The state of women in computer science:

An investigative report

BY ALISON DENISCO

Top colleges boast about reaching gender parity in ‘intro to computer science’ courses. But very few of those women go on to graduate with a CS degree. Here’s why.

Image: iStockphoto/ijeab

In the classrooms at Georgia Tech, among the laptops and notebooks and lines of code, senior computer science major Marguerite Murrell likes to play a game she's dubbed "Count the Girls."

"If I can keep it under two hands, then I win," Murrell said. "There are certainly some girls, probably more than some other computer science programs in the nation. But it's a lot of guys."

Women earn **only 18%** of computer science bachelor's degrees in the United States. And leaders such as Apple CEO Tim Cook have **stated** that if the US tech industry doesn't solve its gender imbalance issues then America will lose its lead in tech.

But in recent years, a number of top colleges have made efforts to draw women into the field with revamped introductory courses that make the technology less intimidating for those that enter college without prior programming experience—largely, women—among other efforts. Many of these schools boast about gender parity in these basic courses and incoming freshman classes. But for upper-level students, men continue to dominate technical courses in robotics, machine learning, and security, and "Count the Girls" still yields poor results in those classes.

A confluence of factors prevent women from pursuing and persisting in computer science majors, according to Wendy DuBow, director of evaluation and senior research scientist at the National Center for Women & Information Technology. A lack of exposure to computer science and engineering concepts in middle school and high school, well-meaning teachers or parents steering girls away from tech-focused classes, and a general lack of awareness of potential careers in the tech field all contribute.

Recent high-profile sexual harassment cases at tech firms such as Uber also do not make the field appear as an attractive place for women to build a career, DuBow said, no matter how lucrative.

Carnegie Mellon University, Massachusetts Institute of Technology (MIT), Harvard University, Stanford University, University of California-Berkeley, and Georgia Institute of Technology have all made a concerted effort to attract female students to computer science programs.

Image: Michael Henninger/Carnegie Mellon University

Students at Carnegie Mellon are glued to their laptops as they prepare their latest assignments.

"Academic institutions that commit to parity really do start to see results when they use research-based practices, like scaffolding their intro courses or making sure their faculty use inclusive pedagogy in the classroom," DuBow said. However, challenges with isolation, stereotyping, and confidence still remain.

What follows is a look beyond the glossy college catalogues into what female computer science majors actually experience on campus, and why changing introductory courses isn't enough to build the pipeline of women needed to fill tech jobs.

Progress made, work ahead

Many colleges recognize that the way their computer science programs were structured discouraged women from entering, said Elizabeth Ames, senior vice president of marketing alliances and programs for the Anita Borg Institute. For example, entry-level courses often assumed that students had a background in programming already. And, women in tech had little community on campus.

The oft-named success story of changing this approach is found at Harvey Mudd College in Claremont, CA, where the percentage of female computer science majors grew from less than 15% in 2006 to 55% in 2016, largely thanks to the **initiatives put in place** by its president Maria Klawe.

Carnegie Mellon University has seen similar results: Women made up more than 48% of incoming freshman in the computer science major in 2016-17—a far cry from 8% in the 1990s, and even 34% in 2013. Many of the changes were spurred by Lenore Blum, a professor of computer science who joined the faculty in 1999.

Her guiding philosophy? "The minority in any community does not have the same access to the critical academic and professional opportunities and advantages that the majority has, and these are critical for success," Blum said. For example, male computer science majors have easy access to role models who look like them, in both their professors and people in the workforce, and are more likely to have roommates or people living in their dorm who are also studying computer science and can help with homework.

> ***Women with up to eight years of programming experience report the same level of confidence as men with zero to one year of programming experience.***
>
> *Harvard University's Women in Computer Science Advocacy Council, 2016*

"If you're a woman, and one out of a very small number, you don't have those built-in connections, and your teachers don't look like you," Blum said. "You have nobody to ask naturally at night to work on homework with you. It would probably be pretty awkward to call up a guy and say, 'Hey, I'm having problems with my homework and it's midnight. Want to come over?' Not so easy to do."

Blum launched the **Women@SCS** program, supported by faculty and funded by the school, meant to connect female students in the major with mentors, advisors, women working in tech, and activities in which they could be leaders.

