



Increasing Female Participation in Computing: The Harvey Mudd College Story

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Over a four-year period, Harvey Mudd College dramatically increased the number of female computer science majors by implementing three innovative changes that other institutions can easily replicate.

One of the critical issues that continue to impede technological advancement in the US is the shortfall of software developers, computer scientists, and computer engineers graduating from colleges and universities. Because of this shortage of talent, major technology companies and start-ups compete intensely for talented college graduates in computer science. The competition is even fiercer for women with CS degrees; despite the rich career opportunities, the percentage of women majoring in CS has hit a 30-year low.

Over a four-year period, Harvey Mudd College dramatically increased the number of females majoring in CS. Other universities and colleges can replicate many of the approaches HMC used, and we are eager to help these institutions succeed.

During the 1980s technology boom, the number of CS graduates was ample, with women representing nearly a third of those receiving CS bachelor's degrees. Only a decade later, however, the percentage of women CS majors had dropped to 20 percent, and now it hovers around 14 percent (<http://archive.cra.org/info/taulbee/women.html>).

The dot-com crash in 2001 caused both male and female students to lose interest in CS, but the decrease over the past decade was nearly twice as sharp for women.

According to the annual Taulbee Survey (<http://cra.org/resources/taulbee>), the number of males receiving CS bachelor's degrees at research institutions fell 35 percent, from 10,903 in 2001 to 7,039 in 2009, while the number of females plummeted 67 percent, from 2,679 to 892.

During the past few years, there has been a turnaround in the overall number of CS graduates as the US enters a new tech boom, but the percentage of female CS majors still greatly lags behind that of males. Society clearly needs the contributions of women as well as men in the computing field, and HMC has embraced the challenge.

TURNING THE TIDE

In 2005, HMC's Computer Science Department began implementing three innovative practices to attract women to the CS discipline. The results were dramatic: the percentage of women CS majors climbed from 10 percent in 2005, to 20 percent in 2006, to the current annual average of between 37 and 50 percent. In just four years, HMC more than tripled its percentage of women CS majors, resulting in a gender ratio that is also triple the national average. Moreover, this increase occurred during a time when the total number of CS majors at HMC roughly doubled, indicating that the number of female CS majors actually rose by a much larger factor.

Enrollment in CS70, the third course for CS majors, which students refer to as a "boot camp for programming," illustrates the magnitude of the changes at HMC. In the five years prior to 2007, the maximum number of female students enrolled in CS70 was 2; in fall 2011, 23 of the 57 students in CS70 were female.

To our knowledge, our results are the best in the nation

and can be attributed to a determined and knowledgeable group of CS faculty as well as a supportive campus community that encouraged implementation of these changes.

THREE INNOVATIONS

Prior research identified three key factors contributing to why females do not major in CS: they do not find CS interesting, believe they will not do well in CS, and feel uncomfortable in the computing culture. The changes HMC instituted address all three factors by increasing potential female CS majors' interest, confidence, and sense of belonging.

Changing the introductory CS course

The CS department's first step was to create an innovative and engaging introductory course, CS5, that explores the range and power of CS and its impact on society (<http://www.cs.hmc.edu/twiki/bin/view/ModularCS1>).

Instead of the typical focus on learning to program, CS5 emphasizes problem solving using computational approaches. This gives first-year students a broader view of CS, demonstrates the breadth of the discipline, and quickly immerses students in various core topics and activities. Students still write plenty of computer programs—in fact they write more code in the new course—but they program in Python, a more flexible and forgiving language than traditional Java. Further, they write programs to solve computational problems applicable to their broader HMC studies in engineering, math, physics, chemistry, and biology.

The wide range of topics appeals to both male and female students, who report that they are excited—and often surprised—to discover that CS is a much more fascinating and rewarding discipline than they previously thought.

To address the confidence issue, students are placed in CS5 sections by prior experience. Those with little or no programming experience are assigned to CS5 “gold,” while those with substantial programming experience are assigned to CS5 “black” (HMC's colors are black and gold). Students with even more CS experience are placed in CS42, a course that combines the material in CS5 with the next CS course, CS60.

In all introductory CS courses, instructors deliberately discourage the most experienced students from intimidating others in class by showing off their knowledge. Eliminating this “macho” effect has significantly improved the culture in all CS courses at HMC, resulting in a more supportive learning environment for all.

Introducing female students to the Hopper conference

To further strengthen female students' interest in CS, HMC offers each female first-year student, independent of planned major, the opportunity to attend the Grace Hopper Celebration of Women in Computing (www.gracehopper.org), the world's largest conference focusing on women

To Learn More

The following resources provide more information about Harvey Mudd College's effective practices to increase women's participation in computing:

- C. Alvarado and Z. Dodds, “Women in CS: An Evaluation of Three Promising Practices,” *Proc. 41st ACM Technical Symp. Computer Science Education (SIGCSE 10)*, ACM, 2010, pp. 57-61; www.cs.hmc.edu/~alvarado/papers/fp068-alvarado.pdf.
- Z. Dodds et al., “Evaluating a Breadth-First CS 1 for Scientists,” *Proc. 39th ACM Technical Symp. Computer Science Education (SIGCSE 08)*, ACM, 2008, pp. 266-270; www.cs.hmc.edu/~dodds/sigcse08FinalWNames.pdf.

