TELLING THE STORIES OF THE BPC ALLIANCES

How One NSF Program Is Changing the Face of Computing

June 2010

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The Current Face of Computing

Computer science is a creative and team-oriented discipline. Its work underlies discoveries made in other STEM (science, technology, engineering, and mathematics) disciplines, with exciting applications to many other fields such as journalism, arts, humanities, gaming, and social science. But trends in degrees earned by U.S. citizens in computer science have been declining (Figure 1). To increase their contributions, groups that historically have participated at very low rates must be recruited: minorities, women, and students with disabilities. Failing to do so will concede talent to other fields, eliminate talent from the Computing/Information Technology (IT) workforce, and rob us all of the diverse perspectives and novelty that will shape the future of technology.

Figure 1.

Notes: Data not available for 1999. Detailed field not collected by race/ethnicity prior to 1995. Racial/ethnic breakouts for U.S. citizens and permanent residents only; temporary resident includes all racial/ethnic groups. Data from 1996 to 2007 based on degree-granting institutions eligible to participate in Title IV federal financial aid programs and do not match previously published data based on accredited higher education institutions.
Source: Science and Engineering Indicators 2010, with data derived from National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science
The Millennial generation of today’s college students—ironically dubbed “Generation Net” due to its technology-immersed lifestyle of hand-held devices and social networking—should be flocking to, not fleeing from, the career opportunities dependent on computing skills. This is not happening. The connection, for instance, between manipulating “apps” and inventing them as a livelihood eludes most students. While STEM jobs are projected to grow at twice the rate of the economy as a whole to 2018, the largest growth is expected to occur in “computer and mathematical” occupations (Figure 2).

![Figure 2](image)


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BPC Alliances as Solutions

Are students uninformed or disinterested in computing? The reasons for the slumping trends in enrollments and degrees are many. Rather than detail the problems, this report will highlight some solutions—in the form of a special array of National Science Foundation-funded projects known as Broadening Participation in Computing (BPC) Alliances. This program is changing the face of computing. The stories of these projects outpace the conventional data that show progress in academic degrees and workforce choices. They are stories of practices on-the-ground, mostly on college campuses but in other settings as well, that break the mold of who does computing, and of against-the-odds achievements by students and faculty.

These stories of BPC are not only inspirational in terms of the people involved, but also instructive about changing the conditions for education, high school to postdoctoral. Cohorts of “underserved” students—those steeped in poverty, first-generation college-goers, ignored through stereotyping and low expectations, academically under-prepared, or just not resembling what computer scientists traditionally look like—are being reached, gaining confidence and skills, and making progress toward degrees and careers in computing. NSF has provided resources for changing the “inflection point” in the lives of many.

In the hands of dedicated and enlightened project leaders, BPC is defying the national trends. These are stories that must be told, but today are incomplete. As those reflected in the stories below can attest, promising practices represent cultural shifts over time. The stories merit an audience, especially those who hear about “best practices” but lack guidance on how to adapt and apply them to their own environment, institutional strengths, and underserved but capable and interested student populations.

Each BPC Alliance has a storyline that conveys the excitement of its work. What follows is a snapshot of data on process and outcomes, the distinctive contributions of each to these data, and an assessment of prospects and impacts that are far from full blossom. Then we offer a look across the Alliances, as part of a program representing returns on an NSF investment in terms of collective impact on computing nationally—human resources, practices in and out of the classroom, and institutional change. This synthesis captures the overarching story of experiments in education that are paying off in one discipline of singular significance in the 21st century.

“This program is changing the face of computing.”
The first 10 BPC Alliances were funded in 2005 and 2006; an 11th predated the BPC program but has been folded into its efforts (see Table 1). Most were operational with students a year or so later. From a vantage 5 years later, there are at least four major storylines to trace: reforming statewide systems, focusing on undergraduate experiences, connecting unlike institutions, and creating national networks. We would suggest that any disciplinary community attend to these (and probably other) dimensions if it seeks program longevity and sustainability beyond a primary sponsor and a few student cohorts.

