Degrees	% Women	Ph.D. Degrees	% Women
1980–81	15,121	32.5	4,218	23.0	252	9.9
1981–82	20,267	34.8	4,935	26.5	251	8.4
1982–83	24,510	36.3	5,321	28.3	262	13.0
1983–84	32,172	37.1	6,190	29.3	251	10.4
1984–85	38,878	36.8	7,101	28.7	248	10.1
1985–86	41,889	35.7	8,070	29.9	344	13.1
1986–87	39,589	34.7	8,481	29.4	374	13.9
1987–88	34,523	32.4	9,197	26.9	428	11.2
1988–89	30,454	30.8	9,414	28.0	551	15.4
1989–90	27,257	29.9	9,677	28.1	627	14.8
1990–91	25,083	29.3	9,324	29.6	676	13.6
1991–92	24,557	28.7	9,530	27.8	772	13.3
1992–93	24,241	28.1	10,163	27.1	805	14.4
1993–94	24,200	28.4	10,416	25.8	810	15.4

the percentages are in an upward trend. However, due to the shrinking of the pipeline at the B.A./B.S. level, it is unlikely this upward trend will continue. From Table 1, we conclude there is some good news at the Ph.D. level.

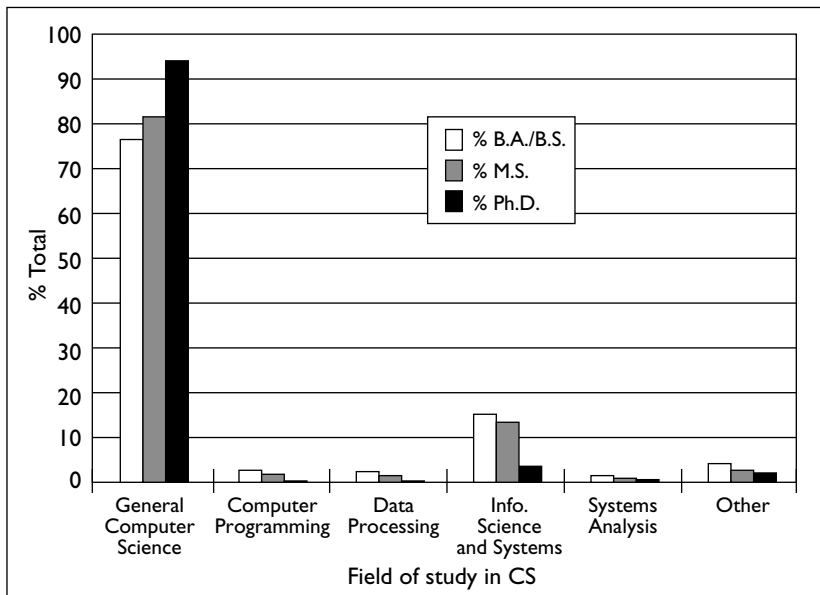


Figure 3. Percentage of degrees awarded for a field of study in CIS: 1993–94

represent all CIS fields. Table 1 lists the number of B.A./B.S., M.S. and Ph.D. degrees awarded in CS from 1980–81 to 1993–94 and the percentage of recipients that were women.

Although the percentages of Ph.D. degrees awarded in CS to women are very low, the numbers from the three most recent years available suggest

- The number of Ph.D. degrees awarded in CS continues to increase.
- The percentage of Ph.D. degrees awarded in CS to women in 1993–94 was equal to the percentage of Ph.D. degrees awarded in CS to women in 1988–89 (the year when the percentage was at its highest level).
- The percentage of Ph.D. degrees awarded in CS to women in 1993–94 was almost 50% higher than the percentage of Ph.D. degrees awarded in CS to women a decade ago (10.4% versus 15.4%).

Some members of our community are concerned about the first point.

As the number of Ph.D. degrees awarded in CS continues to increase, university positions are more difficult to obtain. Furthermore, many recent Ph.D. graduates do not seem prepared for the realities they face in the job market [4].² In contrast to this viewpoint, we present the following numbers. First, the unemployment rate for people with a Ph.D. in CS is extremely low (1.1%) [6].³ Second, the underem-

²Faculty members have a responsibility to disseminate information about the job market to their students, thus allowing students to make informed decisions.