For more information about related efforts elsewhere, see the following:

- V. Chan et al., “Gender Differences in Vancouver Secondary Students: Interests Related to Information Technology Careers,” *Women, Work and Computerization: Charting a Course to the Future*, E. Balka and R. Smith, eds., Kluwer Academic, 2000, pp. 58-69.
- A. Forte, and M. Guzdial, “Motivation and Nonmajors in Computer Science: Identifying Discrete Audiences for Introductory Courses,” *IEEE Trans. Education*, vol. 48, no. 2, 2005, pp. 248-253.
- R. Davies et al., “Virtual Family: Including Girls in the World of Programming,” *Proc. 12th Ann. World Conf. Educational Multimedia, Hypermedia, & Telecommunications (EdMedia 00)*, Assoc. Advancement of Computing in Education, 2000.
- M. Klawe et al., “ARC: A Computer Science Post-Baccalaureate Diploma Program that Appeals to Women,” *Women, Work and Computerization: Charting a Course to the Future*, E. Balka and R. Smith, eds., Kluwer Academic, 2000, pp. 94-101.
- J. Margolis and A. Fisher, *Unlocking the Clubhouse: Women in Computing*, MIT Press, 2003.

computer scientists. Sponsored by the Anita Borg Institute for Women and Technology and ACM, the Hopper conference provides an inspirational introduction to hot technical topics, makes students aware of the variety of jobs available within the discipline, showcases role models at all career stages, and offers an effervescent and welcoming culture.

Eight first-year female students attended the inaugural trip to the conference in 2006. By 2012, that number rose to 45 along with 10 upper-class students. The Hopper conference has proven to be a powerful confidence booster, encouraging females to take more CS classes and attracting more women to the CS major.

Providing summer research opportunities

Numerous studies have shown that research experiences for undergraduate women increase retention and

the likelihood they will attend graduate school. Since the summer after the first year is the most difficult one for college students to find meaningful work experience, our CS department faculty created research projects suitable for those who had completed only one or two CS courses. This offered first-year students the chance to apply their knowledge, boost their confidence, and deepen their interest in the discipline.

Female students embraced this new opportunity to engage in 10 weeks of intensive, challenging summer research on projects such as AI, robotics, and educational video games. They discovered they could do CS research well, and have fun doing it.

SHARING SUCCESS

In 2010, the National Science Foundation (NSF) recognized the breakthrough work at HMC and awarded the CS department an \$800,000 grant to export the highly successful CS5 course. Bucknell University and Northwestern University adopted CS5 in its entirety and report that students and faculty love it; they tell us it is the kind of course they have long wanted to offer.

Our CS professors have designed and taught a condensed version of CS5 at the University of California, Riverside, and a graduate-level version at Claremont Graduate University. They have also led workshops for elementary and high school teachers on how to implement a precollege version of CS5, which has led to several area high schools successfully deploying the curriculum.


Recently, HMC was awarded another major NSF grant to develop a middle-school curriculum based on CS5. The CS faculty have also created a biology-themed version of the course, CS5 “green,” which is very popular at HMC. They are currently working with faculty at the University of California, San Diego, to pilot a version of CS5 green there.

When other CS faculty hear about the HMC transformation, they sometimes question how realistic our innovations would be at their institution. They note our small size, students’ high quality, instructors’ dedication to teaching, and greater access to resources compared to large public institutions. They also point out that every first-year HMC student is required to take a CS course, which enables us to share the excitement and fun of computing with everyone. While these are genuine differences, the truth is that every CS department that has made a serious and sustained commitment to increasing female participation—starting in the mid-1990s with Carnegie Mellon University and the University of British Columbia (UBC)—has had substantial success.

At UBC, for example, where science majors are not required to take a CS course, the number of females taking the standard introductory CS course has increased to about 40 percent due to several novel changes. One early step was encouraging strong students in the computer literacy

course, of which about 60 percent of the students were female, to go on to take the regular introductory CS course. Another was having several instructors teaching introductory biology courses encourage their students to take CS courses because of computing’s increasing role in biology. More recently, UBC has introduced CS “ministreams” that let nonmajors gain expertise in areas like human- and social-centered computing, scientific computing, and software development.

The introductory CS course, the Hopper conference, and early summer research work synergistically to encourage women to pursue CS at HMC. CS5 piques their interest by providing a broad view of what CS is all about and offers a confidence-boosting educational experience, the Hopper conference shows students who they can become, and 10 weeks of intensive summer research helps them discover they can do the work of a computer scientist.

The new CS courses are not more expensive or challenging to teach than our previous introductory course. Eliminating the “macho” effect requires a modest amount of extra time from instructors and has a huge payoff. The Hopper conference costs about \$750 per student, depending on the location. We have found it relatively easy to raise the necessary funds from individuals and companies because the tech industry is genuinely interested in increasing the number of women in related professions. There are now several regional versions of the Hopper conference, making attendance even more affordable. Finally, many foundations provide support for summer research for undergraduates. 

Maria Klawe is president of Harvey Mudd College. She has made research contributions in several areas of mathematics and computer science, including functional analysis, discrete mathematics, theoretical computer science, human-computer interaction, gender issues in information technology, and interactive multimedia for mathematics education. Klawe received a PhD in mathematics from the University of Alberta. She is a board member of Microsoft, Broadcom, and the nonprofit Math for America; a fellow of ACM and the American Academy of Arts & Sciences; a founding fellow of the Canadian Information Processing Society; a trustee for the Mathematical Sciences Research Institute; and a member of the Stanford Engineering Advisory Council and the Advisory Council for the Computer Science Teachers Association. Contact her at klawe@hmc.edu.



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