DOI:10.1145/3300226

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▸ Richard Ladner, Column Editor

Broadening Participation

How Computer Science at CMU Is Attracting and Retaining Women

Carnegie Mellon University's successful efforts enrolling, sustaining, and graduating women in computer science challenge the belief in a gender divide in CS education.

THE PERSISTENT UNDERREPRESENTATION of women in computing has gained the attention of employers, educators, and researchers for many years. In spite of numerous studies, reports, and recommendations we have seen little change in the representation of women in computer science (CS)—consider that only 17.9% of bachelor's degrees in computer science were awarded to women in 2016 according to the annual Taulbee Survey.[15] At Carnegie Mellon University (CMU) we do not believe the situation is an intractable problem.

By paying close attention to culture and environment, and taking a cultural approach rather than a gender difference approach, our efforts continue to pay off. The percentage of women enrolling and graduating in CS at CMU has exceeded national averages for many years (see the accompanying figure and table). Indeed, the school gained attention when 48% (of the total 166 students), 49+% women (of the total 205 students), and just shy of 50% when 105 women (out of 211 students) entered the CS major in 2016, 2017, and 2018 respectively.[a] But CMU is not alone—other institutions have also had success in addressing the gender gap. Harvey Mudd College, for example, went from 10% women in CS in 2006, the year Maria Klawe took over as college president, to 40% women in CS by 2012.[2] These institutions, and the many others who are investing in change to improve gender balance, are proof that—as CMU CS Professor Lenore Blum says—"it's not rocket science!"

This column summarizes CMU's successful efforts in enrolling, sustaining, and graduating women in CS. Since 2002 we have conducted ongoing case studies to understand the CMU story.[b] We have learned many valuable lessons. In a nutshell, for women to be

Women comprised more than 48% of incoming first-year undergraduate students at Carnegie Mellon University's School of Computer Science in fall 2016, establishing a new school benchmark for diversity.

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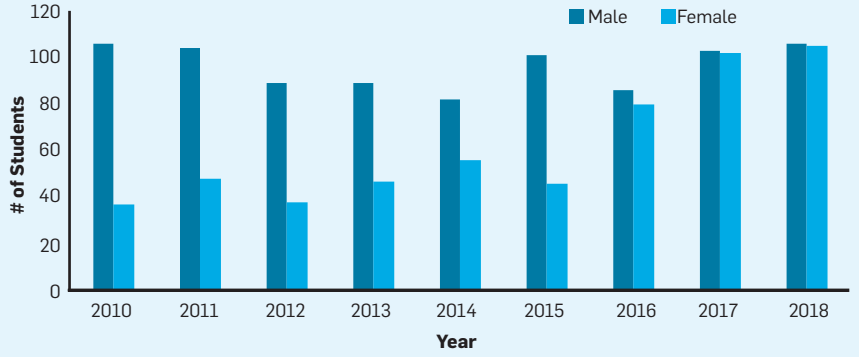
a See https://bit.ly/2ULGgBS

b Case studies were conducted in 2002, 2004, 2009–2010, 2011–2012, and 2016–2017 and included a variety of data-collection tools including face-to-face interviews, surveys, focus groups, and observations. Participants included current undergraduate and graduate students, faculty, and staff.

Percentage of male and female first-year students by year of enrollment.



First-year enrollment by gender (rounded to the nearest full number).

Year	Enrolled	# Male	% Male	# Female	% Female
2010	143	106	74%	37	26%
2011	152	104	68%	48	32%
2012	127	89	70%	38	30%
2013	136	89	65%	47	35%
2014	138	82	59%	56	41%
2015	147	101	69%	46	31%
2016	166	86	52%	80	48%
2017	205	103	50%	102	50%
2018	211	106	50%	105	50%

successful in CS we needed to change the culture and environment, and develop and sustain programs that work to level the playing field without making women feel like a separate species. However, we did not need to change the curriculum to be "pink" in any way. Indeed, gender difference approaches, which tend to assume CS should be changed to suit women's presumed interests, have not provided satisfactory explanations for the low participation of women in CS. Indeed, beliefs in a gender divide may actually be deterring women from seeing themselves in male-dominated fields.