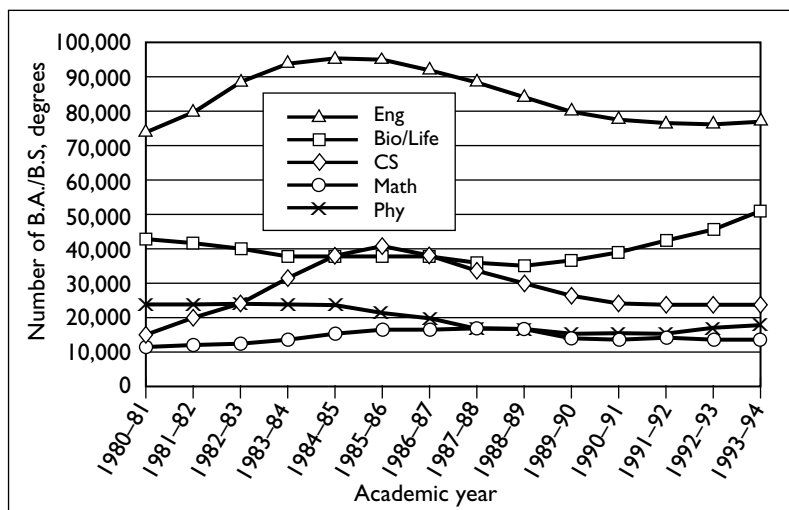


Figure 4. Number of B.A./B.S. degrees awarded in science and engineering: 1980–81 to 1993–94

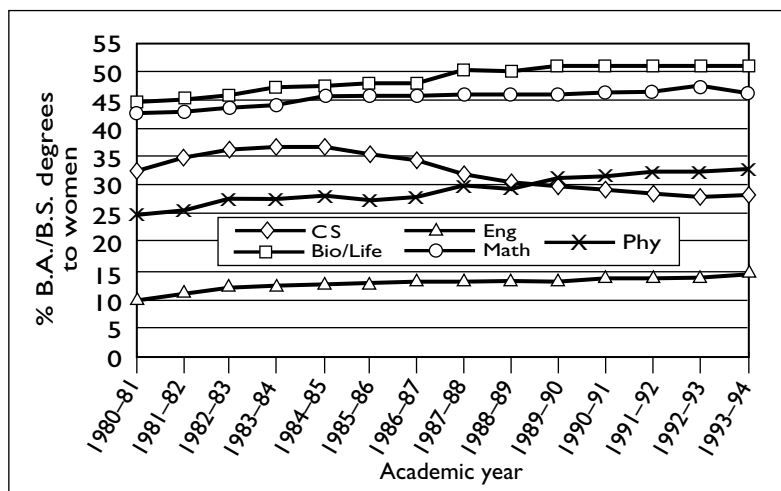


Figure 5. Percentage of B.A./B.S. degrees awarded to women in S&E: 1980–81 to 1993–94

ployment rate for people with a Ph.D. in CS, or the rate of people with a Ph.D. in CS who work outside the CS discipline, is low (3.6%) [6]. Third, there is only a 4% Ph.D. surplus in CS, which is “the lowest surplus of any science and engineering field.” [6].

There is mixed news at the M.S. level as well. The number of M.S. degrees awarded in CS continues to increase, but the percentage of M.S. degrees awarded in CS to women has reached its lowest level since 1980–1981. Due to the shrinking of the pipeline at

Table 2. B.A./B.S. degrees awarded in all disciplines: 1980–81 to 1993–94

Academic Year	B.A./B.S. Degrees	% Women
1980–81	935,140	49.8
1981–82	952,998	50.3
1982–83	969,510	50.6
1983–84	974,309	50.5
1984–85	979,477	50.7
1985–86	987,823	50.8
1986–87	991,264	51.5
1987–88	994,829	52.0
1988–89	1,018,755	52.5
1989–90	1,051,344	53.2
1990–91	1,094,538	53.9
1991–92	1,136,553	54.2
1992–93	1,165,178	54.3
1993–94	1,169,275	54.5

the B.A./B.S. level, it is likely the percentage of M.S. degrees awarded in CS to women over the next few years will continue to decline.

At the B.A./B.S. level, there is only bad news: The number of B.A./B.S. degrees awarded in CS has steadily decreased since 1985, and the decrease is occurring at a faster pace for women than men. The fact that the number of B.A./B.S. degrees awarded in CS is decreasing at a faster pace for women than men is especially striking when one considers the total population receiving B.A./B.S. degrees, and the percentage of bachelor’s degrees awarded to women by disciplines sim-

ilar to CS.