Universities are dynamic institutions with constant throughput. People come and go, state budgets fluctuate, perceptions and politics ripple through campuses in unpredictable ways. This is the uncertainty that all multiyear projects must anticipate. Planning helps, but is hardly foolproof. The impacts on enrollments, curricular innovations, student performance, organizational partnerships, and administrative patience are all variable. This is the backdrop for all BPC stories.

**The Storylines**

NSF's “broader impacts” criterion defines “the infrastructure for research and education” as “facilities,

<table>
<thead>
<tr>
<th>Table 1. NSF-Broadening Participation in Computing Alliances Funded 2005-2007, Active in 2010</th>
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<tr>
<td><strong>2005-2006</strong></td>
</tr>
<tr>
<td>A4RC (N. Carolina A&amp;T)</td>
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<tr>
<td>Gerry Dozier</td>
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<td><a href="http://www.a4rc.org">www.a4rc.org</a></td>
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<td>AccessComputing (U. Washington)</td>
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<td>Richard Ladner</td>
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<td>CAHSI (U. Texas-El Paso)</td>
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<td>Ann Gates</td>
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<td><a href="http://cahsi.org">http://cahsi.org</a></td>
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<tr>
<td>Widening the Association Research Pipeline (Computing Research)</td>
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<td>Lori Clarke</td>
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<td><a href="http://www.cdc-computing.org">www.cdc-computing.org</a></td>
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<tr>
<td>STARS (U. N. Carolina)</td>
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<tr>
<td>Teresa Dahlberg</td>
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<td><a href="http://www.starsalliance.org">www.starsalliance.org</a></td>
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<tr>
<td><strong>2006-2007</strong></td>
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<tr>
<td>ARTSI (Spelman College)</td>
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<tr>
<td>Andrew Williams</td>
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<td>CAITE (U. Massachusetts)</td>
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<td>Rick Adrion</td>
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<tr>
<td>EL (Rice U.)</td>
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<tr>
<td>Richard Tapia</td>
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<td><a href="http://empoweringleadership.org">http://empoweringleadership.org</a></td>
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<tr>
<td>Georgia Computes (Georgia Tech)</td>
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<td>Mark Guzdial</td>
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<td><a href="http://www.georgiacomputes.org">www.georgiacomputes.org</a></td>
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<tr>
<td>Into the Loop (U. California-LA)</td>
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<tr>
<td>Jane Margolis</td>
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<td><a href="http://intotheloop.gseis.ucla.edu">http://intotheloop.gseis.ucla.edu</a></td>
</tr>
<tr>
<td>PRE-BPC (preceded funding of the 10 projects called Alliances, but functions as one)</td>
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<tr>
<td>NCWIT (Nat’l Ctr for Women &amp; IT)</td>
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<tr>
<td>Lucy Sanders</td>
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<td><a href="http://www.ncwit.org">http://www.ncwit.org</a></td>
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3 The following section is based on second-year site visit reports produced for NSF by a team led (in 8 of the 10 projects) by Daryl Chubin, with updates stemming from Alliance presentations at the Feb. 1, 2010 annual PI Meeting and email communications received by Chubin in the months ever since. The storylines are also overlapping, so Alliances fit into more than one category. For simplicity sake, we have assigned them only to one below, a convention we abandon later.
instrumentation, networks, and partnerships.”⁴ Thus, infrastructure encompasses physical and social components of the proposed activity. These are essential for the BPC Alliances and each of the Alliances has built its own infrastructure in support of its storyline.

Reforming Statewide Systems

Working across institutions is hard enough; working across different systems within a state is even more challenging, especially when those systems focus on different segments of the education continuum, e.g., K-12, 2-year, and 4-year. The Commonwealth of Massachusetts and the state of Georgia both have BPC Alliances that focus on students and educational systems across their states.

CAITE—the Commonwealth Alliance for Information Technology Information Education—is distinctive in its emphasis on community colleges that serve as the gateway for underserved populations to careers and higher education. CAITE’s programs include outreach (college and career fairs, campus visits, computing camps, and IT internships), and pathway activities (introductory courses, transfer agreements, peer mentoring, and advising) in collaboration with other state initiatives focused on education and STEM pipeline issues.

