"Georgia Computes!": Improving the Computing Education Pipeline

Amy Bruckman, Maureen Biggers, Barbara Ericson, Tom McKlin, Jill Dimond, Betsy DiSalvo, Mike Hewner, Lijun Ni, and Sarita Yardi
College of Computing & CEISMC
Georgia Institute of Technology
Atlanta, GA 30332
{asb, ericson, jpdimond, bdisalvo, hewner, lijun, yardi}@cc.gatech.edu,
biggersm@indiana.edu, tom.mcklin@gatech.edu

ABSTRACT
Computing education suffers from low enrollment and a lack of diversity. Both of these problems require changes across the entire computing education pipeline. The "Georgia Computes!" alliance, funded by the National Science Foundation's *Broadening Participation in Computing* program, seeks to improve the computing education pipeline in Georgia. "Georgia Computes!" is having a measurable effect at each stage of the pipeline, but has not yet shown an impact across the whole pipeline.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education–*computer science education.*

General Terms
Experimentation and Human Factors.

Keywords
Computing education pipeline, summer camps, introductory courses

1. CHANGING A PIPELINE
The challenges in computing education today are well-documented [1-4]. "Georgia Computes!" highlights two concerns of interest: Low enrollment and a lack of diversity. Enrollment in computer science programs is at levels not seen since the 1970s. The students that do enroll are overwhelmingly male, and either Caucasian or Asian.

"Georgia Computes!" sees these as related problems. By improving diversity, Georgia could draw more students, including females and under-represented ethnic groups, into computer science. Both problems can be addressed, in part, by improving computing education across the pipeline. We know computing education problems are really pipeline issues—they cannot be addressed at a single point.

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Many pre-teens have already made up their minds that computer science is boring and characterized as nerdy and uninteresting [4]. Declining interest in high school computer science means fewer students are being drawn into undergraduate computer science. The high failure rates in undergraduate computer science make it more difficult to retain the students that are drawn into computer science classrooms. Changing only one aspect of the pipeline doesn't correct the problem, e.g., if we got pre-teens excited about innovations in computer science, they would only be discouraged in high school and undergraduate classes if those classes didn't reflect similar innovations.

The National Science Foundation *Broadening Participation in Computing* program funded the alliance, "Georgia Computes!" in October 2006. "Georgia Computes!" is an attempt to change an entire state's computing education pipeline. The alliance is directed by Mark Guzdial and is based at Georgia Institute of Technology (*Georgia Tech)*, as the lead technological institute in the University System of Georgia. The effort is an alliance between different units at Georgia Tech, the Georgia Department of Education, the University System of Georgia, the YWCA, and the Girl Scouts of Greater Atlanta, Incorporated. OurThe strategy is to increase interest in computing at the pre-teen level, improve quality of computing education at the high school level, draw students into the undergraduate level, and make apparent to students the opportunities for graduate study in computing. The number of participants is one measure of the growth of the alliance and its impact (see Table 1).

Why Georgia? The challenges and opportunities are enormous in Georgia, with high minority enrollment and low K-12 academic achievement. The University System of Georgia's systemwide enrollment is 22.7% African American. Only 57.6% of Georgia high school students graduate high school on-time, and the numbers are lower for specific under-represented groups: 47.5% for African American students and 42.4% for Hispanic students [5,6]. Georgia has one of the lowest rates of high school students going on to higher education. Benchmarks such as the SAT show Georgia's academic achievement level is among the worst in the nation, 47th out of the 50 states for 2008. Georgia's Black and Hispanic students, in particular, score well below the already low average on the SAT as well as on other standard measures of academic achievement, such as Advanced Placement test scores, college matriculation rates, and the need for college remediation. Georgia had one of the lowest levels of students taking the Computer Science AP exam, which isn't surprising given that CS

AP was available in less than 10% of the public high schools in the state when we started. If "Georgia Computes!" makes a difference in Georgia, with everything else working against it, it will be a significant model for others to adopt and adapt.