Table 2 lists the total number of B.A./B.S. degrees awarded in all disciplines from 1980–81 through 1993–94, and the percentage of the recipients that were women. The number of B.A./B.S. degrees awarded in all disciplines continues to increase, and the increase is at a faster pace for women than for men.

Figures 4 and 5 compare the trend of degrees awarded in CS with the trends of degrees awarded in disciplines similar to CS from 1980–81 through 1993–94. The majors within a discipline are determined by the National Center for Education Statistics:

- *Bio/Life* = Biological/Life Sciences which includes biology, biochemistry and biophysics, botany, cell and molecular biology, microbiology/bacteriology, zoology, and other biological sciences.
- *Eng* = chemical, civil, electrical, mechanical, and other engineering-related technologies.

³The two most recent CRA Taulbee surveys cite the unemployment rate of new Ph.D. graduates at 1.7% in 1995 and 0.8% in 1996 [1]. Some claim the unemployment rate of the Taulbee surveys may be misleading [4]; for example, the 1995 and 1996 surveys do not know what 18.5% and 15.2%, respectively, of the Ph.D. graduates are doing. The unemployment rate from [6], however, is based on a report from the Survey of Doctorate Recipients conducted by the National Science Foundation. Since the two unemployment rates are comparable, we believe the rate is sound.

- *Math* = mathematics and statistics.
- *Phy* = Physical Sciences which includes astronomy, chemistry, geology, physics, and other physical sciences.

Figure 4 illustrates that while the number of B.A./B.S. degrees awarded in other science and engineering disciplines decreased from 1985–86 to 1993–94, the decrease in CS was the most extreme. From 1985–86 to 1993–94, Eng decreased 18.2% (95,660 to 78,225), Math decreased 16.0% (17,147 to 14,396), and Phy decreased 15.3% (21,717 to 18,400), but CS decreased 42.2% (41,889 to 24,200). Bio/Life increased 33.4% (38,524 to 51,383) during the same period. Figure 5 illustrates that the percentages of B.A./B.S. degrees awarded to women by science and engineering disciplines (except CS) increased annually over the last 13 years. CS is the *only* science and engineering discipline where the percentage of bachelor's degrees awarded to women decreased. From 1980–81 to 1993–94, Bio/Life increased 16.3% (44.1% to 51.3%), Eng increased 44.7% (10.3% to 14.9%), Math increased 10.0% (42.1% to 46.3%), and Phy increased 36.6% (24.6% to 33.6%), but CS decreased 12.6% (32.5% to 28.4%). From 1983–84 to 1993–94, CS decreased 23.5%.

In summary, even though more women are awarded B.A./B.S. degrees, and even though the percentages of B.A./B.S. degrees awarded to women in disciplines similar to CS increased, the percentage of B.A./B.S. degrees awarded in CS to women decreased.

The College of Engineering Effect

We now consider the relationship between the percentage of degrees awarded to women by a CS department, and the college the CS department is within. We find that CS departments in engineering colleges graduate proportionately fewer women on average than CS departments in non-engineering colleges.

We derived the results in the following manner. The National Center for Education Statistics provided a list of the number of degrees awarded in CS for two academic years: 1991–92 and 1992–93. This list was itemized by gender, institution, and degree. A CS department within a university was classified in either an engineering college (CoE) or a non-engineering college (which we denote as A&S), based on

Table 3. Data classified in this study

Academic Year	B.A./B.S. Degrees Classified	M.S. Degrees Classified	Ph.D. Degrees Classified
1991–92	11,561 (47.1%) from 263 depts.	7,139 (74.9%) from 243 depts.	671 (86.9%) from 86 depts.
1992–93	11,591 (47.8%) from 260 depts.	7,618 (75.0%) from 241 depts.	691 (85.8%) from 94 depts.

Table 4. The College of Engineering effect

Academic Year/College	B.A./B.S. Degrees	% Women	M.S. Degrees	% Women	Ph.D. Degrees	% Women
1991–92/CoE	3,633	22.5	2,613	23.6	360	11.7
1991–92/A&S	7,928	28.3	4,526	29.2	311	12.5
1992–93/CoE	3,710	22.8	3,082	23.4	351	12.2
1992–93/A&S	7,881	26.8	4,536	28.2	340	13.2

the description of the university within the 1993 *Peterson's Guide to Graduate Programs in Engineering and Applied Sciences*. (Only universities that offer graduate degrees in CS were considered, since most universities without a CS graduate program are within A&S. See [3] for more details.)

