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Gender Differences in Students' Experiences in Computing Education in the United States*

ROLI VARMA[1] and HEIKO HAHN[2]
[1]*School of Public Administration, University of New Mexico, Albuquerque, NM 87131, USA. E-mail: varma@unm.edu*
[2]*Institute for Applied System Science and Information Management, University of the Federal Armed Forces, Munich, Germany*

This paper presents the experiences and perceptions of undergraduate computer science and computer engineering students from Minority Serving Institutions with regard to the classes, teachers, academic advisors, and teaching assistants within their programs. It is based on 150 in-depth interviews with female and male students, members of five major ethnic/racial groups (White, Black, Hispanic, Asian, and American Indian). It shows that significant differences exist between female and male students with respect to their perceptions of classes, teachers, and advisors. Both male and female students noted their dissatisfaction with teaching assistants. The paper concludes with suggestions regarding policy directions to improve the situation for female students.

Keywords: academic advisement; minority-serving institution; pedagogy; retention

INTRODUCTION

THE NUMBER OF bachelor's degrees awarded in computer science (CS) and computer engineering (CE) in the United States grew sharply in the early 1980s, peaked a few years later, and then dropped precipitously before leveling off in the early 1990s; over the next decade, the number of degrees awarded increased steadily but slowly. The number of female students earning a bachelor's degree in CS grew significantly between 1977 and 1985—almost tenfold—whereas for males the increase was about fivefold. In the 10 years between 1985 and 1995, the number decreased by 50% for women and by 30% for men. During the dotcom boom, the number of women earning CS degrees rose by about 50%; the percentage increase for men, 52%, was about the same. However, while male enrollment in CS surpassed its previous 1985 peak, the number of women awarded CS degrees in 2000 was still 30% fewer than in 1985 [8, 9]. Despite some gains, women continue to be underrepresented in CS education and consequently in the CS workforce.

Not surprisingly, scholars [3, 6, 12, 13, 14], professional associations [1, 2, 15], and government analysts [8, 9] have been concerned with factors that lead to underrepresentation of women in CS education. In order to tackle this shrinkage problem in general, a pipeline metaphor for CS education has been proposed. It is believed that if sufficient females are encouraged to pursue science and mathematics in their elementary, middle, and high school years, are exposed to computing early on and encouraged to enter CS programs in college/university, the gender disparities now present in CS will disappear. While these steps are crucial to making improvements, they do not take into account the persistence of barriers to the retention of women in CS programs. Elaine Seymour and Nancy Hewitt, in their book *Talking About Leaving: Why Undergraduates Leave the Sciences* [11], have shown that the primary reason for loss of interest, which leads to students thinking about leaving or leaving the science, mathematics, and engineering (SME) disciplines, was pedagogy. Jane Margolis and Allan Fischer, in their book *Unlocking the Clubhouse: Women in Computing* [6], found that what was true for SME disciplines was also true for CS education. Similarly, a study of CE in Sweden found that the culture of engineering institutions, prevailing teaching methods, and the way subject matter is organized make female students react more negatively than male students [10].

Yet, there have been very few CS studies conducted on women from different ethnic/racial groups and in Minority Serving Institutions (MSI). Generally, it is assumed that what applies to White women and institutions that are not classified as MSI also applies to minority women and MSI, respectively. This paper examines gender differences between male and female students in diverse student populations from MSI in regard to classes, teachers, academic advisors, and teaching assistants—four main pillars of learning in institutions

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of higher education—within their programs. Specifically, it tests the following hypotheses:

H_1: Females and males will differ significantly on their perceptions of CS/CE classes.
H_2: Females and males will differ significantly on their perceptions of CS/CE teachers.
H_3: Females and males will differ significantly on their perceptions of CS/CE academic advisors.
H_4: Females and males will differ significantly on their perceptions of CS/CE teaching assistants.