"We helped change the culture by explicitly offering these important professional advantages," Blum said. "We did not change our curriculum. We just changed our culture. It's not rocket science, it's common sense."

At the same time, the dean Raj Reddy changed admissions policies to accept students with strong math and science experience, but also with broader interests. "This opened a door to our admissions office to look more closely at talented women who could really do our program, even if they haven't been programming since they were three years old," Blum said.

Despite the positive changes, that gender parity seen in the freshman class has yet to come up to more senior levels, Blum said. And males tend to transfer into the major more often than females, leading to more of a disparity in upper-level courses. In 2016, just 21% of computer science bachelor's degrees were awarded to women at Carnegie Mellon.

Rachel Holladay, who graduated with degrees in computer science and robotics from Carnegie Mellon in 2017, said that her incoming class was about 35% female. "I was rarely the only one [in computer science classes]," Holladay said. "But in my upper-level computer science classes and robotics classes, there were fewer women."

While she felt accepted by most of her peers and professors, "You experience individual situations where you feel as though you're being slightly disrespected, or someone's not listening to you," Holladay said. "I'll tell the experience to another woman in the technical field, and she'll immediately understand what I'm talking about, because she's been through it. It's very subtle, and it's hard to really see if there's a line."

Larger issues, including a male-dominated culture and reports of sexual harassment at many tech giants, will likely continue to keep young women out of the field, Holladay said. "A friend told me that they were at a tech startup, and there was free beer, but tampons and pads in the bathroom cost $0.25," Holladay said. "Those are little things, but when you hit them every single day everywhere you go...we need to fix those smaller society things to make people more comfortable in their own work environment, because nobody wants to fight small battles every day. You get tired."

Image: Michael Henninger/Carnegie Mellon University

At a collaborative space on campus, Carnegie Mellon students discuss their assignments.

The intro course and the confidence gap

Research shows that when a male and a female student enter a computer science course at the same level, the male thinks he's more skilled than he is, and the female thinks she's less skilled than she is, said Barb Ericson, director of computing outreach for the College of Computing at Georgia Tech. A 2016 study from Harvard's **Women in Computer Science Advocacy Council** found that women with up to eight years of programming experience report the same level of confidence as men with zero to one year of programming experience.

"A lot of women tend to leave the major even though they have better grades than the guys who stay, because they're not confident in their abilities," Ericson said.

The confidence factor also impacts who takes computer science introductory courses, and who opts out. At Harvard, the intro course CS50 is designed for both majors and non-majors, and had 38% women during the 2016-2017 school year.

"It's taken on its own persona in the college," said Priscilla Guo, a senior technology, policy, and society concentrator at Harvard. "It's very sensationalized, and is one of those must-take courses. Every single lecture is almost like one of those showcases at a tech conference, in that there is a lot of interaction and engagement with the audience. It's like a show."

> *"Academic institutions that commit to parity really do start to see results when they use research-based practices."*
>
> *Wendy DuBow, director of evaluation and senior research scientist at the National Center for Women & Information Technology*

The course's goal is to make programming more relatable, and students are offered a lot of support, including several teaching assistants and 24-hour office hours. However, once you get to the second intro course, the number of women drops, Guo said. And in 2017, 29% of Harvard's computer science bachelor's degrees were awarded to women.

Image: Georgia Tech

A computer science student at Georgia Tech works on a coding project.

The problem? "So many more men than women come to college with programming experience, and skip CS50," said Michelle Danoff, who graduated from Harvard in 2017 with a degree in computer science, and now works as an associate product manager at Google. "If you look at how students progress through the department, there's a de-

> *"A lot of women tend to leave the major even though they have better grades than the guys who stay, because they're not confident in their abilities."*
>
> *Barb Ericson, director of computing outreach, College of Computing, Georgia Tech*

crease [of women] in the higher-level courses in large part because there's just so many men going directly to them."

Further, women who do have past programming experience often still choose to take CS50, while men with comparable experience choose to skip it, playing into those confidence dynamics, Danoff said.

Male students even sometimes sign up to be teaching assistants for courses they never took themselves, because they feel confident enough to take on that role, Guo said. Female students, on the other hand, are more likely to justify not signing up by saying, "I've never taken the class, so I have no expertise and shouldn't be a TA," Guo added.

Making computer science a requirement

At Georgia Tech, every student is required to take one of three computer science intro courses: One for engineering majors, one for computer science majors, and one for all other students.