Although we were not able to classify every department, and although we only considered B.A./B.S. degrees from departments that offer M.S. or Ph.D. degrees, we were able to classify a large number of the CS degrees awarded in 1991–92 and 1992–93 into either CoE or A&S. For example, we were able to classify 47.1% of all B.A./B.S. degrees awarded in CS in 1991–92 (11,561 of 24,557). These 11,561 degrees were awarded from 263 CS departments. (See Table 3 for further details on the data classified in this study.) Note that we only considered degrees awarded in CS; we did not include degrees awarded in computer engineering. (The percentage of degrees in computer engineering awarded to women is dramatically lower than the percentage of degrees awarded in CS to women. For example, only 11.7% of the B.A./B.S. degrees awarded in computer engineering went to women in 1992–93.)

The results are displayed in Table 4. The table contains the number of degrees classified into either CoE or A&S at the B.A./B.S., M.S., and Ph.D. levels, and the percentage of female recipients for the two academic years analyzed. At both the B.A./B.S. and M.S. levels, if a CS department moves from A&S to CoE, the percentage of degrees awarded to women decreases by approximately 18%–26%. At the Ph.D. level, the decrease is less pronounced; if a CS department moves from A&S to CoE, the percentage of

Ph.D. degrees awarded to women decreases by approximately 7%–8%.

The results shown in Table 4 suggest that CS departments in engineering colleges, on average, graduate proportionally fewer women than CS departments in non-engineering colleges. We performed statistical analysis on the percentage of women graduates for the 1991–1992 academic year. We found the difference between the percentage of B.A./B.S. degrees awarded to women by CS departments in engineering colleges and the percentage of B.A./B.S. degrees awarded to women by CS departments in non-engineering colleges was statistically significant with the traditional cutoff of $\text{ALPHA} = 0.01$. The difference for bachelor's degrees was significant both on the raw percentage data and when the percentages were transformed using the arcsin transformation [9]. The difference in the M.S. degrees awarded was significant at $\text{ALPHA} = 0.2$. The statistical analysis strongly suggests that the proportion of females graduating with B.A./B.S. degrees is significantly lower when a CS department is within an engineering college. (In other words, it is highly unlikely the observed difference is a random event.) The statistics do not allow a similar confidence in the significance of the M.S. data.

Over the last decade, we are aware of a number of universities that have moved their CS department from a non-engineering college to an engineering college (for example, Pennsylvania State University and University of Washington). If CS departments continue to move to engineering colleges, we may continue to see a decrease in the percentage of B.A./B.S. degrees awarded in CS to women. There are, however, other factors that may affect the percentage of B.A./B.S. degrees awarded in CS to women as well.

Future Predictions: 1994-95 through 2006-07

The computer industry is growing rapidly. There is a critical shortage of computer scientists in today's job market—nearly 190,000 unfilled information technology positions, not counting small business, government, and nonprofit employers, exist in the U.S. alone [2]. Furthermore, in the year 2005, it is predicted the number of computer professionals

employed as computer scientists and system analysts will be almost double what the numbers were in 1994 [6]. In 1994, there were more than 149,000 and 482,000 computer scientists and system analysts, respectively, in the work force. In 2005, it is predicted there will be more than 282,000 and 927,000 computer scientists and system analysts, respectively, in the work force. As Table 1 shows, we have only been graduating approximately 35,000 students with degrees in CS each year. Thus, it is critical the number of B.A./B.S. degrees awarded in CS over the next decade increases instead of continuing on its current decreasing trend. Fortunately, there is positive evidence a dramatic increase will occur in the near future.

Table 5 lists the projected total number of B.A./B.S. degrees awarded in all disciplines over the next decade, and the projected percentage of the recipients that will be women [8]. The National Center for Education Statistics predict the number of B.A./B.S. degrees awarded at the turn of the century will be slightly fewer than the number currently awarded. However, the number of B.A./B.S. degrees awarded a decade from now will overcome this turn of the century decrease, as well as significantly

surpass the number that is currently being awarded. Furthermore, while the number of B.A./B.S. degrees awarded will fluctuate over the next decade, the percentage of B.A./B.S. degrees awarded to women will continue on its upward trend.

Although the total number of degrees awarded at the B.A./B.S. level is expected to decrease over the next five years, we should see a dramatic increase, not a further decrease, in the number of B.A./B.S. degrees awarded in CS. According to the 1996 CRA Taulbee Survey, the number of B.A./B.S. degrees awarded in CS should increase in the near future, as the number of new bachelor students enrolled in computer science Ph.D-granting departments increased 40% in fall 1996 [1]. Since the number of B.A./B.S. degrees awarded in CS by Ph.D-granting departments should dramatically increase in the near future, we expect to see a corresponding increase in the number of B.A./B.S. degrees awarded in CS by non-Ph.D-granting departments.