We hope the CMU story can help challenge the gender divide in CS, show that women can master this field successfully, and inspire others to think more broadly about intellectual and academic expectations. We acknowledge that the CMU experience may not be fully generalizable. For example, CMU is a private institution that may not have some of the constraints state institutions have because of various laws and regulations. While recognizing the potentially limited generalizability of our experiences, we summarize five key takeaways we believe may be replicated at other institutions where there is the motivation for change.

Women Do Not Need a Female-Friendly Curriculum

From 1999 onward some dramatic changes occurred at CMU, changes that contributed to a successful and much-improved undergraduate experience for students in the CS major. Most significantly these changes led from women feeling out of place and small in number to being well represented, being an integral part of the CS culture, contributing to the culture, and being successful in the field alongside their male peers. Indeed, men and women graduate at the same rate. This success occurred without compromises to academic integrity, without changing the curriculum to suit women, nor by accommodating what are perceived to be "women's" learning styles and attitudes to CS. Changes to the CMU curriculum, as in any department committed to providing the best academic program possible are made for the benefit of all students. CMU, with its School of Computer Science and the seven departments within the school, offers a wide variety of courses—some of which are applications focused—but the core CS curriculum and a wide variety of advanced courses have become increasingly theory driven and rigorous without impacting students' retention and success.

Cultural Change Is Key—And It Can Change at the Micro Level

In 1999, CMU dropped the programming/CS background requirement from the admissions criteria and added leadership potential while keeping high SAT scores, particularly in math and science. Dropping this requirement was prompted by a valuable finding from the 1995–1999 research studies.[11] Various entry levels into the first-year courses were created for students with little to no background. Other major contributing factors included: CMU Dean Raj Reddy's vision to produce leaders in the field that also brought institutional support for change; Lenore Blum joined the CS faculty bringing long-standing expertise and advocacy for women in science and math; and the development of Women@SCS, an organization of faculty and students (mostly, but not all, women) led by a Student Advisory Committee, working to ensure that the professional experiences and social opportunities for women reflect the *implicit* opportunities for those in the majority (see https://www.women.cs.cmu.edu/).

These changes brought in many more women, and more students—both male and female—with a broader range of characteristics and interests. We started to see a more balanced student body, balanced in terms of gender, of student characteristics, and balanced in terms of leveling-the-playing-field opportunities for women through Women@SCS. In this more balanced environment our observations and series of studies, including our 2016–2017 study,[3–7] found CMU students relating to CS through a spectrum of attitudes along with many more similarities than differences. For example, we found most students (men and women) have a deep interest in computer science and want to

do something useful with their skills in order to contribute to the social good.

Institutional Support Is Critical

We believe sustained student leadership, with women at the helm, has been critical for building a more inclusive community at CMU, and for enhancing the academic and social life of the entire community. At the same time, cultural change requires serious institutional support and cannot be left to chance, especially in a stubbornly male-dominated field like CS.

At CMU, we have found that institutional investment, providing funding, guidance, and endorsement for programs developed through Women@SCS, has paid off. The organization has become a valuable resource for everyone while strengthening the image of women in CS and challenging the stereotypes about who fits the field.

Cultural Factors Are More Important than Gender Differences

Gender difference approaches often argue that there are strong gender differences in the way girls and boys, or men and women, relate to the field; gender differences that work in favor of men and against women. To solve this problem and increase women's participation in CS it is suggested that we need to pay more attention to women's interests and attitudes and change CS accordingly. But approaches that recommend accommodating differences—without recognizing that such differences can change according to the culture and environment—risk perpetuating the gender divide.

This has not been our approach. Indeed, we questioned these assumptions and constraints. Gender is first and foremost a cultural issue not a women's issue, so rather than looking at "gender differences" as our working model we need to address the underlying culture in which attitudes and opportunities for equality are influenced and situated. This approach is supported by evidence from other cultures outside the U.S. Galpin describes the participation of women in undergraduate computing in more than 30 countries concluding "(t)he reasons that women choose to study computing will vary from culture to culture, and from country to country." Studies of women in computing in Mauritius and in Malaysia found no problem with women's participation concluding "the underrepresentation of women in CS is not a universal problem."[9]

We see culture as a dynamic process; shaping and being shaped by those who occupy it, in a synergistic diffusive process.