In the past, computer science was not taught in a very interesting way, Ericson said. And getting professors to change their habits after so much time proved difficult, she added.

Further, "a lot of instructors believe in the 'geek gene'—that you're born to do it or you're not, and they often think women are not," Ericson said. "Women can face an uphill climb from some of their professors or friends or family who are like, 'Wait, what? Why are you doing this?'"

Intro courses should be interesting, creative, and social, and offer plenty of help, especially for women who tend to come in with less experience and less confidence, Ericson said.

Murrell is a teaching assistant for one of Georgia Tech's introductory courses. "I see a lot of girls get really excited about coding, but what ends up happening a lot is that girls say, 'I don't know if I want to switch, I don't know if it'll be too hard. Maybe I'll just get a minor,'" she said. "So it's really easy to see the girls get interested, but it's harder to actually convince them to switch their entire track."

Maria Ximena Rueda-Guerrero graduated from MIT with a bachelor's in computer science in 2017 and is now pursuing a master's in the field at the school. She did switch her course of study from math to computer science after taking an intro course for non-majors her freshman year and realizing a passion for coding. That course also had a 50-50 split of men and women, she said. But as she became more interested in computer systems and networking courses, the number of women dropped significantly.

Dropping percentages

Stanford's intro course is also close to 50-50 gender parity, said Mehran Sahami, professor and the associate chair for education in the computer science department. "I think there's more awareness of the potential impact someone can have through computing—that computer science isn't just seen as a discipline to go become a programmer, but as a way to

be able to harness the power of technology to solve problems across many different fields," Sahami said.

However, the percentage of women in computer science classes drops after that. Women often take the intro course later, even as late as senior year, Sahami said. In 2017, just 32% of Stanford's computer science graduates were women.

At University of California-Berkeley, a revamped introductory computer science course for non-majors has been split 50-50 between men and women since 2013.

"If you have a really great non-majors experience, you kind of serve as a pied piper of sorts to entice folks into a really great field that people have unfortunately had a misperception about in high school," said Dan Garcia, a professor in the department of electrical engineering and computer science at Berkeley's College of Engineering.

The course's name, Introduction to Symbolic Programming, was recast as the Beauty and Joy of Computing. In it, Garcia allows students to choose their own projects and work in pairs. There are also components of the social implications of computing and lab time.

Image: Georgia Tech

An engineering student at Georgia Tech works on a hardware project.

But those changes have yet to make an impact: In 2016, 28% of Berkeley's computer science graduates were women.

Saloni Shah, a senior computer science major at Berkeley, said she noticed the drop-off in women as classes increase in difficulty. "You start to realize there are not as many people like you, and there are a lot of stereotypes, and can feel really out of place," Shah said. For example, in one discussion section, Shah was one of two women out of about 30 students.

> ***"We did not change our curriculum. We just changed our culture. It's not rocket science, it's common sense."***
>
> *Lenore Blum, professor of computer science, Carnegie Mellon University*

And at an information session for a machine learning club, Shah said she was the only female attendee out of about 200 people. "I don't think it's the topic ... that draws women away," Shah said. "But when you know that it is all men, there is no guarantee that those men are the ones who will support you."

One particular aspect of computer science does see more equitable numbers of men and women in classrooms across the universities examined in this story: User interface (UI) and user experience (UX) courses. These subjects tend to be more focused on the design elements of computers.

What draws more females to this area? "Even when you're little, you're given crayons and markers to draw with, whereas guys are given LEGO blocks to build things," said Lindsay Knapp, a

junior computational media major at Georgia Tech. Knapp said her UX/UI courses include far more women than those in subjects such as artificial intelligence or security. There is also a perception that this part of the field is easier, especially for people who have not been coding since they were children, Murrell said.

Sexism: Alive and well

The majority of female students interviewed for this story said that generally, they feel they are respected and treated equally by their male professors and peers. But everyone had experienced the exceptions.

Shah has participated in—and won—several collegiate hackathons, where there are usually few women in attendance. Sometimes, after she gets accepted to one, "some of my guy friends are like, 'Oh, well, obviously you got in because you're a girl, and they need girls to be present. We didn't make it in because we actually had to try.' That's kind of silly, because it's not like they accepted all women—at the end of the day it's still like 80% guys," she said.

