Addressing the CS Capacity Challenge by Improving Undergraduate Peer Mentoring

By Heather Pon-Barry, *Mount Holyoke College*, Audrey St. John, *Mount Holyoke College*, Becky Wai-Ling Packard, *Mount Holyoke College* and Chris Stephenson, *Google*

The increasing enrollment in undergraduate computer science (CS) programs has led to a myriad of capacity challenges for post-secondary institutions across the United States. Because CS programs vary significantly from institution to institution, addressing these challenges without diminishing students' academic experience negates a one-size-fits-all solution. Rather, a variety of interventions need to be conceived, developed, and tested to ensure that CS programs can choose interventions and tools that best suit their circumstances. One solution that seems to be gaining popularity involves increasing the number of undergraduate peer mentors and teaching assistants. This solution, however, is most effective when paired with some method of preparing these students to succeed in this role [6]. At Mount Holyoke College, over the past two years we have developed a novel curriculum for preparing students to be peer mentors to beginning students in CS1 and CS2, emphasizing effective teaching and learning, diversity in CS, and the role of social identity in learning. This article presents the content in the context of the enrollment crisis, describes our goals and early results, and offers suggestions as to how it might be incorporated, in whole or in part, at other institutions. The curriculum is openly accessible online [3].

INCREASING ENROLLMENT AND THE GOOGLE CS CAPACITY PROGRAM

According to the 2015 Taulbee Report [8], CS bachelor's degree production in the United States (US) in 2014 increased 21.8%, marking the second year of double-digit increases. In addition, the total undergraduate enrollment in computing majors among US departments (including both CS and CE) increased 22.5%, continuing and surpassing a pattern of increase demonstrated over the previous eight years. These figures, however, do not tell the entire story—as Eric Roberts [7] pointed out, many universities are able to shield themselves from the increases to some extent by raising their admission requirements. Such measures may have the unintended consequence of excluding underrepresented minority students. Increased enrollments [2] lead to more competition for CS programs. Increased competition creates advantages for students with previous CS experience, and students from underrepresented populations are less likely to be able to access CS in high schools [4].

In March of 2015, Google launched the Computer Science Capacity Awards program, a three-year program to support innovative, inclusive, and sustainable approaches to address the scaling issues in college and university CS educational programs. The rationale for this program was that innovations in teaching and technologies, while additionally ensuring better

engagement of women and underrepresented minority students, were necessary to creating inclusive, sustainable, and scalable educational programs. After an extensive proposal review process, Google selected eight institutions to participate in this program, among them Mount Holyoke College.

MEGAS AND GIGAS EDUCATE (MaGE)

Mount Holyoke is a women's liberal arts college of approximately 2,200 undergraduate students. The Computer Science Department, established in 2000, has experienced sudden and tremendous growth in recent years in both number of majors (Figure 1) and introductory course enrollments. The department currently has 5.5 tenure-track faculty and two visiting lecturers. With over 120 current majors (students typically declare in their sophomore year) and a growing number of non-majors interested in learning computer science, the department faces the challenge of trying to meet extraordinarily high interest with limited resources.

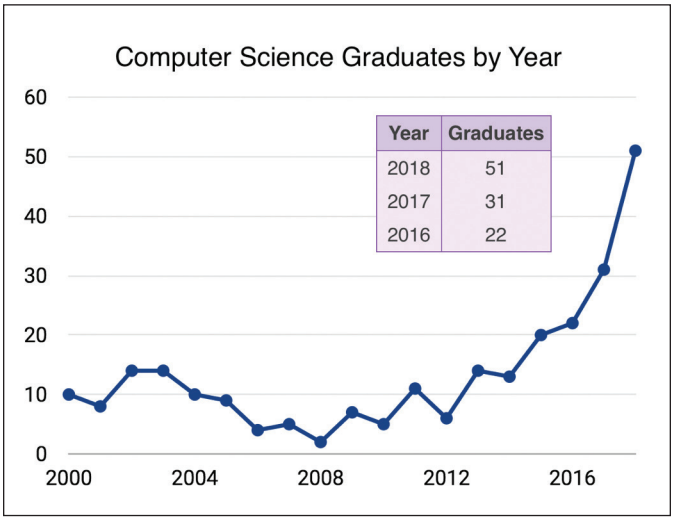

Figure 1: Number of computer science graduates by year at Mount Holyoke, 2000-2018.