However, one question remains: How will the increase in the number of B.A./B.S. degrees awarded

Table 5. Future predictions of B.A./B.S. degrees awarded in all disciplines: 1994–95 to 2006–07

Academic Year	B.A./B.S. Degrees	% Women
1994–95	1,181,000	54.9
1995–96	1,186,000	55.2
1996–97	1,183,000	55.4
1997–98	1,169,000	56.5
1998–99	1,140,000	56.1
1999–00	1,138,000	56.0
2000–01	1,151,000	56.2
2001–02	1,169,000	56.5
2002–03	1,191,000	56.7
2003–04	1,216,000	57.0
2004–05	1,237,000	57.6
2005–06	1,253,000	57.8
2006–07	1,268,000	58.0

in CS affect the percentage of women recipients? As listed in Table 1, the decrease in the number of B.A./B.S. degrees awarded in CS over the last decade was at a faster pace for women than for men. Will the increase in the number of B.A./B.S. degrees awarded in CS occur at a faster pace for women? Or will the proportion of women continue to lag behind their male colleagues? The 1996 CRA Taulbee Survey does not classify the 40% increase of bachelor students in CS by gender [1], so we can only speculate on what the outcome will be.

First, we consider why there is such an increase in the number of new bachelor students in CS. The 1996 CRA Taulbee Survey suggests the marketplace and the Web contributed to this increase [1]; the job opportunities in CS are becoming well-known, and the Web has brought more attention to our discipline than anything in the past.

Second, let us speculate on how the Web will affect the percentage of B.A./B.S. degrees awarded in CS to women. The seventh study of Web users at the Graphic, Visualization, & Usability Center (GVU) at Georgia Institute of Technology states that the core demographics of Web users are stabilizing [5]. In other words, the rate of change in the demographics is much slower than in previous years; for example, the percentage of female respondents to the seventh survey is almost exactly the same as the percentage of female respondents to the survey the previous year. In the seventh survey, with almost 20,000 unique participants, 31.3% of the responses were from females. While other available Web surveys claim a higher proportion of female respondents, we find the Gvu survey is appropriate in our speculation. The Gvu survey claims that, by the nature of their sampling method, the respondents represent *active* Web users. If the Web has affected the increase in new students enrolled at the bachelor's level, we believe it is the active users that are contributing to this effect.

The percentage of B.A./B.S. degrees awarded in

CS to women in 1993–94 was 28.4%. Since the female ratio of active Web users is slightly higher (31.3% versus 28.4%), we may see a *slight* increase in the percentage of degrees awarded in CS to women in the near future. This slight increase, however, is much lower than the 37.1% we enjoyed in 1983–84.

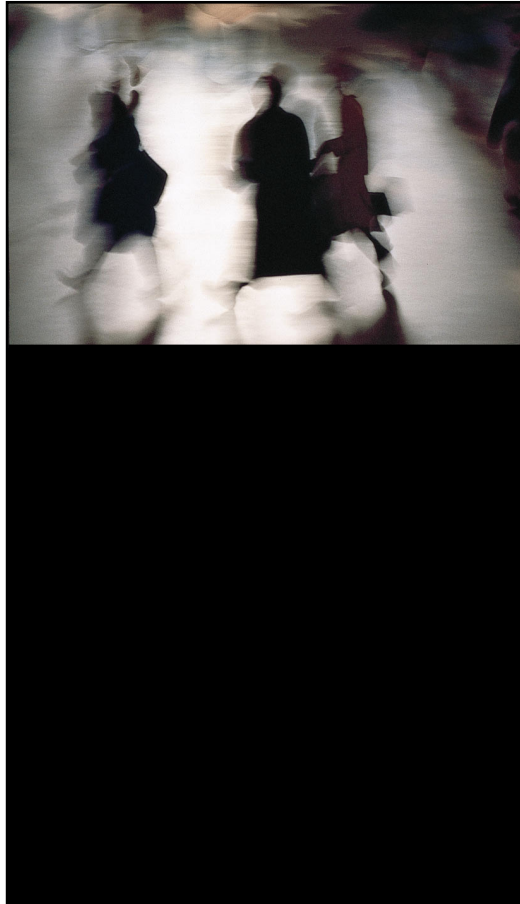
Community Response

Why has the number of B.A./B.S. degrees awarded in CS decreased since 1985? Why is the decrease


