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Why so few women enroll in computing? Gender and ethnic differences in students' perception

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Women are seriously under-represented in computer science and computer engineering (CS/CE) education and, thus, in the information technology (IT) workforce in the USA. This is a grim situation for both the women whose potential remains unutilized and the US society which is dependent on IT. This article examines the reasons behind low enrollment of women in CS/CE education at institutions of higher education. It is based on 150 in-depth interviews of female and male undergraduate students majoring in CS/CE, members of five major ethnic groups (White, Afro-American, Hispanic, Asian American and Native American) from seven Minority-Serving Institutions in the USA. The article finds bias in early socialization and anxiety toward technology as two main factors responsible for the under-representation of women in CS/CE education. It further shows significant gender and ethnic differences in students' responses on why so few women enroll in CS/CE.

Keywords: gender gap; gender socialization; math anxiety; minority-serving institutions

Introduction

A mapping of the development of the US computer science (CS) field in the last 30 years shows significant gender variations. The number of women earning a bachelor's degree in CS increased annually from 1539 in 1977 to 14,431 in 1985, by almost 10-fold; whereas, for men, the increase was about 5-fold, from 4887 to 24,690 for the same period (National Science Board, 2004). Subsequently, the total number of bachelor's degrees awarded in CS dropped precipitously before leveling off in the early 1990s. By 1995, this number had decreased by half for women (7063), whereas, there was a 30% decrease for men (17,706). During the dotcom boom in the late 1990s, a surge occurred. By 2000, the number of men gaining a bachelor's degree in CS (26,914) surpassed its previous

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1985 peak year; however, the number of women earning a bachelor's degree in CS (10,474) was still 30% less than in 1985. In 2005, men increased their share to 39,329 or 78% of bachelor's degrees in CS, whereas, the increase for women was marginal (11,235 or 22%) (National Science Board, 2008). This suggests that CS does not seem to be a popular major among female students in the USA.

Since the early 1990s, literature on the under-representation of women in computing education in the USA has proliferated (see, Ahuja, 2002; Cohoon & Aspray, 2006; Singh, Allen, Scheckler, & Darlington, 2007). The National Science Foundation (e.g. Information Technology Workforce Program from 2000 to 2005; Broadening Participation in Computing Program since 2005) has been supporting projects to increase representation of women and minorities in computing education and the information technology (IT) workforce. Continued research on the reasons behind under-representation of women in computing education has centered on two broad areas: (i) the gendered differences in the socialization of computer-oriented knowledge and (ii) the gendered differences in performance and self-efficacy in mathematics and computing.

The role socialization plays, both at an early age and once in a collegiate setting, in developing gendered participation in and attitudes about the domain of computing cannot be under-emphasized in explaining the continued presence of the gender gap. As Cohoon and Aspray (2006) have argued in their compilation titled, *Women and Information Technology: Research on Underrepresentation*, biological gender differences simply cannot account for the participation gap. Instead, issues of deeply seeded social and cultural ideas lead to an emphasis on the masculine with regard to computing.

Studies show that the dearth of women in the computing field is chiefly a leaky pipeline issue – a concept generally used to refer to the steady attrition of women throughout the formal computing system, from primary education to decision making (Beyer, DeKeuster, Walter, Colar, & Holcomb, 2005). By the end of middle school, students develop the notion that mathematics, sciences, and computing fields are for white males (Clewell & Braddock, 2000). Furthermore, these perceptions are found to exist more often for girls than for boys (Trauth, 2002). Many school teachers, due to insufficient training and unequal emphasis to male and female students, act in complicity with the gendered binary of masculine domination in the fields of mathematics, sciences, and computing (Barker & Aspray, 2006). The ideas held by females of who should participate in computing affect the educational pipeline into students' undergraduate years.