METHODS

An empirical study was conducted with women and men who had decided to major in CS/CE fields. The study was carried out in seven institutions that granted undergraduate degrees in one or more CS and CE programs and were designated as MSI—belonging to a category of educational establishments such as Hispanic-serving institutions, historically Black colleges and universities, and tribal colleges and universities. To be considered a Hispanic-serving institution, the Hispanic enrollment at a college or university must be at least 25% of the total student enrollment. There are about 200 designated Hispanic-serving institutions. Historically Black colleges and universities were established prior to 1964, their principal mission being the education of Blacks, and are accredited by a nationally recognized accrediting agency or association. There are about 105 designated historically Black colleges and universities. Tribal colleges and universities are those institutions that have American Indian/Alaska Native student enrollments that represent at least 50% of the total student enrollment. There are over 30 tribal colleges and universities, most of them located on reservations (areas with boundaries established by treaty, statute, and/or executive or court order).

Primary data were acquired by Varma through in-depth interviews in 2004–2005. These sessions used interview guides who asked open-ended questions, and followed up with additional relevant questions or probes. The technique of in-depth interviews was considered useful primarily because there is little information on the barriers women in different ethnic/racial groups face in pursuing a CS/CE education. Interviews were conducted with 150 students, divided into groups of 30 (15 female and 15 male) belonging to one of the following five major ethnic/racial groups as designated by the US Census: White, Black, Hispanic, Asian, and American Indian. Random sampling was used to select subjects on sites with sufficient numbers of women and men; however, purposive sampling was used at sites lacking sufficient numbers of some groups (e.g. American Indians) majoring in CS/CE disciplines.

A content analysis coding scheme was developed to assess classes, teachers, academic advisors, and teaching assistants. Two trained coders coded the interviews to ensure that coded data are consistent. The following terms were operationalised:

1. Assessment of the *classes* was any comment about a positive or a negative perception of the CS/CE courses. Example: 'Overall I think they are really good, and I like the material.' = positive perception. 'I thought it would be easy for me to focus on classes. It would be easy for me to stay inspired. But, I need support from fellow students and I need study groups to understand concepts.' = negative perception.
2. Assessment of the *teachers* was any comment about a positive or a negative perception of the teachers. Example: 'I have had good experiences with all of the teachers. I can't think of a bad experience.' = positive perception. 'Not everyone can teach. They all have Ph.D.s and all, obviously they know their subject, but not everyone can teach.' = negative perception.
3. Assessment of the *academic advisors* was any comment about a positive or a negative perception of the academic advisors. Example: 'I appreciate a lot of my academic advisor. Because I think she advises me well. And she helps a lot too.' = positive perception. 'I think they are no help at all. I never feel like I learn anything from them that I don't already know.' = negative perception. Students who did not make use of their academic advisors were put into a third category.
4. Assessment of the *teaching assistants* was any comment about a positive or a negative perception of the teaching assistants. Example: 'They are good. They are the ones that help a lot. Because they are students, they know what you are going through. They are more available for help. And, you can build a more personal relationship with them.' = positive perception. 'Teaching assistants are horrible. They have a stuck-up attitude, kind of snotty at times. They don't know anything.' = negative perception. Students who did not have teaching assistants were put into a third category.

The cross-tabulation function of SPSS version 14.0 was used for testing the significance of the differences in the perceptions of male and female students (H_1–H_4). Statistical testing was either based on Pearson Chi-square or Fischer's exact test. The latter was used if expected counts were less than five. Significant results for differences between female and male students for the five ethnic/racial groups are also reported.

FINDINGS

Assessment of classes

Decisions about what will be taught, how it will be taught, and the standards for evaluating what has been learned are generally made by the faculty in the majority of universities/colleges. Most CS/CE faculty members have access to information about new research on ways to improve classroom instruction through problem-based learning, hands-on experience, use of new technology, and critical thinking. Unfortunately, many CS/CE faculty may not know how to incorporate new methods or may not have the resources to make the necessary changes. In addition, some may not have the time to devote to changing their teaching practices because they are carrying a full teaching load, conducting research activities, and fulfilling their service responsibilities. What is more, although individual faculty members can make style changes, alterations to content and curriculum require support from the department and school/college/university. Too often, this means that CS/CE classroom instruction does not get fine-tuned to meet the emerging needs of diverse students.