But the gender difference mindset—epitomized by the bestseller *Men Are from Mars, Women Are from Venus*[10]—has a strong hold on public thinking in the U.S. and many parts of the Western world. For example, "... anonymous, aggregate data from Google searches suggests that contemporary American parents are far more likely to want their boys smart and their girls skinny."[13] The belief that men are innately better at coding than women, is a case in point. This mindset, fed by stereotypes, is relentlessly perpetuated. In turn stereotypes feed our unconscious biases, which, if left unchecked, can often lead to negative consequences for women in computing, and ultimately for the field itself.

Cultural Interventions Are Needed for Change

We see culture as a dynamic process; shaping and being shaped by those who occupy it, in a synergistic diffusive process. A cultural approach examines a range of factors beyond gender as determinants of women's participation in CS including (but not limited to) the parts played by the K–12 curriculum, stereotype threat, opportunities for engagement in CS, opportunities for leadership, confidence levels, gender ratios, implicit bias, myths and stereotypes. A cultural approach examines these factors and develops actions and programs to intervene as needed. Our latest intervention—BiasBusters@CMU—developed in collaboration with CMU's College of Engineering and Google, works with the entire campus on the difficult issue of mitigating implicit bias.[8]

Interventions from Women@SCS have increased the visibility of women, placing them in leadership positions, providing opportunities for them to demonstrate their abilities, and to challenge stereotypes, all with the critical support of our deans, faculty and staff. For example, recognizing an often-familiar situation in which students can go through their entire school life without having a female instructor, Women@SCS developed a faculty-student lunch series, providing female students an opportunity to meet role models and have personal interactions in an informal setting. Most importantly Women@SCS has not been inward-looking. The organization has facilitated many outside the classroom programs for the benefit of the entire student body such as peer-to-peer interview and speaking skills workshops, outreach in the community, and peer-to-peer advice sessions. In 2014, Women@SCS was asked to take the lead on SCS4ALL—http://www.scs4all.cs.cmu.edu/—a student organization reaching out beyond gender. Women@SCS has shown that a women's organization can be much more than a "support" group for each other, they can be a valuable resource for building an inclusive community.

Conclusion

We have found that cultural change, not curriculum change (often recommended by gender-difference approaches), is the key to sustaining a community of women in CS. Indeed, we advise caution when making changes based on appealing to stereotypes—this may perpetuate the gender divide.

Institutional support is also critical for real change and ultimate success—this includes funding, guidance, and philosophical advocacy for leveling the playing field. CMU has not been afraid to give women a voice, to listen to women, and let women take the lead, enabling them to play a valuable role in changing the culture.

We suggest monitoring student attitudes toward, and experiences in, the

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CS major. Are men and women getting similar opportunities for such things as leadership, visibility, networking, mentoring, and advocacy? Are women involved and given a central voice in shaping the culture?

While a good academic life is critical for success, students also need to feel like they belong socially[14]— this will enhance their sense of academic fit. Indeed college life is best viewed holistically. Do not underestimate the value of student organizations, and of social events where information is exchanged, friendships and communities are formed, and where everyone gets a chance to be included in the latest student discussions.

The persistent gender gap in CS is well documented, but there is less sharing of the success stories. By telling the CMU story we hope to illustrate a successful approach, one that can help the field of computing become more inclusive.[c] At the same time, we cannot become complacent. Gender balance at the undergraduate level is not an end in itself and our efforts need to continue. Success with gender diversity is one important step in developing strategies to be more inclusive of all who are underrepresented in the field of computing. In doing so we believe the CMU approach, with a focus on culture is particularly advantageous because culture is mutable and potentially open to the changes we seek. This means we aim to continue to pay close attention to the issue, provide institutional support, a willingness to act, and flexibility to enable change. The CMU approach recognizes that ultimately diversity and inclusion benefit the school, the community, and field of computing. C

c We recognize that women and men are not single separate categories and yet we are as guilty as anyone for using the term "women" and "men." We are all shaped by complex identities and experiences and a multitude of determinants are involved in our choosing or not choosing to study computer science.

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This column is derived from the authors' book *Kicking Butt in Computer Science: Women in Computing at Carnegie Mellon University*;[6] the authors' next book, *Global Perspectives on Women in Computing* (working title), will be published in early 2019 by Cambridge University Press.