The intrinsic nature of the white male orientation of the computing field, including a competitive classroom environment and differences in faculty treatment of male and female students, is seen to support

incoming male assumptions while challenging their female peers (Seymour & Hewitt, 1997). One significant factor for the replication of these norms is the lack of female role models in computing (Jepson & Perl, 2002). Role models could help to de-mystify aspects of the field such as stereotyping of those who study computing as "nerdy" or the prevalence of geek culture (National Academy of Sciences, 1997). It seems students in an all-female CS classroom tend to report higher levels of teacher support, computer-related confidence, and academic intentions to pursue CS than females in mixed-gender CS courses (Crombie, Abarbanel, & Trinneer, 2002).

Due to bias in early socialization, an observable gender gap in mathematics and science appears by the end of 5th grade. This is despite the fact boys and girls enter kindergarten with an equal ability in overall mathematics and science performance levels. The difference in mathematics and science continues in both the 8th and 12th grades (National Science Board, 2008). The end result is that boys and girls enter a university with different achievement levels in mathematics and science. It should be noted that since the mid-1990s, the gender gap in standardized mathematics and science scores has narrowed.

It is, therefore, no surprise that men consistently maintain more positive attitudes and confidence in their abilities in computing in a university than women (Cooper & Weaver, 2003). One study found that though women were generally positive about the field of CS and the career possibilities, the group negatively assessed their ability to perform well in classes (Beyer, Rynes, & Haller, 2004). Margolis and Fisher (2002) have asserted that difference in socialization and the frequency of technical anxiety in women explain why it may take up to two full years for female students to feel comfortable with the classroom and material of CS. Irani (2004) has argued that the act of establishing an "identity of competence" is necessary for women to situate themselves in CS culture and verify legitimacy.

The development of a debilitating anxiety based on students' underlying perceptions of the field and a loss of self-confidence is often a leading factor in women switching out of the computing field (Margolis & Fisher, 2002). Varma (2007) showed that female students talk about leaving the computing field mostly because of technical difficulties they face in the program. Beyer et al. (2005) found that many women found their teachers' perceptions of females to be generally lower than those of the males. Such factors result in a decrease in self-confidence and an increase in anxiety toward computing.

Yet, there have been few empirical studies conducted on why students think there are few women pursuing a degree in CS; most empirical studies assess under-representation of women, for example, from the enrollment trends and graduation rates in CS, exposure and use of

computers, performance and self-confidence in mathematics and/or CS, academic environment of CS programs, and the image of careers with a CS degree. It is important to get students' thoughts and impressions on the challenges women face to enroll in CS. Furthermore, very few empirical studies have included students from different ethnic groups and from Minority-Serving Institutions. Generally, it is assumed what is true of the White group is also true for minorities, and what holds for main stream institutions also holds for Minority-Serving Institutions.

This article analyzes differences between female and male students from different ethnic groups in CS/ computer engineering (CE) programs at Minority-Serving Institutions in the USA with respect to why there are few women studying CS/CE. To examine cross-gender and cross-ethnic differences on women's participation in CS/CE education, the article tests the following five hypotheses:

(1) H_1: Female and male students will vary significantly in their perception on under-representation of women in CS/CE.
(2) H_2: Students belonging to different ethnic groups will vary significantly in their perception on under-representation of women in CS/CE.
(3) H_3: Female students belonging to different ethnic groups will vary significantly in their perception on under-representation of women in CS/CE.
(4) H_4: Male students belonging to different ethnic groups will vary significantly in their perception on under-representation of women in CS/CE.
(5) H_5: Female and male students belonging to different ethnic groups will vary significantly in their perception on under-representation of women in CS/CE.