Georgia Computes! is the other statewide BPC Alliance. It operates at many levels of the education pathway, working with students both in and out of school, with K-12 teachers and college faculty, and with parents. GA Computes! is less a "pipeline" project than an unapologetic recruitment-to-computing effort. The Alliance sought in its first two years to maximize the number of Georgia middle schools students interested in the broad array of opportunities associated with computing as an activity, a college major, and a career. By building that pool, especially working with girls through the Girl Scouts and the YMCA, they hope to impact participation at the high school and ultimately college levels. In addition, GeorgiaComputes! trains high school teachers to teach computer science up through the AP course. It trains college faculty in running summer camps and in teaching high-retention curricula. Virtually every BPC Alliance works with the GeorgiaComputes! PI and many have adopted his methodology of teaching computing in context.

CAITE and GeorgiaComputes! have worked together on building capacity around evaluation of their programs. Their respective state systems historically have not promoted, and in some cases have inhibited, data reporting in a standard format, data sharing across system lines, and efforts to collaborate to ease student transitions and track progress. Despite this,

⁴ NSF BPC Program Guidelines Solicitation 09-534, p. 8
these Alliances have made notable strides in developing and implementing a common data framework. This framework is a prerequisite for identifying, and ultimately sharing, effective collaborative practices.

**Connecting Unlike Institutions**

*Into the Loop* connects a major university—UCLA—with the second largest (and one of the most diverse) U.S. school districts—Los Angeles Unified School District (LAUSD). This partnership is focused on the introduction of a new high school computer science curriculum and the teacher training and support needed to offer it. It is unique among BPC Alliances in several ways: (1) attempting change from within—in policy and practice—a formal K-12 system; (2) implementing a research-based and pilot-tested approach described by the PI’s 2008 book *Stuck in the Shallow End*, which serves as a rationale and blueprint for the project; (3) pursuing the oft-heard, but seldom realized injunction of “cohesion in instruction” by creating in tandem teacher professional development and a rigorous college-preparatory curriculum in high school computer science; and (4) communicating with all stakeholders the intellectual, political, and social necessity of institutionalizing and sustaining the teaching and learning of computing for underserved populations. Attaining any one of these goals would distinguish UCLA, LAUSD, and NSF. That all have been undertaken, in a carefully designed way, is remarkable indeed. Conviction, energy, and singularity of purpose demonstrate that “technology rich, curriculum poor” is a challenge, not a verdict. *Into the Loop* is an “existence proof” that uplifts students, and all who harbor high hopes for a public pathway to educational achievement....”

Two other BPC Alliances—A4RC and ARTS I—serve the equally important and challenging function of connecting students at Historically Black Colleges and Universities (HBCUs) with the resources of top research universities (R1s). In the stratified universe of higher education, institutions specialize their services. Among the specializations with the longest tradition is the distinction between minority-serving institutions, like the HBCUs, and the R1 (research) universities that tend to be large, federally research-driven, and Ph.D.-focused. Many top students successfully attend colleges at minority-serving institutions, but find the transition to an R1 university for graduate school difficult. Both A4RC and
ARTSI aim to connect faculty and students across institutional types, but establishing meaningful relationships that impact both the participants and their home environments is a daunting process. A4RC and ARTSI, each in its own way, are making this happen.

A4RC—the Alliance for the Advancement of African-American Researchers in Computing—is a 20-institution Alliance headquartered at North Carolina A&T and including the University of Indiana, Clemson University, Shaw University, Auburn University, Fort Valley State University, Prairie View A&M, Mississippi Valley State University, Virginia State University, Florida A&M, Winston-Salem State University, Hampton University, Sinte Gleska College, Georgia Tech, the University of Colorado, Virginia Tech, Norfolk State University, Bennett College, Jackson State University, Dillard College, and the University of Arkansas at Pine Bluff). The Alliance features a dual-feeder model that seeks to connect HBCUs, research-oriented minority-serving institutions, and R1 students and faculty. A4RC is based on the idea of a “research pod” that unites students and faculty at the minority-serving institutions and R1s in year-round research collaborations that include a research methods course, spring visits, and summer residential research experiences at the R1 schools. The Alliance is dedicated to building an environment that creates pathways from undergraduate computing and IT programs at HBCUs to graduate degrees (and research partnerships) in computing to faculty research careers.