Table 1: Participation in Georgia Computes! activities

	Pipeline	Years	Num
YWCA Workshops	K-12	2006-2007	30
		2007-2008	40
Girl Scouts Computing Workshops	K-12	2005-2006	190
		2006-2007	372
		2007-2008	1595
HCI Camps	K-12	2007	10
		2008	15
CS AP Teachers	Teachers K-12	2003-2004	44
		2007-2008	87
Faculty Workshops	Faculty	2007	26
		2008	14
Summer Workshops (262 unique teachers have taken one or more workshops with us)	Teachers	2004	40
		2005	72
		2006	79
		2007	82
		2008	92
Summer Camps at Colleges and Universities	Institutions	2006	1
		2007	4
		2008	8

2. STARTING EARLY

Previous work shows that student attitudes about computing are set early on [4]. During middle school, students make up their minds about whether computer science is worth exploring, or not. It is important for any pipeline effort to start at least that early.

Our aim in reaching out to students at these ages is to provide them with a broad definition of computing. Students tell stories using Carnegie Mellon's Alice software [7,8], explore robot programming with LEGO robot kits, create digital arts and crafts using PicoCrickets, and create animations and games using MIT's Scratch [9]. In our summer camps, students start programming in languages like Python.

"Georgia Computes!" offers summer computing camps to high school (started 2004) and middle school students (started 2006) in the Atlanta area. These camps have been highly successful—so successful, in fact, that they are completely full, all summer long, with multiple sessions of each. The "Georgia Computes!" alliance is now helping other University System schools to offer camps. This is discussed further in Section 4.

Additional work with the YWCA's after-school Teen Girls in Technology program in Atlanta reaches middle school girls. The students served by the YWCA program are predominantly African-American. The YWCA program is staffed with undergraduate and graduate students from Georgia Tech who serve as mentors and teachers to the students. We hire student mentors who are female and/or who are members of underrepresented groups, to serve as role models. We sponsored an all-female, majority African American YWCA team to compete in the LEGO FIRST competition (Figure 1).

The Girl Scouts of Greater Atlanta, Inc. has a membership of 40,000 girls in grades K-12 comprising rural, suburban, and urban Georgia. In Saturday computing workshop and summer camp sessions students explicitly explore computing concepts through tools like Alice, PicoCrickets, LEGO robots, and Scratch.

The Girl Scout workshops have been growing extremely fast. Work started with the Girl Scouts during 2005-2006. That year about 190 girls had some introduction to computing with LEGO robots. In 2006-2007 327 girls had some introduction to computing with LEGO robots or Alice. In 2007-2008 1595 girls had some introduction to computing using LEGO robots, Scratch, PicoCrickets, or Alice. The Saturday workshops grew from 20 girls at a time to 65 girls at a time. Additionally, three short workshops were offered for majority-Hispanic Girl Scout troops at a local elementary school. Thanks to the Anita Borg Systers Pass-it-On Grant we were able to provide transportation for Hispanic Girl Scouts to Georgia Tech for a 4 hour workshop.

The results of these activities have been overwhelmingly positive. Tom McKlin is the external evaluator on the team. The Saturday computing workshops are only four hours long; however, despite the short period of time, McKlin found statistically significant improvements in students' attitudes about computing in response to survey questions like "Computer jobs are boring," "Girls can do computing," and "Programming is hard." Of 13 events where we have both pre-surveys and post-surveys, 7 of the workshops had a statistically significant improvement (using Mann-Whitney U-Test, with $p < 0.10$) in participants' attitudes about computing.

Figure 1: An All-Female, majority African-American LEGO FIRST team, sponsored by "Georgia Computes!" and a first for the Atlanta YWCA TGI-Tech Program.

3. HIGH SCHOOL

The "Georgia Computes!" alliance includes Georgia Tech's *Institute for Computing Education* (ICE@GT). ICE@GT is a collaboration between Georgia's Department of Education and Georgia Tech. The state wanted to grow the number of computer science teachers in the state, with a particular emphasis on developing Computer Science (CS) Advanced Placement (AP) teachers. The state's strategy was to teach existing high school teachers how to teach computer science.