Table 1 shows that, whereas 51% of students approved of their CS/CE classes, 49% disapproved of them. In accordance with H_1, significant gender differences exist ($p < 0.05$). Only 43% of female students gave a positive assessment in comparison to 60% of the male students. This result was consistent across the different ethnic/racial groups, with the exception of the Asian group. Comparing the different ethnic/racial groups (i.e. ignoring gender differences), the majority of White and Black students were critical about the classes, whereas the majority of students from other ethnic/racial groups were positive.

Assessment of teachers

An effective teacher places a high priority on his/her students' learning and their appreciation of the subject, and knows it is important for the student to feel valued both for his or her potential and as a person. Although too often taken for granted, it is extremely important to build a respectful relationship between teacher and student because, without a good relationship, new teaching methods, no matter how creative or cutting-edge, will not succeed. Students are affected by what they believe their teachers think of them and their aptitude for a particular subject. Therefore, if teachers treat female and/or minority students differently than their male and White counterparts, they send a message, albeit subtle, that those students are not expected to fully participate or succeed in their CS/CE programs.

Table 2 shows that, overall, students were more or less equally divided between positive (53%) and negative perceptions (48%) of their teachers. However, a deeper examination reveals a significant gender difference ($p < 0.05$) among the students, confirming H_2. Sixty-three percent of the male students thought their teachers were good in comparison to only 42% of the female students. Among ethnic/racial groups, only 20% of White females and 33% of Black and Asian female students had a positive perception of their teachers. Only Hispanic students showed a higher percentage of positive female responses (58%) in comparison to male responses (43%). For all other ethnic/racial groups, at least 50% of the male students gave positive responses, with American Indian male students being the highest (92%). Comparing the female and male students separately for the five ethnic/racial groups, the differences between White, Black, and Asian female and male students were significant at a less strict level of $p < 0.1$. American Indian (81%) students gave the highest positive assessments, followed by Black (52%), Hispanic (50%), Asian (48%), and White (35%).

Assessment of academic advisors

The purpose of having academic advisors is to help students develop a plan to attain their degrees.

Table 1. Assessment of classes

		% within Gender		Total
		Female	Male	
	Positive	43.1	59.7	51.4
	Negative	56.9	40.3	48.6
Statistical significance	Pearson Chi-Square: $p<0.05$; $\chi^2 = 4.003$, df = 1			
Ethnicity of respondents		% within Gender		Total
		Female	Male	
White	Positive	35.7	61.5	48.1
	Negative	64.3	38.5	51.9
Black	Positive	33.3	53.3	43.3
	Negative	66.7	46.7	56.7
Hispanic	Positive	46.7	64.3	55.2
	Negative	53.3	35.7	44.8
American Indian	Positive	42.9	60.0	51.7
	Negative	57.1	40.0	48.3
Asian	Positive	57.1	60.0	58.6
	Negative	42.9	40.0	41.4

Table 2. Assessment of teachers

		% within Gender		
		Female	Male	Total
	Positive	42.3	63.2	52.5
	Negative	57.7	36.8	47.5
Statistical significance	Pearson Chi-Square: $p<0.05$; $\chi^2 = 6.132$, df = 1			
		% within Gender		
Ethnicity of respondents		Female	Male	Total
White	Positive	20.0	50.0	34.5
	Negative	80.0	50.0	65.5
Black	Positive	33.3	71.4	51.7
	Negative	66.7	28.6	48.3
Hispanic	Positive	58.3	42.9	50.0
	Negative	41.7	57.1	50.0
American Indian	Positive	71.4	91.7	80.8
	Negative	28.6	8.3	19.2
Asian	Positive	33.3	64.3	48.3
	Negative	66.7	35.7	51.7

Academic advisors provide assistance in the enrollment process, monitor students' academic progress, address academic concerns, and assist with the program of study. In other words, it is the advisor's job to act as a resource for students every step of the way towards earning a degree. A good academic advisor should be well versed in the particular nature of the field he or she is advising in and be sensitive to the diversity of the students being advised. CS/CE programs are rigorous, demanding, and highly technical; the pace of instruction is fast and a large volume of coursework is presented to students who must master it quickly.