Methodology and analysis

To understand reasons for under-representation of women in CS/CE in institutions of higher education, an empirical study was conducted with undergraduate students who were majoring in a CS or CE field in 2004–2005. It was carried out in seven institutions that granted undergraduate degrees in one or more CS and/or CE programs and were designated as Minority-Serving Institutions in the USA – a category of educational establishments, such as Hispanic-Serving Institutions, Historically Black Colleges and Universities, and Tribal Colleges and Universities. Face-to-face interviews were conducted with 150 students, divided into groups of 30 (15 females and 15 males) belonging to one of the following five major ethnic groups: White, Afro-American, Hispanic, Asian American, and Native American. Data collection involved using interview guides, asking

the same 61 open-ended questions, recording the answers, and following up with additional relevant questions or probes. Students interviewed were in their second and third years of CS/CE study. Random sampling was used to select students on sites with sufficient numbers of female and male students; however, purposive sampling was used at sites lacking sufficient numbers of some groups (e.g. Native Americans) majoring in CS/CE.

This article presents findings from one key question: Why do you think there are so few women pursuing a degree in CS/CE at your institution? A content analysis coding scheme was developed to analyze interview data. Students' responses were coded into three categories: (1) gendered socialization, (2) technical anxiety, and (3) other reasons. Statements were coded only once in a single category, creating an exclusive coding system. Two independent trained coders coded the interviews to ensure consistency and objectivity. The cross tabulation function of SPSS version 14.0 was used for testing the significance of the differences in students' perceptions along gender and ethnic lines (H_1–H_5). Statistical testing was based on Pearson Chi-square (χ^2) test or Fischer's exact test. The latter was used if expected counts were less than five. Findings are presented first by using interview excerpts to demonstrate how concepts are defined and operationalized. Then, they are presented by using quantitative data and statistical analysis to illustrate the tests of significance.

Findings

The "gendered socialization" category incorporated students' statements which showed that society (including family members) has higher expectations for boys than girls, that children are taught by teachers with bias that girls are good in "soft" fields whereas boys are good in "hard" fields, and suggested there is a scarcity of role models for girls both at home and in schools for computing.

A number of students talked about the "gender stereotype" which ties men to technology, but not women. As one Hispanic male believed, "I do not think women and technical stuff go together". Similarly, a White male proclaimed, "Well, it is a sexist thing to say. But, boys are rational and girls are emotional". An Afro-American male generalized, "The society teaches children that men are supposed to take on the larger tasks, important tasks and women are supposed to take manageable tasks". Female students were conscious of the cultural role assigned to them. One Hispanic female noted, "It is in the air, it is everywhere that women should not get into engineering, science or mathematics fields". The same sentiment was expressed by an Asian American female, "There is a stereotype that girls are not meant to be in computer science".

Some students were rather specific on the sources of the gendered division. A Hispanic male blamed "parents [who] want their sons to be computer engineers or computer scientists and do whatever it takes to make it happen. But, they do not do the same for their daughters". It is partially because, a Native American male generalized, "Motherhood comes early for a lot of Native American females, so immediately the success rate for freshmen women to get to the point of computer science, is very low". Similarly, a Hispanic male justified, "This is mainly because of our culture. Hispanic women are supposed to get some sort of careers so they can have enough time to be a housewife, raise children, and prioritize family". This Hispanic female resented family responsibility laid solely on women, "We have children. So, we have to take care of them. Men are not expected to deal with children. They get out easier than women".

Most students, however, pointed their fingers to schools for not properly encouraging girls in mathematics and sciences. A White male said, "It is the mental block girls get in schools. They get some teachers who tell them they cannot do it and they end up believing them". Similarly, an Afro-American male noted that "from elementary school onwards, men are more encouraged to go into math and science type of fields and women are discouraged to go into those fields". A Native American female recalled, "Girls are not encouraged to do well in math in elementary school, in middle school, and in high school, at least this has been my experience". Similarly, an Afro-American female had encountered teachers "at the lower level of school pushing girls towards English and boys towards math". A White female explained, "It is not as direct as it once was, like your school counselor in high school will not tell you, 'you are a girl, what are you thinking about doing that for'. But, when I went to get counseled, it was not the first thing on the counselor's agenda, 'oh, you could take more math and science'".