> *"There's more awareness of the potential impact someone can have through computing... as a way to be able to harness the power of technology to solve problems across many different fields."*
>
> *Mehran Sahami, professor of computer science and associate chair for education and director of educational affairs for computer science, Stanford University*

"I have all of these projects. I have definitely shown I can do it," Shah added. "I don't think they actually believe that women don't belong in computer science. But what happens often is that it's a means of justifying why they didn't get something."

Shah has also interned at Google the past two summers, but said she doesn't talk about it much. When she has in the past, some of her male peers have made comments like, "'Well, you got in because they needed diversity.' I'd rather just not get into that, so I just don't mention it," she said.

Murrell said there are "very few" instances when she has felt defeated being a woman in this field. "I have a part-time job being a teaching assistant, and have a really great network of female friends in my classes," she said. "If I didn't have those things, it would probably be a little tougher, and a little lonelier."

Still, on Murrell's first technical interview for an internship, she said that she found the male interviewer was a bit standoffish, and gave her a very easy coding question. "I was surprised—I learned that stuff two years ago," Murrell said. "Part of me was like, 'I wonder, if I had looked like more like a quintessential 'girl coder,' would he have expected more from me?'"

Rueda-Guerrero at MIT said she found the computer science community at school far more welcoming than that in her native country of Colombia. "I found this extremely supportive community here that tries really hard to treat women the same as men," she said.

But nothing is perfect. After helping create the **Women in Electrical Engineering and Computer Science** group at MIT, Rueda-Guerrero said she heard some upsetting stories from her classmates. "Some women in the group

said that they've heard sexist comments from their lab partners, things like, 'Oh what's wrong with you today, you have your period?'" she said. "Or some professors have less expectations of women, or have made comments like, 'Some of you need to get married soon.'"

Lack of women in faculty

A lack of representation among computer science professors may also keep women from continuing in the major: **Only 15%** of tenure-track computer science faculty members in North America are women.

This is another pipeline issue, according to Blum of Carnegie Mellon. "Many of our women students are not going to graduate school," she said, because they are offered jobs at top tech firms right out of college. "If women don't go to graduate schools to get PhDs, we're not going to have the role models at the faculty level, and that is a concern for me."

After a survey of MIT computer science and engineering students found women tend to have more doubts about their abilities than men, and feel more negative bias, it was recommended that the school provide more role models at multiple levels, including teaching assistants and faculty.

But this is easier said than done. "The best thing to do is continue to do our best to attract and retain and promote more women in these fields," said Ian Waitz, dean of the school of engineering at MIT. "It can be hard. When we hire faculty in computer science, it may be as few as 10% of the applicants are women. We still have a ways to go. It starts with the undergrads coming in and the fact that the undergrads are getting more diverse, so it will move forward, but the timeline is very long."

The pipeline gets smaller and smaller after the undergraduate level, said Garcia from Berkeley. "The percentage of women in the graduate student population is much lower than the undergraduate population," Garcia said. At Berkeley in spring 2017, 21% of computer science masters and PhD students were women. "The higher up you go in the totem poll, the lower percentage of female faculty." This is also true for minorities, Garcia said.