The majority of Mount Holyoke students enrolling in the introductory CS1 course have little-to-no prior experience. We believe that close interaction with students and careful feedback are key factors in attracting and retaining students traditionally underrepresented in computer science. An important pedagogical component in our introductory courses has been one-on-one contact between students and instructors (particularly through small lab sections) and careful review of code. Specifically, programs are graded with consideration to style and approach; automated grading approaches cannot provide this level of feedback.

We designed the Megas and Gigas Educate (MaGE) program in 2015 with the goal of providing introductory CS students with one-on-one feedback from and close interaction with trained peer mentors, while at the same time increasing the capacity of the introductory courses. By building a vibrant community of peer mentors as role models, we also aim to increase the participation and retention of women, underrepresented minorities, and first-generation college students.

We see diversity and inclusion as key tools for creating a welcoming and diverse learning environment, especially for students who may not initially see themselves as computer scientists. The MaGE curriculum prepares students for educating, mentoring, and supporting others in inclusive ways. Peer mentors work closely with a group of up to nine CS1 or CS2 students for an entire semester. Their responsibilities go beyond those of a typical course assistant (see section on 'Peer Mentor Responsibilities'). Prior to beginning as a mentor, students must complete the MaGE Training course, a half-semester course taught by a member of the faculty (Figure 2).

Figure 2: Mount Holyoke students in the MaGE Training course.

The MaGE Training curriculum includes research-based instruction on effective learning—motivation, strategic learning, self-efficacy, and growth mindset—enabling peer mentors to strengthen their education toolkits by self-assessing their strengths, engaging in group discussions, and adjusting and stretching their personal perspectives [5]. Throughout the course, students also increase their awareness of the role of social identity in learning, while gaining practice and preparation in code review, giving effective feedback, and creating active learning lessons. The curriculum was developed by computer science faculty in collaboration with a colleague in psycholo-

gy and education who has research expertise in motivation, identity, and mentoring. While the structure of the mentorship responsibilities is informed by successful peer education programs at Mount Holyoke and at other institutions, we believe the MaGE curriculum for preparing students to become computer science peer mentors is novel in its emphasis on diversity, inclusion, and the role of social identity in learning.

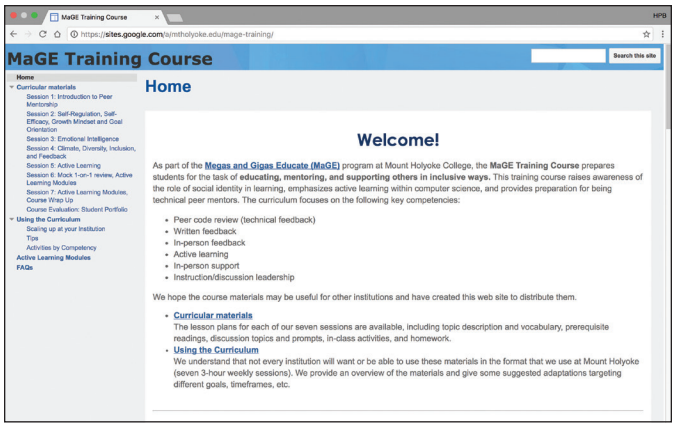

Figure 3: MaGE Training course landing page.

The MaGE Training course site [3] has complete lesson plans and materials for use by educators and students; Figure 3 shows the landing page. These materials and adaptations of them are currently in use at other institutions, including small colleges and large universities. An excerpt from a Mount Holyoke student's written reflection upon completion of the training course is shown below.