Some students also mentioned that fewer females in the field further reinforce the image that computer-related fields are not meant for women. As an Asian American male noted, "There are not many females in computer science so they get discouraged and walk away". Similarly, this Hispanic male believed, "It has been a male dominated industry. There are not large numbers of big females at the corporate level of computer science so it draws attention more to the male". An Afro-American female said jokingly, "I guess, we are waiting for Mrs. Bill Gates, the Oprah Winfrey of computer science".

The category of "technical anxiety" consisted of students' remarks which conveyed women lack confidence in mathematics, the sciences, and CS/CE; believe CS/CE curricula is too demanding; vision computers as being only for men; contemplate that CS/CE makes them look geeky and unfeminine; and do not have exposure to and use of computers at home and in schools.

Many male students used words such as "anxious", "apprehensive", "frightened", "intimidated", "nervous", "petrified", "scared", "terrified", and "worried" to describe women's self-efficacy and self-confidence in technical fields in general and mathematics and CS/CE in particular. They further contrasted this with women opting for "less technical" and "easier" majors, such as arts, English, humanities, and social sciences. A Hispanic male believed, "Women do not like to get too technical. So, they take a liberal arts major or sociology major rather than computer science because it is very very technical". Similarly, an Afro-American male believed, "There are a lot of men because they are interested in computers, in the technical aspect of it. I am not talking about getting on the Internet and browsing around for clothes or checking email. Most women do not want to be bothered with the technical stuff". A White male proclaimed, "You have to have a technical background to go into computer science and women are kind of turned-off by that. So, you find them going into fine arts". Likewise, an Asian American male spoke, "In general women tend to hate math and you have to go through a certain level of math to get into the computer science". This Native American male narrated his own experience, "I know one of my friends who is a woman and she always says that I cannot do engineering, I am not smart enough. So, I think they may be thinking they are not smart enough to be in computer science".

Most female students found anxiety in technical fields either due to lack of exposure/use of computers or an outcome of gendered socialization. An Afro-American female found, "Guys are so confident, even when they do not have a reason to be, they just are ... Many women are intimidated because they have not really had that much experience with computers from the programming aspect". A Hispanic female narrated, "Once, I went to a guy friend of my younger sister who I believe is in the CS program. He had all sorts of equipment and was showing me games and programs that he had made. And, I felt not so advanced. I never had such equipment. Actually, I did not know about some of them". A White female thought women think CS is "a scary subject because they did not get the encouragement from their high schools". Similarly, an Asian American female found, "A lot of women are intimidated by it" because they "did not get proper training back in high school".

In addition, there is a perception that the fields of CS/CE are difficult and demanding. An Asian American female believed, "Just the horror stories they hear that CS requires a lot of work". Similarly, an Afro-American female thought, "Honestly, it is tough, it is very tough, most of them just run away". A Hispanic female acknowledged, "The reputation of this career is very difficult, very tedious and it is not something within our culture that we would go for". Another one said, "It is very time consuming. You have to have a lot of time to dedicate. Look at me, I really do not have time to do my hair and fix myself". A Native American

female noticed that her female friends "thought that it was a lot of work and after the first semester they got scared and started backing up and started something else".

Some anxiety among women was seen as associated with the image of computing work. A White male said, "There is sort of a stigma attached to computers. Sort of nerd thing, anti-social, weirdoes who smell funny, wear glasses, and have difficulty standing upright". An Afro-American male thought, "Computer science is looked down upon because of the geekier stuff and women do not want to be associated with it so much". Female students talked about incompatibility between computers and social relations. A White female believed, "[Women] cannot sit in front of a computer that long because they are more social, and this is a pretty anti-social career choice. If you cannot really talk to anyone about what you are doing, and you sit in front of your computer for so many hours, it really strains your social status". Similarly, a Native American female characterized, "I honestly think you have to be very non-communicative. You have to sit there for hours at a time not talking to anybody, just staring at a screen. I know a lot of girls who just have to talk to somebody like every couple of hours or something".

The final category of "other reasons" included observations when students gave no particular reasons, had not thought about it, or mentioned not everyone has to go into CS/CE. It is not clear why some students chose not to respond to this question.