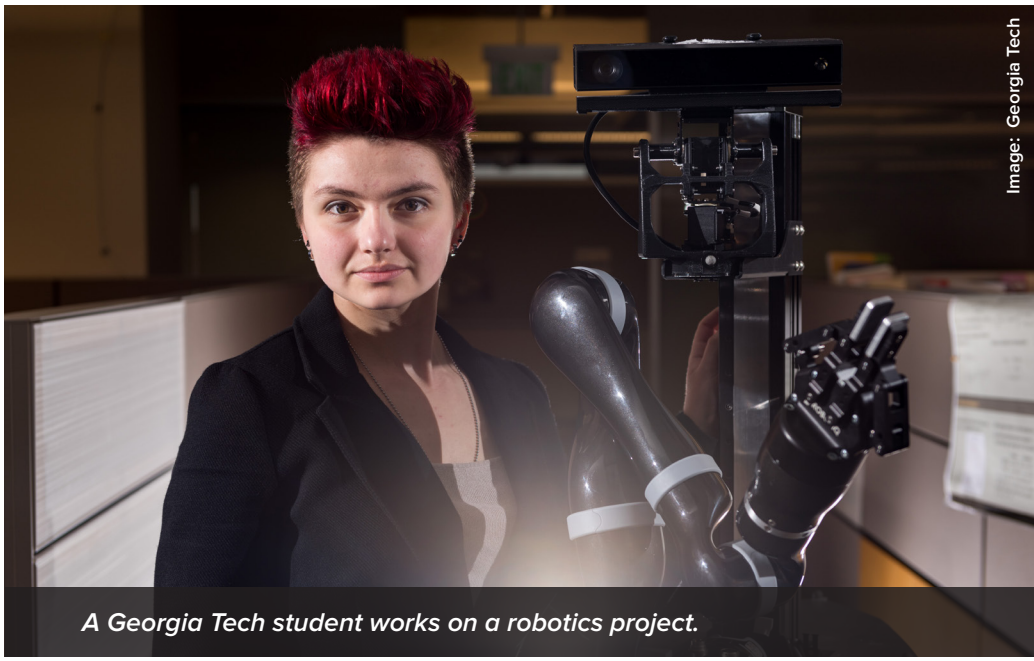

Image: Georgia Tech

A Georgia Tech student works on a robotics project.

A lack of female representation among faculty and teaching assistants impacts students. Holladay, a Carnegie Mellon graduate, is now pursuing a PhD in the field at MIT, with the aim of becoming a research professor. "I had one computer science class that was co-taught by a female professor. And all of my other computer sciences were taught by male professors," Holladay said. "It bothered me, to be honest. I think if you had more female faculty, that would also encourage more retention of the pipeline."

At Harvard, the majority of Danoff's professors were also

male, she said. "There is nothing more powerful in terms of feeling like you can do something than seeing someone like yourself doing it," Danoff said. "I think it's incredibly important to have more female faculty."

Where do schools and the tech industry go from here?

Despite the gender disparities that persist in modern computer science classrooms, the fact remains that these top colleges are graduating women at levels above the national average of 18%, and taking positive steps in the right direction—which many smaller schools may lack the resources to do.

"Our challenges are sometimes less than those of engineering schools as a whole, which is true of a lot of the very competitive universities," Waitz of MIT said. "We have an opportunity to pick from an exceptionally large applicant pool for a very small number of students. What we want to have is not only a class that's made up of individually excellent people, but that is collectively excellent, and we need a broadly diverse class from different genders, backgrounds, and countries. We have that opportunity here to do that because of the large number of applicants."

But any school can alter their introductory course, create women's groups and mentorship programs, and be more persistent in searching for and promoting female faculty members. "Even in colleges without a lot of resources, if their faculty chair or their dean commit to wanting a more diverse student body, they can take these kinds of steps," DuBow said. Colleges can also up recruiting efforts among undecided students, and those in STEM majors that are typically female-dominated but have a limited number of seats available, such as nursing.

> *"Tech leaders have to stop saying 'it's a pipeline problem,' because that's essentially a cop out."*
>
> *Elizabeth Ames, senior vice president of marketing alliances and programs, Anita Borg Institute*

The professional technology world also has a long way to go to better attract and retain women, Ames said, starting with advancing the women they already have working for them. Research shows that companies with women in senior and executive technical roles better attract women into other technical roles, she added.

"Tech leaders have to stop saying 'it's a pipeline problem,' because that's essentially a cop out," Ames said. "They need to focus on what they can do in their organization to improve the ecosystem overall."

The microculture of any organization or college greatly impacts women's participation in computer science, Blum said. "It doesn't have to be that the whole world changes," she added. "We can change the culture right where we are."

TechRepublic is a digital publication and online community that empowers the people of business and technology. It provides analysis, tips, best practices, and case studies aimed at helping leaders make better decisions about technology.

Published by TechRepublic, September 2017

Credits

Global Editor in Chief
Jason Hiner

Editor in Chief, EMEA
Steve Ranger

Editor in Chief, APAC
Chris Duckett

Managing Editor
Bill Detwiler

Senior Editors
Jody Gilbert
Mary Weilage
Conner Forrest

Chief Reporter
Nick Heath

Multiplatform Producer
Derek Poore

Senior Writers
Teena Maddox
Dan Patterson

Staff Writer
Alison DeNisco

Associate Editor
Amy Talbott

Graphic Designer
Kimberly Kalisik