> *"I believe one's path to becoming an inclusive peer mentor should start from self-reflection. Ask yourself questions such as, "What impact do my own culturally-bound assumptions have on my interactions with my mentees? How might the background and experiences of my mentees influence their motivation, participation, and learning? How would I modify one-on-one meetings to make them more accessible to all students?" Reflecting on assumptions that we made about hypothetical students was a particularly beneficial exercise: unfortunately, everyone is vulnerable to making assumptions about others, but one needs to be fully aware of these assumptions in order to prevent them from affecting his/her behavior." —Mount Holyoke trained peer mentor*

STRUCTURE OF THE MaGE TRAINING COURSE

We teach the MaGE training course at Mount Holyoke as a half-semester seminar-style course, meeting weekly for seven three-hour sessions. Students receive two course credits for MaGE Training (half the credits of a typical Mount Holyoke course). The core modules of the course and their interdependencies are shown in Figure 4. Practice code review activities are spread across several modules because code review is one of the primary responsibilities of peer mentors and it is a new skill for nearly all students.

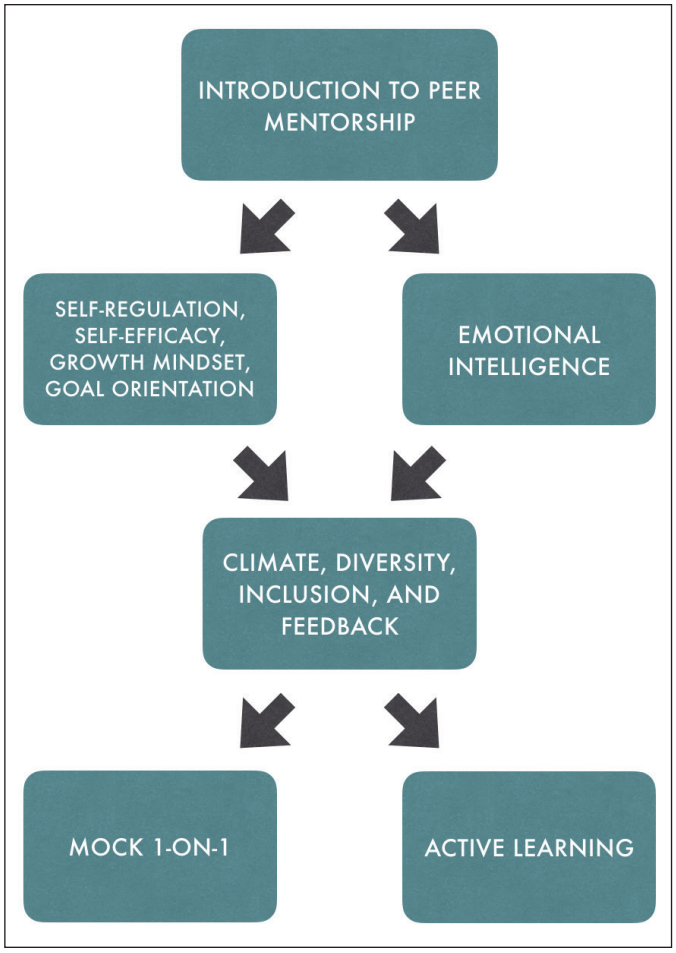

Figure 4: Dependencies among modules in the MaGE Training course.

Between sessions, assigned homework includes reading scholarly articles, completing self-inventories of learning strategies and emotional intelligence, practicing code reviews, shadowing a current mentor, completing a "mock one-on-one" 10-minute feedback conversation with a classmate, writing self-reflections, and creating an active learning lesson plan.

During class, the three-hour block of time is split into shorter activities. For example, the objectives of Session 4 are: a) to continue to gain competence and confidence in practical code review skills; b) to reflect on one's own assumptions and biases; c) to reflect on and understand the complexities of diversity, inclusion, and climate in a technical setting and to be able to apply this when interacting with students and providing feedback. To help achieve these objectives, Session 4 is broken into the following activities.