The ARTSI—Advancing Robotics Technology for Societal Impact—Alliance, led by Spelman College, includes thirteen other HBCUs (Elizabeth City State University, Florida State University, Hampton University, Howard University, Jackson State University, Morgan State University, Norfolk State University, North Carolina A&T, the University of Arkansas-Pine Bluff, the University of the District of Columbia, Tennessee State University, and Winston-Salem University) and ten R1 institutions (Carnegie Mellon University, Brown University, Duke University, Georgia Institute of Technology, Rice University, University of Alabama, University of Michigan, University of Pennsylvania, University of Pittsburgh, and the university of Michigan). Their collaboration joins the strengths of HBCUs in conducting outreach and education in a nurturing learning environment with those of the R1’s for conducting world-class research and state-of-the-art educational programs. While A4RC covers a range of research topics, ARTSI focuses entirely on robotics. Its activities span the academic pipeline with outreach activities and Robotics Olympiads for K-16, improved course and lab facilities at the HBCUs, and collaborative research experiences for students and faculty that focus on robotics and emphasize societal benefits.

In each of these efforts, the building of productive relationships between dissimilar institutions is no small feat. In each case, the resulting
infrastructure has been a significant contribution to the cause of broadening participation.

Focusing on Undergraduates

Two Alliances, STARS and CAHSI, target undergraduates as the pivotal population for advancing computing as major and career choices for students who are largely uninformed about and/or under-prepared for the opportunity. Working through the in-class gateway of introductory courses and the out-of-class power of peer-group interaction and service learning experiences, these projects have documented startling gains across institutions in student participation and aspiration, many of whom are first-generation college-goers.

The STARS—Students & Technology in Academia, Research and Service—Alliance has, at its core twenty colleges and universities (Landmark College, Virginia Tech, Hampton University, NC State University, Meredith College, Shaw University, St. Augustine’s College, NC A&T, the University of Tennessee, UNC Charlotte, Johnson C. Smith University, the University of SC, Spelman College, Auburn University, Georgia Southern University, Florida State University, Florida A&M, USF Polytechnic, and the University of New Orleans). This core in turn partners with K-12 school districts, community colleges, and local businesses. The STARS Alliance members pool efforts and resources to strengthen local programs for underrepresented groups, aiming to spread the adoption of effective practices, such as the Affinity Research Group model and pair programming. It envelopes established regional programs (K-12 outreach, community service, and research experiences) with common, Alliance-wide activities intended to develop students’ technical excellence, leadership skills, and civic engagement around computing. The centerpiece of the Alliance is the STARS Leadership Corps (SLC), a program that draws students from all member institutions in a year-long team-based leadership projects. Many of the students work in concert with partners to motivate, recruit, mentor, and retain younger students while advancing their own technical and leadership skills. The SLC motivates students to reach their personal best in computing, while bringing younger students into the field.

CAHSI—the Computing Alliance of Hispanic-Serving Institutions—is a consortium of ten institutions, including seven HSIs (Cal State-Dominguez Hills, Cal State-San Marcos, Miami Dade College, Florida International University, New Mexico State University, Texas A&M-Corpus Christi, Houston-Downtown, Puerto Rico-Mayaguez, UT-El Paso, and UT-Pan American). They are committed to creating a unified voice and expanded resources to increase the number of Hispanics who earn baccalaureate and advanced degrees in computing. CAHSI interventions center on an introductory computing course designed to attract majors and bolster
under-prepared students; peer-facilitation in the gatekeeper courses to provide an active learning experience and to create leadership positions for undergraduates; undergraduate professional socialization and research experiences; mentoring for success in graduate school and careers in the professoriate; and professional development to support the advancement of students and faculty. This is the only BPC Alliance that is dedicated to HSIs and the strengthening of career pathways for Latino students and faculty. Unlike the Alliances discussed so far, CAHSI institutional partners already had long-standing relationships with one another that originated in an NSF precursor to BPC.