Table 3 shows that half the students gave a positive assessment of their academic advisors, 31% gave a negative assessment, and 19% did not make use of their academic advisors. In accordance with H_3, significant gender differences exist ($p < 0.05$). More female (59%) than male (42%) students gave a positive assessment of their academic advisors. The percentage of students being critical about their academic advisors was almost equal for female (32%) and male students (29%). The percentage of students not seeing their academic advisors is much higher for male students (29%) than for female students (9%). In summary, female students gave more positive

Table 3. Assessment of advisors

		% within Gender		
		Female	Male	Total
	Positive	59.4	41.7	50.4
	Negative	31.9	29.2	30.5
	Don't use	8.7	29.2	19.1
Statistical significance	Pearson Chi-Square: $p<0.05$; $\chi^2 = 10.002$, df = 2			
		% within Gender		
Ethnicity of respondents		Female	Male	Total
White	Positive	53.3	25.0	40.7
	Negative	46.7	25.0	37.0
	Don't use	0	50.0	22.2
Black	Positive	80.0	40.0	60.0
	Negative	13.3	40.0	26.7
	Don't use	6.7	20.0	13.3
Hispanic	Positive	73.3	33.3	53.3
	Negative	26.7	26.7	26.7
	Don't use	0	40.0	20.0
American Indian	Positive	40.0	53.3	48.0
	Negative	50.0	33.3	40.0
	Don't use	10.0	13.3	12.0
Asian	Positive	42.9	53.3	48.3
	Negative	28.6	20.0	24.1
	Don't use	28.6	26.7	27.6

assessments and consulted their academic advisors more intensively.

An analysis of the five ethnic/racial groups reveals significant gender differences ($p < 0.05$) for White, Black, and Hispanic students, but not for American Indian and Asian students. The largest difference was found for the 'don't use' category between White female and White male students. Fifty percent of White male students said that they don't see their academic advisors; in contrast, no White female student gave this response. Similar differences existed between Hispanic female and Hispanic male students (0% vs. 40%). Asian students were the only group with a higher percentage for female students (29%) in comparison to male students (20%). For the 'positive' category, similar large differences were found between Black female (80%) and Black male (40%) students and Hispanic female (73%) and Hispanic male students (33%). In contrast, higher values were found for American Indian and Asian male students. The largest difference for the 'negative' category was between Black female (13%) and Black male (40%) students, which is the only group with a higher rate of male than female students.

Assessment of teaching assistants

Teaching assistants are often delegated considerable responsibility for teaching the basics and responding to undergraduates' questions and problems. For the past 20 years, an increasing number of foreign-born students have been awarded master and doctoral degrees in CS/CE in the United States. This increase along with a declining number of US-born students earning those degrees has resulted in an almost even split between American and foreign-born students enrolled in CS/CE graduate programs. Because most of these foreign-born graduate students are supported by assistantships, they are the ones playing a major role in the instruction, advising, and evaluation of undergraduate students and acting as liaisers between students and faculty. To successfully fulfill their obligations, these teaching assistants must be experts in their subjects and able to facilitate learning by their students. As a general rule, they must also pass the Test of English as a Foreign Language (TOEFL) and meet the minimum proficiency requirements for spoken English before accepting teaching responsibilities.

It should be noted that 17% of the students mentioned that their CS/CE programs did not have teaching assistants. For the students that had contact with teaching assistants, as Table 4 shows, a majority of students (58%) was negative and a minority positive (42%). Female students (63%) were more critical than male students (53%). However, the differences between the perceptions of female and male students were smaller and non-significant; hence H_4 was not confirmed. The comparison of female and male students was consistent across the different ethnic/racial groups. Neither for any female nor for any male group is the percentage of positive responses higher than the percentage of negative responses, even though for some males (Black, Hispanic, and Asian) the percentage of positive and negative responses is equal (50%). Comparing the overall results for the different ethnic/racial groups, the majority of students are negative. Most negative are White (67%), followed by American Indian (61%), Hispanic (56%), Asian (55%) and Black (52%) students.