ICE@GT developed a multi-year plan for developing high school teachers, many without previous computer science experience, into CS AP teachers [10]. During the first summer, teachers enroll in a one week summer workshop where they learn to teach an introductory computing course using LEGO robots, Scratch and/or Alice. Teachers should teach that course for at least one year and then take a beginning programming in Java workshop. Teacher training used the *Media Computation* approach [11] which has worked successfully with liberal arts and management (Business) majors [12]—the most common majors of existing Georgia high school computing teachers [13,14]. The teachers are expected to teach beginning programming for a year or more. During years three and four, the teachers take summer workshops in teaching intermediate programming and then CS AP. The combination of four years of experience teaching computing, with in-service workshops, plus summer workshops, can successfully help teachers to become CS AP teachers.

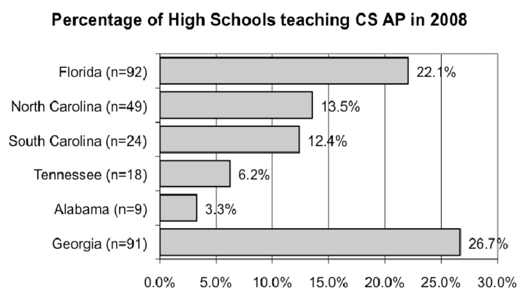

Figure 2: Percentage of High Schools Teaching CS AP in Georgia and Neighboring States

The goal for "Georgia Computes!" was to increase the number of CS AP teachers by 50% over the three years of our NSF BPC grant. By year two of the project, the number of Georgia schools authorized by the college board to teach AP CS had increased by 107%, (from 44 to 91). Georgia has a higher percentage of high schools teaching CS AP than any state in the Southeast (Figure 2). While we can't claim that "Georgia Computes!" and ICE@GT alone accounted for that increase, the broad reach of the increase to counties far away from Atlanta, where most CS AP initiatives have been based, suggests that "Georgia Computes!" has had a significant role in this change (Figure 3).

In addition to supporting high school teachers with training, teachers are provided direct support in their classrooms with student supporters. Marion Usselman, from Georgia Tech's Center for Education Integrating Science, Mathematics, and Computing (CEISMC), is the co-PI on a Student and Teacher Enhancement Partnership (STEP) NSF GK-12 program. CEISMC is the educational outreach center at Georgia Tech. The STEP program, partners advanced undergraduate and graduate student fellows (from fields supported by the National Science Foundation) for ten hours per week with metro-Atlanta area high school science, mathematics, and technology (STEM) teams that are led by master teacher-coordinators. The program uses the exceptional scholarly expertise available at Georgia Tech to assist in increasing the mathematics, science, and computing performance of Atlanta-area school students. "Georgia Computes!" funds STEP students to work in CS teachers' classrooms.

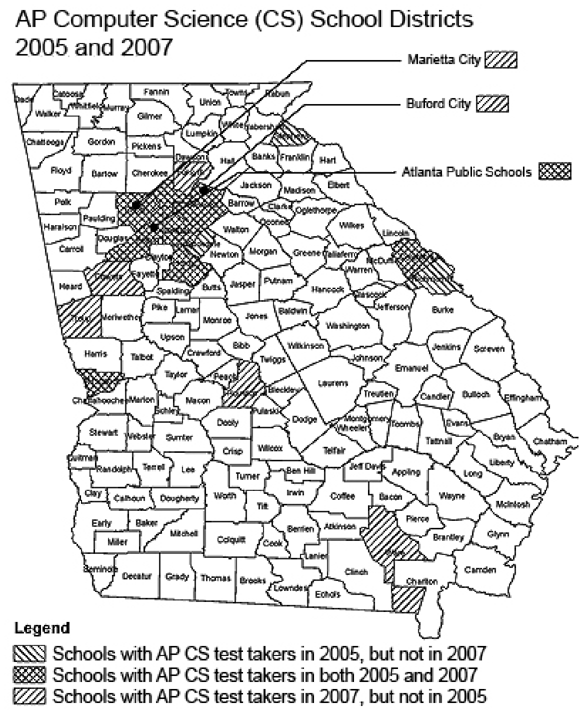

Figure 3: AP CS Test-Takers by County in Georgia. *Note increase beyond the central Atlanta counties.*

4. UNDERGRADUATE

Efforts at the undergraduate level are of two types:

- Workshops to teach Georgia university CS faculty how to offer innovative undergraduate classes that match (in context and motivation) the kinds of activities "Georgia Computes!" using at the pre-teen and high school levels.
- Training and seed-funding to help University faculty in offering middle school and high school student camps, like the ones offered at Georgia Tech.