Generally, students conveyed, "[We] do not know. Honestly, [we] do not know". Some students questioned under-representation of women in computing. A Hispanic male sought clarification, "I do not know why. Are you sure there are not enough women in computer science?" An Asian American female was puzzled, "I really do not know why women do not take up computer science. They should take it actually". "I thought it was strange that a lot of foreign women come over here to learn our computer technology. They do not even speak good English. But, they are jumping at a chance to learn. But many American women do not jump at a chance to learn computer technology", noted another one. This Hispanic female was rather casual, "Not everyone has to be in computer science". A Native American female advised, "There is a woman sitting there, go and ask her why she is not a computer science major. I know why I am in the field and I do not know why others are not in the field".

Gender differences

The first hypothesis predicted that female and male students would differ significantly in their perception on under-representation of women in CS/CE. Table 1 gives χ^2 value of 6.770 with small p-value (0.034) for df = 2,

which is significant at $\alpha = 0.05$. This suggests that gender strongly affects students' perception on why there are few women studying CS/CE, thus confirming H_1.

Table 1 shows that most students attributed gendered socialization (39.3%) and technical anxiety (38.7%) as the main reasons for under-representation of women in CS/CE. The table also shows that female students are more likely to say gendered socialization (45.3%) than male students (33.3%). Similarly, slightly more female (41.3%) than male (36.0%) students are likely to point out technical anxiety. In contrast, male students (30.7%) are more likely to say other reasons than female students (13.3%).

Ethnic differences

The second hypothesis predicted that students belonging to different ethnic groups would vary significantly in their perception on under-representation of women in CS/CE. Table 2 gives large χ^2 (16.638) with small p-value (0.034) for df = 8, which is significant at $\alpha = 0.05$. This

Table 1. Reasons for so few women in computing, by gender.

Reasons	Total students		Female students		Male students	
	n	%	*n*	%	*n*	%
Gendered socialization	59	39.3	34	45.3	25	33.3
Technical anxiety	58	38.7	31	41.3	27	36.0
Others	33	22.0	10	13.3	23	30.7
Total	150	100	75	99.9	75	100

Statistical significance H_1: $\chi^2 = 6.770$; $p = 0.034$; df = 2.

Table 2. Reasons for so few women in computing, by ethnicity.

Reasons	Total students		White students		Afro-American students		Hispanic students		Asian American students		Native American students	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Gendered socialization	59	39.3	16	53.3	12	40.0	13	43.3	10	33.3	8	26.7
Technical anxiety	58	38.7	9	30.0	13	43.3	13	43.3	15	50.0	8	26.7
Others	33	22.0	5	16.7	5	16.7	4	13.3	5	16.7	14	46.7
Total	150	100	30	100	30	100	30	100	30	100	30	100

Statistical significance H_2: $\chi^2 = 16.638$; $p = 0.034$; df = 8.

suggests that ethnicity strongly affects students' perception on why there are few women studying CS/CE, thus supporting H_2.

Table 2 demonstrates more students pointed out gendered socialization or technical anxiety than other reasons for under-representation of women in CS/CE for each ethnic group except for Native American, in which more students chose other reasons. A breakdown by ethnicity shows that White students (53.3%) are more likely to believe in gendered socialization than Hispanic (43.3%), Afro-American (40.0%), Asian American (33.3%), and Native American (26.7%) students. Asian American students (50.0%) are more likely to criticize technical anxiety than Afro-American and Hispanic (43.3% each), White (30.0%), and Native American (26.7%) students. Native American students (46.7%) are more likely to consider other reasons than White, Afro-American, and Asian American (16.7% each), and Hispanic (13.3%) students.

Women by ethnicity

The third hypothesis predicted that female students belonging to different ethnic groups would vary significantly in their perception on under-representation of women in CS/CE. Table 3 gives large χ^2 (17.184) with small p-value (0.028) for df = 8, which is significant at $\alpha = 0.05$. The Fisher exact test also gives small p-value (0.048). This suggests that ethnicity strongly affects female students' perception on why there are few women studying CS/CE, thus verifying H_3.