occurring at a faster pace for women than men? While the number of B.A./B.S. degrees awarded in CS in 1993–94 is almost equivalent to the number of B.A./B.S. degrees awarded in CS in 1982–83 (24,200 versus 24,510), why is the percentage of degrees awarded to women dramatically smaller today (28.4% versus 36.3%)? The percentage of B.A./B.S. degrees awarded to women in all disciplines increased from 1980–81 to 1993–94; the percentages of B.A./B.S. degrees awarded to women in disciplines similar to CS increased over the same time period. Why has the percentage of B.A./B.S. degrees awarded to women in CS decreased? Why is the percentage of B.A./B.S., M.S., and Ph.D. degrees awarded to women by CS departments in engineering colleges smaller than the corresponding percentages in non-engineering colleges? Will the percentage of degrees awarded in CS to women

continue to lag behind, as we speculate they will, in the next decade? And, most importantly, what can we, as a community, do to improve the situation?

In a paper on women in science and engineering, John White, Dean of Engineering at Georgia Institute of Technology, said, "If we want a different outcome, we're going to have to do things differently. We're making too little progress doing more of the same thing. The time for evolution is passed; it's time for revolution" [11]. White requests a revolution to improve on the small amount of progress in attracting and retaining more women in science and engineering over the last decade. Instead of progress, however, we have seen a deterioration in CS. In order to eventually make progress, computer scientists and



educators seem to need dramatic change in direction. We hope the CS community will become involved in exploring the options and steering those changes. The ACM Committee on Women in Computing (ACM-W)⁴ has established a web site <<http://www.acm.org/women>> that includes data, references, and some of the ideas suggested for improving the current situation. There is also an interactive survey available at the web site.

We urge the CS community to consider the posed questions and respond to the survey. We will compile the responses of the community and present the results, including strategies proposed for attracting and retaining women in CS, in a future issue of *Communications*. If we work together, perhaps we can identify and implement the changes that are necessary to reverse the alarming decline of women's participation in CS. 

REFERENCES

1. Andrews, G. CRA Taulbee surveys. *Computing Research News*, March 1994–97.
2. Arnheim, L. IT Companies heavily courting CS grads. *Computing Research News* 9, 3. (May 1997).
3. Camp, T. CS programs in engineering colleges = fewer females. *J. Women and Minorities in Sci. Eng.* To appear.

⁴The mission of ACM-W is to engage in activities that aim to increase the representation of women in computing.

4. Chandra, A.K., Patterson, D.A., Traub, J., and Young, P. Do we produce too many Ph.D.s? *Computing Research News* 6, 3. (May 1994).
5. Georgia Institute of Technology. GVU's 7th WWW User Survey. Graphic, Visualization, & Usability Center (April 1997). http://www.gvu.gatech.edu/user_surveys/survey-1997-04/
6. Keaton, J. and Hamilton, S. Employment 2005: Boom or bust for computer professionals? *IEEE Comput.* 29, 5 (May 1996), pp. 87–98.
7. National Center for Education Statistics. Digest of Education Statistics. U.S. Department of Education, Washington, D.C., (Nov. 1996).
8. National Center for Education Statistics. Projections of Education Statistics to 2007. U.S. Department of Education, (June 1997) <http://www.ed.gov/NCES/pubs/pj/index.html>
9. Steel, R., and Torrie, J. *Principles and Procedures of Statistics: A Biometrical Approach* (2nd Ed). McGraw-Hill, New York, 1980.
10. Walker, E., and Rodger, S. PipeLINK: Connecting women and girls in the computer science pipeline. In *Proceedings of the National Education Computing Conference*. (1996), pp. 378–384.
11. White, J.A. Women in engineering and science: Does anyone care? In *Proceedings of Bridging the Gender Gap in Engineering and Science: The Challenge of Institutional Transformation* (1995) pp. 41–48.

This work was supported in part by NSF Grant NCR-9702449.

TRACY CAMP (camp@cs.ua.edu) is an assistant professor in the Computer Science Department at The University of Alabama. She is a member of ACM-W.

Permission to make digital/hard copy of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage; the copyright notice, the title of the publication, and its date appear; and notice is given that copying is by permission of ACM, Inc. To copy otherwise, to republish, to post on servers, or to redistribute to lists requires prior specific permission and/or a fee.