The University System of Georgia (USG) consists of 35 public colleges and universities, overseen by a single Board of Regents and Chancellor. The University System includes two year, four year, and research universities. Not all 35 institutions offer degree programs in computing. Those institutions that do offer computing programs have representatives on the Academic Advisory Committee on the Computing Disciplines (AACCD). "Georgia Computes!" works directly with the AACCD, e.g., offering workshops at an AACCD meeting, and contacting AACCD representatives for available programs and workshops.

4.1 Faculty Workshops

"Georgia Computes!" has offered a half dozen workshops in a year and half to USG CS faculty. The first workshop was a half-day workshop following an AACCD meeting in February 2007. Since then, workshops have been offered in two day and three day formats in Atlanta (on both weekends, and during summers), and a four day workshop at the Georgia Southern University, to reach faculty in the southern part of the state.

The focus of the workshops is to provide faculty with resources and ideas to teach introductory computer science using the contextualized approaches that we are using successfully at the earlier stages in the pipeline. Workshops demonstrate teaching introductory computing with media, robotics, and engineering, using a variety of languages (Python, Java, and MATLAB). These approaches have been shown to improve retention at Georgia Tech and at other schools [14]. Teachers are provided with materials (e.g., example texts, homework assignments, lecture slides) including infrastructure support (e.g., materials to evaluate their own classes, websites and mailing lists for additional support and collaboration with other teachers). The goal of the workshops is to support teachers in adapting these materials for their schools and contexts.

Three-fourths of the state's universities offering some kind of computing program have now had at least one faculty member take one of our workshops. In a study of USG faculty who attended workshops in summer 2007, half of all faculty who attended reported adopting some of the materials in classes [15].

4.2 Growing Summer Camps

As mentioned, the middle school and high school summer camps at Georgia Tech are completely full. While Georgia Tech could look for ways to expand the camp, a broader and more effective impact on the state's computing education pipeline is being developed by helping other USG institutions to offer their own middle and high school student summer camps. Camps at colleges and universities across the state that draw from their own regional school districts will have an added advantage in recruiting those local students into their degree programs.

Faculty are invited to attend workshops on "How to Run a Summer Camp." Each fall a one-day workshop is offered on the logistics of running a camp, e.g., how to advertise, the kinds of permission and consent forms required, and how to put together a sustainable business model. In the spring, a two day workshop is offered on curricula that has been used at Georgia Tech summer camps.

"Georgia Computes!" offers seed grants for up to $5,000 to up to four USG institutions a summer. Institutions are asked to create an application that describes the camp in detail, including the financial plan and how the seed grant will be used. Institutions are encourage to develop a plan where the camp fees sustain the camp, and the seed grant can be used as initial funding as a source for purchasing materials, like robot kits or PicoCricket kits. Institutions are encouraged to use the kits as a lending library to local middle and high schools during the academic year —thus creating another connection between the institutions and the local schools.

"Georgia Computes!" has funded seven new summer camp programs around the state. These range in type from a focus on robotics to a broad focus on mathematics and computing. Funded camps are a part of the evaluation effort, and analysis of their surveys is still on-going.

5. GRADUATE

Georgia Tech's College of Computing is the leader in graduate computing education for the University System of Georgia and is a national leader in creating graduate computing education that has a more diverse population. Georgia Tech offers two non-traditional-CS graduate degrees that emphasize the relevance of computing in everyday settings. The MS in Human-Computers in Interactions involves students in classes in computing, psychology, new media, and industrial design, and has had strong female participation (25% to 52%). The Ph.D. in Human-Centered Computing (HCC) emphasizes the study of computing for humans through the lens of psychology, sociology, learning sciences, and cognitive science, and has always been female-majority.