CONCLUSION

The results showed significant differences between the attitudes of female and male students

Table 4. Assessment of teaching assistants

		% within Gender		
		Female	Male	Total
	Positive	37.0	46.4	41.8
	Negative	63.0	53.6	58.2
Statistical significance	Pearson Chi-Square: ns; $\chi^2 = .997$, df = 1			
		% within Gender		
Ethnicity of respondents		Female	Male	Total
White	Positive	28.6	38.5	33.3
	Negative	71.4	61.5	66.7
Black	Positive	46.2	50.0	48.0
	Negative	53.8	50.0	52.0
Hispanic	Positive	37.5	50.0	44.4
	Negative	62.5	50.0	55.6
American Indian	Positive	28.6	45.5	38.9
	Negative	71.4	54.5	61.1
Asian	Positive	41.7	50.0	45.5
	Negative	58.3	50.0	54.5

Note: The table represents results for students who had contact with teaching assistants.

of CS/CE with respect to the classes, teachers, and academic advisors, thus confirming H_1, H_2, and H_3. The perception of teaching assistants was very critical across all groups and the responses of female students were more critical than those of male students. The results, however, were non-significant and H_4 was not supported. With the exception of academic advisors, the majority of female students showed negative perceptions of the remaining three factors. For male students, a majority of students with negative perceptions could only be found with regard to teaching assistants. Also, male students do not seem to accept their academic advisors, as reflected in the relatively low rate of male students making use of them. Nevertheless, female students showed much lower overall positive perceptions of their studies and related aspects than male students did.

The pipeline metaphor has been used to describe science and engineering career paths from elementary to middle to high school to college to scientists or engineers. Underrepresentation of women and minorities has been explained in terms of a 'leak' in the pipeline. In recent years, however, the pipeline metaphor has been criticized. Scholars have argued instead that the pipeline is obstructed at specific points [5], primarily due to gender bias [4, 7]. Though the issue of gender bias is not a new one, studies on women are seldom disaggregated by ethnicity and race. By including women from different ethnic/racial groups, one can discuss gender bias in undergraduate education in analytical terms, which this study has done.

CS/CE departments can take some steps to make learning experiences more positive for students, particularly for female and non-Asian minority students. With respect to classes, students were mostly critical of the extreme difficulty and high workload, but also because courses were too abstract and tedious, and the class schedule was somewhat inflexible. Students' frustrations can be minimized by increasing feedback on course material, teaching debugging techniques to reduce the time commitment, and adding those assignments that demonstrate the relevance of CS/CE requirements to real-world problems. With respect to teachers, students were critical mostly of the lack of communication, poor teaching styles, and dismissive attitudes towards female students. Teachers can make an effort to interact with students outside the classroom to improve communication. Furthermore, teachers could express their passion for teaching and learn about the latest research in pedagogy. Students were critical of their academic advisors because they planned the entire CS/CE curricula to be finished in four to five years; for many students, however, this schedule was not appropriate due to their marital status, family commitments, and the necessity of having employment. Academic advisors, therefore, need to be aware of students' economic situations and the family obligations of female students when planning their program of study. Students were critical of their teaching assistants because of lack of accessibility, poor language and communication skills, and incomprehensible accents. The relationships between teaching assistants and students can be improved by requiring teaching assistants for whom English is a second language to take courses that will improve their communication and public speaking. In addition, departments could develop handbooks that teaching assistants can reference when the need arises; merely giving teaching assistants an orientation session in their first semester and then leaving them alone is not effective.

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Roli Varma is a Professor and Regents' Lecturer in the School of Public Administration at the University of New Mexico, Albuquerque. She also teaches a core curriculum course, Technology in Society, for the School of Engineering. Her research focuses on women and minorities in information technology education, new immigrants in the science and engineering workforce, the management of industrial research, and professional ethics. She is author of *Harbingers of Global Change: India's Techno-Immigrants in the United States.*

Heiko Hahn received his Ph.D. in Management Information Systems (MIS) from the University of Augsburg, Germany. He worked for the University of New Mexico in 2006 as a Postdoctoral fellow. Currently, he is a Postdoctoral fellow at the University of the Federal Armed Forces, Munich. His main research areas are information systems and statistical and econometric analysis.