- Code review activity: With their code reviews completed prior to class, students compare with a partner, imagining they are CS1 students, thinking about how it feels to receive the written feedback. The exercise is discussed as a class, with respect to both technical content and style of feedback.
- Writing activity: A three-sentence description of a hypothetical CS1 student is presented to the students, who are then given the following free-writing prompt: what

assumptions did you make about the student as a person and about how they will perform in CS1?

- Small-group discussion: Students break into groups based on the diversity-themed article they read prior to class (among five options); they discuss reactions and relevance to the MaGE program.
- Discussion: As a class, discuss the scholarly article, "The Mentor's Dilemma: Providing Critical Feedback Across the Racial Divide" [1]—read prior to class—with a focus on understanding buffered feedback.

The impact of these activities on two MaGE peer mentors is exemplified by the following written reflections:

"I naturally make assumptions about people, but by being self-aware of that fact, I can reduce my assumptions and their effects on my views of people."

"I realized in this class that giving effective feedback is not an easy task. A lot of people think they are offering great feedback and constructive criticism but instead, they only end up saying a few praise words and inexpressive compliments. While giving feedback, it is very important to make sure it is buffered. This means that feedback needs to have a balance between strengths and weaknesses, so as to avoid it being too positive to the point that it may seem inauthentic or too negative to the point that it may discourage the feedback receiver."

PEER MENTOR RESPONSIBILITIES

After taking the MaGE Training course, peer mentors work with a group of around nine CS1 or CS2 students (half a lab section) for a whole semester. Each week, the peer mentors perform written code reviews on completed student assignments, give feedback in one-on-one 10-minute meetings, lead active learning lessons, and assist in the lab section of the course. The cohort of peer mentors meets weekly for a 75-minute MaGE Practicum course with the program coordinator and a faculty member to discuss topics related to the MaGE Training course and further develop as mentors. Being a peer mentor requires a commitment of approximately 10 hours/week for an entire semester. Mentors receive wages for 5 hours/week and two course credits for MaGE Practicum (half the credits of a typical Mount Holyoke course).

EARLY RESULTS OF THE MaGE PROGRAM

The MaGE Program at Mount Holyoke is currently embarking on its third year. In the first year, peer mentors were integrated into CS1; in the second year, peer mentors were integrated into CS1 and CS2. The enrollment capacity in CS1 has increased from 36 to 72 (from one 36-seat lecture to two 36-seat lectures) since the MaGE Program was established. In the first year of the MaGE Program, retention from CS1 to CS2 was 89% for first year students, 79% for sophomores, 38% for juniors, and 33% for seniors. These retention rates are higher than the CS1 to CS2 retention in the previous year, which was 56% for first years, 55% for sophomores, 18% for juniors, and 0% for seniors. After the third year of the MaGE program, with the understanding that changes in instructors and curricular materials might affect the data, we plan to report on retention over multiple semesters, broken down by student class year and race.

Initial findings from the first year of the MaGE program show that CS1 students feel that they belong to the computer science community and that they found their Giga Education Mentor (GEM) to be highly knowledgeable, approachable, and creative. Surveys were completed at the end of each semester. It should be noted that there is no control group; all students have peer mentors. In one survey (N=87 students), on a 5-point scale from 1 (strongly disagree) to 5 (strongly agree), the average rating for "I feel that I belong to the computer science community" was 4.43. In a second survey (N=51 students), on a 6-point scale from 1 (strongly disagree) to 6 (strongly agree), the average ratings for "GEM was knowledgeable", "GEM was approachable", and "GEM was flexible/creative when helping students" were 5.3, 5.4, and 5.3 respectively.

USING THE CURRICULUM AT OTHER INSTITUTIONS

Factors of size, faculty, focus, budget and physical space all contribute to how undergraduate CS programs are being impacted by the capacity challenge. For this reason, institutions need to carefully consider and adopt the interventions that best meet their needs and the needs of their students. It is clear, however, that increasing the number of undergraduate mentors and focusing on peer-to-peer learning is a strategy being employed on several campuses. We believe that the MaGE program and resources offer an effective and efficient way to prepare students to take on and succeed in a variety of roles including peer mentors and teaching assistants.