These graduate students are active in various "Georgia Computes!" programs, serving as role models from diverse backgrounds. Furthermore, these students' work demonstrates a broader definition of computing, including HCI and HCC. We hypothesize that a broader definition of computing may appeal to a larger and more diverse group of students.

6. CHALLENGES AND OPPORTUNITIES

While each of the individual efforts seems to be having impact, we have not yet shown effects throughout the pipeline. Part of the problem is simply the short time of the effort. In the two years of "Georgia Computes!" one can hardly expect pre-teens, whose attitudes may have been changed about computing, to have even completed high school, let alone entered undergraduate or graduate study in computing. Nonetheless, there are changes that we might expect which we would like to track—and yet are finding roadblocks to gathering this data.

One of these challenges is capturing data about enrollment in computing programs across the state of Georgia. Our efforts at the high school level should be influencing undergraduate computing enrollment, and efforts to innovate in computing curriculum should be having an effect on retention rates around the state. How do we gather data from 30+ individual institutions, with different degree programs and different course numberings (and meanings)? The original hope was to gather data from the USG's own "Data Warehouse" which gathers detailed data from every USG institution on its enrollment. However, the "Data Warehouse" does not map all data to a central format—rather, it stores 35 separate databases in 35 separate formats. We are now engaged in the tedious process of learning the mappings between course meanings at all relevant institutions and how to gather data from each individually.

While the challenges are large, so are the opportunities. The interactions in "Georgia Computes!" have created opportunities for new interventions and new research. Here are two brief examples of these kinds of opportunities.

6.1 Research at a Girl Scout Summer Camp

Each of the last two summers, we have had the opportunity to place a Georgia Tech student at a Girl Scout Summer Camp to teach computing. Girls could take robotics or animation as a summer camp activity, along with horseback riding and swimming. In this way, we give girls a chance to interact with technology outside of a classroom context, in a leisurely setting.

During Summer 2008, one of the HCC Ph.D. students, Jill Dimond, used the opportunity to trial a new approach to teaching computing. She taught the girls to design and build chat tools for the One Laptop Per Child XO laptop to be used in the developing world. The response was terrific—she had to hold two sessions daily, rather than the one she planned, because of the number of girls interested. This kind of activity furthered Dimond's research and offered the girls a new model for what graduate students in computing might do.

6.2 Beyond the Girls at the YWCA

Betsy DiSalvo is an HCC Ph.D. student who is focusing her attention on African-American boys who were not being reached through our YWCA program. In partnership with Morehouse College, DiSalvo is starting a new effort to build on the interest of many African-American boys in sports-related console video games. She is trying to engage the boys in becoming video game *testers*, and she has signed up several video game companies to offer unreleased versions of their games for the boys to work on. By engaging the boys in testing games, she sets up the situation where they must necessarily dig into the underlying technology and try to understand how the games they love work. Work testing video games is coupled with contextualized computing education in an after-school program that she intends to transform into an after-school jobs program in year two or three. Low-income teens typically must work to earn money once they turn 16 years old. A jobs program could bring educational benefit through their work time.

7. CONCLUSION

The challenge of impacting an entire state's computing education pipeline is enormous. "Georgia Computes!" is doing it the best way we know how, piece-by-piece, by:

- Broadening the definition of computing at the level where students are most likely to lose interest, at the pre-teen/middle school level.
- Improving the training of high school teachers and providing them with support and interesting curricula.
- Innovating in undergraduate computing education across the state.
- Helping colleges and universities across the state to recruit from their local communities.
- Offering computing graduate programs that might draw a more diverse population of students.

The particular challenges today are in assessment. While evaluation results at the piece-by-piece level are strong, demonstrating an impact on the entire *pipeline*, that interventions are crossing the boundaries between levels, is the next big challenge.

At the same time, the opportunities that arise from this alliance are tremendous. We offer just two examples of how the connections that this alliance is creating allows for new kinds of interventions and new kinds of activities that probably would not happen without the alliance. We continue to develop these opportunities and look for ways to further the alliance's goal of improving computing education across the entire state.

8. ACKNOWLEDGMENTS

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