Table 3 shows that more female students indicated gendered socialization (45.3%) or technical anxiety (41.3%) than other reasons (13.3%) for under-representation of women in CS/CE. Gendered socialization seems to be a reason more for White (60.0%), followed by Afro-American and Hispanic (53.3% each), and the least with Asian American (26.7%), followed by Native American (33.3%) female

Table 3. Reasons for so few women in computing, women by ethnicity.

	Total students		White students		Afro-American students		Hispanic students		Asian American students		Native American students	
Reasons	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Gendered socialization	34	45.3	9	60.0	8	53.3	8	53.3	4	26.7	5	33.3
Technical anxiety	31	41.3	6	40.0	7	46.7	6	40.0	8	53.3	4	26.7
Others	10	13.3	0	0	0	0	1	6.7	3	20	6	40.0
Total	75	99.9	15	100	15	100	15	100	15	100	15	100

Statistical significance H_3: $\chi^2 = 17.184$; $p = 0.028$; df = 8; Fisher exact test $p = 0.048$.

students. Technical anxiety appears to be a reason more for Asian American (53.3%), followed by Afro-American (46.7%), White and Hispanic (40% each), and the least with Native American (26.7%) female students. Interestingly, more Native American female students (40%) thought there were other reasons for under-representation of women in CS/CE whereas White and Afro-American female students did not give this to be the case at all; very few Hispanic (6.7%) and Asian American (20%) female students pointed their fingers to other reasons.

Men by ethnicity

The fourth hypothesis predicted that male students belonging to different ethnic groups would vary significantly in their perception on under-representation of women in CS/CE. Table 4 gives large χ^2 (9.053) with large p-value (0.338) for df = 8, which is insignificant at $\alpha = 0.05$. The Fisher exact test also gives large p-value of 0.367. This suggests that ethnicity does not affect male students' perception on why there are few women studying CS/CE, thus refuting H_4.

Table 4 exhibits that there are no significant differences among male students belonging to different ethnic groups. The differences among technical anxiety (36%), gendered socialization (33.3%), and other reasons (30.7%) for male students are small. The only exception is other reasons for Native Americans (53.3%) who have the biggest representation among all ethnic groups.

Gender within ethnicity

The fifth hypothesis predicted that female and male students belonging to different ethnic groups would vary significantly in their perception on under-representation of women in CS/CE. Table 5a–e shows that gender has a strong effect for White and Afro-American ethnic groups, but not

Table 4. Reasons for so few women in computing, men by ethnicity.

	Total students		White students		Afro-American students		Hispanic students		Asian American students		Native American students	
Reasons	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Technical anxiety	27	36.0	3	20.0	6	40.0	7	46.7	7	46.7	4	26.7
Gendered socialization	25	33.3	7	46.7	4	26.7	5	33.3	6	40.0	3	20.0
Others	23	30.7	5	33.3	5	33.3	3	20.0	2	13.3	8	53.3
Total	75	99.9	15	100	15	100	15	100	15	100	15	100

Statistical significance H_4: $\chi^2 = 9.053$; $p = 0.338$; df = 8; Fisher exact test $p = 0.367$.

Table 5. Reasons for so few women in computing gender within ethnicity.