At Mount Holyoke, students take the MaGE Training course during one semester and then become eligible to be a peer mentor the following semester. One benefit of this model, contributing to an inclusive learning environment, is that students who want to be a peer mentor but do not feel ready to jump into a demanding peer mentorship position have a semester to practice code reviews and mock feedback sessions while gaining confidence in their abilities.

Given the limitations in faculty resources that all CS departments are facing, the Mount Holyoke model of completing the training course prior to beginning peer mentorship may not be a good fit for all institutions (especially where students are not performing code review). We believe, however, that elements of this approach and course can be adopted and adapted by many CS programs. Following are some suggestions for other ways to use the MaGE Training curriculum.

If the primary role of the undergraduates is to hold **drop-in help** sessions, or to **lead small group sections**, training could be offered in a single-day boot camp. Sample sequences of topics are listed below.

Single-day boot camp for drop-in help[1] or leading small sections[2]
Introduction
Learning and motivation: self-regulation, self-efficacy, growth mindset, goal orientation
Emotional intelligence
Climate, diversity, inclusion
[1]Effective feedback / [2]Active learning
Videotaped mock activity

We consider the topics of learning and motivation, emotional intelligence, and climate, diversity, and inclusion to be relevant for all peer educators. To prepare students for holding drop-in help sessions for beginner students to ask questions and get help on assignments, we recommend including the unit on effective in-person feedback, including practicing serving as an effective *mirror* and *coach*. To prepare students for leading small group sections that review and practice core course concepts, we recommend including the unit on active learning, to help improve access for all learners in the section.

In all versions, we recommend including a **videotaped mock activity** (either giving feedback or leading a section), to prompt self-reflection. In the MaGE Training course, each student submits one of their own past CS1 assignments to be reviewed by a classmate. Outside of class, the pair schedules a 10-minute appointment with a course assistant who videotapes the mock conversation. Students watch their own video and selected clips of classmates' videos before writing a final reflection on the activity. For a single-day boot camp, video sessions could be scheduled in parallel. In our surveys and interviews, the mock one-on-one feedback session was the activity that students found most useful to their learning and growth.

A challenge for a single-day boot camp is that while small group discussions and activities can help students quickly absorb new concepts, there is less time for the ideas to sink in. Taking time for short written reflections may aid in retention and critical thinking about the topics.

At institutions with existing programs that hold weekly meetings throughout the term for the group of peer educators (mentors or teaching assistants), engaging students in discussions of these topics might contribute to a more inclusive learning environment. Some activities, such as the videotaped mock sessions and the creation of active learning lessons would be most useful either before the start of the term or very early in the term.

CONCLUSION

As enrollments in undergraduate computer science programs continue to grow, many institutions are striving to become more inclusive and engaging of all students. The MaGE Program at Mount Holyoke College aims to create a welcoming and diverse learning environment, especially for students who may not automatically see themselves as computer scientists. The MaGE Training curriculum is designed to prepare students for their roles as peer mentors by engaging them in group discussions on effective learning and the role of social identity in learning. At the same time, students gain practice with code reviews and mock feedback sessions. We hope that other computer science educators and students might consider similar training for peer mentors and teaching assistants at their institutions. Detailed lesson plans including discussion prompts, writing prompts, classroom activities, and homework for the MaGE Training course are available online [3]. ❖

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Heather Pon-Barry
Department of Computer Science
Mount Holyoke College
50 College St., South Hadley, MA USA
ponbarry@mtholyoke.edu

Audrey St. John
Department of Computer Science
Mount Holyoke College
50 College St., South Hadley, MA USA
astjohn@mtholyoke.edu

Becky Wai-Ling Packard
Department of Psychology and Education
Mount Holyoke College
50 College St., South Hadley, MA USA
bpackard@mtholyoke.edu

Chris Stephenson
Head of Computer Science
Education Strategy
Google
stephensonc@google.com

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