Reasons	Total students		Female students		Male students	
	n	%	*n*	%	*n*	%
(a) Gender within White ethnicity*						
Gendered socialization	16	53.3	9	60.0	7	46.7
Technical anxiety	9	30.0	6	40.0	3	20.0
Others	5	16.7	0	0	5	33.3
Total	30	100	15	100	15	100
(b) Gender within Afro-American ethnicity†						
Technical anxiety	13	43.3	7	46.7	6	40.0
Gendered socialization	12	40.0	8	53.3	4	26.7
Others	5	16.7	0	0	5	33.3
Total	30	100	15	100	15	100
(c) Gender by Hispanic ethnicity‡						
Gendered socialization	13	43.3	8	53.3	5	33.3
Technical anxiety	13	43.3	6	40.0	7	46.7
Others	4	13.3	1	3.3	3	10.0
Total	30	100	15	100	15	100
(d) Gender within Asian American ethnicity§						
Technical anxiety	15	50.0	8	53.3	7	46.7
Gendered socialization	10	33.3	4	26.7	6	40.0
Others	5	16.7	3	20.0	2	13.3
Total	30	100	15	100	15	100
(e) Gender within Native American ethnicity¶						
Others	14	46.7	6	40.0	8	53.3
Gendered socialization	8	26.7	5	33.3	3	20.0
Technical anxiety	8	26.7	4	26.7	4	26.7
Total	30	101	15	100	15	100

*Statistical significance H_5: $\chi^2 = 6.250$; $p = 0.044$; df = 2; Fisher exact test $p = 0.0461$.
†Statistical significance H_5: $\chi^2 = 6.410$; $p = 0.041$; df = 2; Fisher exact test $p = 0.054$.
‡Statistical significance H_5: $\chi^2 = 1.769$; $p = 0.413$; df = 2; Fisher exact test $p = 0.492$.
§Statistical significance H_5: $\chi^2 = 0.667$; $p = 0.717$; df = 2; Fisher exact test $p = 0.791$.
¶Statistical significance H_5: $\chi^2 = 0.786$; $p = 0.675$; df = 2; Fisher exact test $p = 0.892$.

for Hispanic, Asian American, and Native American ethnic groups on why there are few women in CS/CE.

For the White ethnic group, Table 5a gives χ^2 value of 6.250 with small p-value (0.044) for df = 2, which is significant at $\alpha = 0.05$. The Fisher exact test also gives small p-value of 0.0461. This suggests that gender affects White students' perception on why there are few women studying CS/CE, thus substantiating H_5 for the White ethnic group.

Table 5a shows that a large majority of White students believed gendered socialization (53.3%) resulted in fewer women in CS/CE, followed by technical anxiety (30%); very few thought there were other reasons (16.7%). There are more female (60%) than male (46.7%) students suggesting gendered socialization, and more female (40%) than male (20%) students pointing to technical anxiety. Whereas male students

(33.3%) thought there may be other reasons, none of the female students thought this to be the case.

For the Afro-American ethnic group, Table 5b gives χ^2 value of 6.410 with small p-value (0.041) for df = 2, which is significant at $\alpha = 0.05$. The Fisher exact test also gives p-value of 0.054, which is close to significant at $\alpha = 0.05$. This suggests that gender affects Afro-American students' perception on why there are few women studying CS/CE, thus proving H_5 for the Afro-American ethnic group.

Table 5b shows that a large majority of Afro-American students believed technical anxiety (43.3%) resulted in fewer women in CS/CE, followed by gendered socialization (40%); very few thought there were other reasons (16.7%). There are more female (53.3%) than male (26.7%) students suggesting gendered socialization, and slightly more female (46.7%) than male (40%) students pointing to technical anxiety. Whereas male students (33.3%) thought there may be other reasons, none of the female students thought this to be the case.

For the Hispanic ethnic group, Table 5c gives χ^2 value of 1.769 with large p-value (0.413) for df = 2, which is insignificant at $\alpha = 0.05$. The Fisher exact test also gives large p-value of 0.492. This suggests that gender does not affect Hispanic students' perception on why there are few women studying CS/CE, thus not supporting H_5 for the Hispanic ethnic group.

Table 5c shows that a large majority of Hispanic students believed gendered socialization (43.3%) resulted in fewer women in CS/CE. Here, differences between female (53.3%) and male (33.3%) students are large. However, differences between female and male students for technical anxiety (40% vs. 46.7%) and for other reasons (3.3% vs. 10%) are not large.

For the Asian American ethnic group, Table 5d gives χ^2 value of 0.667 with large p-value (0.717 for df = 2), which is insignificant at $\alpha = 0.05$. The Fisher exact test also gives large p-value of 0.791. This suggests that gender does not affect Asian American students' perception on why there are few women studying CS/CE, thus disproving H_5 for the Asian American ethnic group.

Table 5d shows that half of Asian American students thought technical anxiety resulted in fewer women in CS/CE; little over one-third believe it to be due to gendered socialization. Except gendered socialization, differences between female and male students on technical anxiety (53.3% vs. 46.7%) and other reasons (20% vs. 13.3%) are small.

For the Native American ethnic group, Table 5e gives χ^2 value of 0.786 with large p-value (0.675) for df = 2, which is insignificant at $\alpha = 0.05$. The Fisher exact test also gives large p-value of 0.892. This suggests that gender does not affect Native American students' perception on why there are few women studying CS/CE, thus refuting H_5 for the Native American ethnic group.

Table 5e shows that a large majority of Native American students believed other reasons (46.7%) resulted in fewer women in CS/CE than gendered socialization and technical anxiety. The differences between female and male students on other reasons (40% vs. 53.3%) and gendered socialization (33.3% vs. 20%) are small; there are no differences between female and male students on technical anxiety.

Discussion and conclusions

A large majority of students believe either gendered socialization or technical anxiety is a prime reason explaining why fewer women than men pursue an undergraduate degree in CS/CE. The study has further shown that there are significant gender and ethnic differences on students' perceptions about why few women enroll in CS/CE studies. Female students are more likely to point out gendered socialization and technical anxiety than male students. White students, more than the other groups, tend to blame gendered socialization and Asian American students lean towards the role played by technical anxiety. Ethnicity shows significant differences among female students, but not among male students. Interestingly, Native American female students do not believe either in gendered socialization or in technical anxiety but feel there are other reasons for low enrollment of women in CS/CE. Also, gender correlated with a strong divide for White and Afro-American ethnic groups, but not for Hispanic, Asian American, and Native American ethnic groups on why few women enroll in CS/CE studies.

This study suggests that teachers in elementary, middle, and high schools need to improve their style of teaching so as not to reproduce the mindset that girls should be motivated towards arts, humanities, and social sciences fields and boys towards mathematics, hard sciences, and computing fields. Both boys and girls need to be taught that computers are for them. Most importantly, school teachers need to equally expose both boys and girls to specific uses of computers, and must rid themselves of the view that boys are "naturally" better than girls in mathematics. The stereotypes regarding computers and good CS/CE students need to be dealt with. It is important that female students perceive that studying CS/CE is consistent with their view of themselves as members of a group. To make the general environment more female student-friendly, faculty need to be educated about the types of attributes and behaviors that create the stereotypes about CS/CE. These steps would help to alleviate much of the problem related to technical anxiety that female students face.

Since female students feel their schools do not prepare them well for CS/CE study at the university level, there is a need to improve their mathematical and programming skills. It is important that those teaching beginning programming and remedial mathematical courses are

experienced in female students' issues. These courses should be taught by experienced teachers, and not by graduate students or part-time faculty. To foster user-friendly classrooms for female students, CS/CE departments should train faculty to demonstrate appreciation for their learning styles and social context. Also, it will be helpful if female students interact with the faculty outside of the classroom so that they may develop a sense of belonging to the CS/CE program. A positive student–student relationship is also important for maintaining a healthy environment. CS/CE departments should recruit graduate female students from all ethnic groups, not just from White group, to serve as mentors for female undergraduate students.

Though this study has included students from different ethnic groups, it is not a study of the status of minorities in CS/CE. There is a need to conduct future investigations on why Afro-Americans, Hispanics, and Native Americans are under-represented, whereas, Asian Americans are over-represented in CS/CE. Since results suggest that there are important differences in the perception of students belonging to different ethnic groups, studies need to be undertaken with regard to how gender and ethnicity intersects in women's decisions to consider enrolling in CS/CE.

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