Building National Networks

Three BPC projects have taken national leadership and scale as their points of departure. The AccessComputing Alliance is building a national network to recognize and support students with disabilities as a vital segment of the technical workforce. The EL Alliance is building a network to produce future academic leadership among students at research universities. The CRA-W/CDC Alliance is bringing professional development opportunities to women and minorities at the undergraduate, graduate, postdoc, and early faculty levels. A fourth project is NCWIT—the National Center for Women and Information Technology—which leverages the work of organizations across the country to increase the participation of women from K-12 and higher education through industry and academic careers.

AccessComputing is opening computing departments (and faculty minds), other Alliances, and professional organizations to students with disabilities. The Alliance aims to increase the number of students with disabilities who successfully complete postsecondary degrees in computing and enter the computing workforce. It is led by a collaboration between the Department of Computer Science and Engineering and the DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Center at the University of Washington, which includes as partners the NSF-funded Regional Alliances for Persons with Disabilities, Gallaudet University, the Rochester Institute of Technology/National Technical Institute for the Deaf, Landmark College, CAITE, ARTSI, CAHSI, EL, the National Girls Collaborative, and SIGACCESS of the Association for Computing Machinery. AccessComputing engages individuals with disabilities as well as those who support, serve, guide, educate, and employ them. It leads capacity building institutes for CS departments, and a number of targeted “communities of practice” that aim to raise consciousness about the recruitment and enrollment of students with disabilities in the computing fields. AccessComputing is sharing

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For the record, one 2005 Alliance clustered around the high school-to-college transition ended without showing significant progress, as determined by a 2008 NSF reverse site visit. All other alliances were given the opportunity for extension beyond three years.
research and successful practices through its ever-growing searchable Knowledge Base at www.washington.edu/accesscomputing/kb.html.

The EL—Empowering Leadership: Computing Scholars of Tomorrow—Alliance aims to increase the number of students from underrepresented groups who earn undergraduate or graduate degrees in the computing disciplines at research universities. What sets ELA apart is its national scope and focus on research universities. The underlying hypothesis, championed by PI Richard Tapia of Rice University, is that leadership germinates at the most prestigious, productive, and visible institutions of higher education, and that students of color and women (who are woefully underrepresented at those schools) must be supported in their efforts to join that pool of potential leaders. EL employs three models depending on the size of the university minority community: a local model that provides in-person relationships with on-campus faculty and peers for schools with a sufficient critical mass; a regional model that focuses on multi-institutional collaborations and exchanges for smaller schools; and a national model that seeks out and supports individuals across the country through virtual and in-person mentoring.

The CRA-W/CDC—the Computing Research Association’s Committee on the Status of Women (CRA-W) and the Coalition to Diversify Computing (CDC)—builds on two existing organizations to encourage women and underrepresented minorities to earn undergraduate degrees in computer science (CS), pursue graduate degrees, and prepare for research careers in academe or industry. The project starts at the undergraduate level, putting students on a research track, then continues to support researchers throughout their graduate and professional careers. CRA-W/CDC interventions include a variety of new and long-standing projects. The Alliance offers a variety of direct interventions, including discipline-specific workshops, a distinguished lecture series, CREU (Collaborative Research Experiences for Undergraduates), and DREU (Distributed Research Experiences for Undergraduates). Organizing and maintaining these activities at the national level across the two target groups creates complexity and the need for coordination, both organizationally between CRA-W and CDC, and individually at the project level (since voluntary leadership is key).

NCWIT—the National Center for Women in Technology—is a coalition of over 200 prominent corporations, academic institutions, government agencies, and nonprofits working together to increase women’s participation in IT. NCWIT has programs in K-12 education, college-level outreach and curriculum reform, corporate recruitment and retention, and entrepreneurial endeavors. It is the only national organization actively researching women and IT innovation, including women as IT patent holders, women’s contribution to open source, women as authors of
computing research papers, women starting IT companies, and women as technical conference speakers. NCWIT also functions as a foundational clearinghouse for information and resources relevant to women in computing. Its resources are widely cited in the media.

**Evidence of Promise and Innovation—Illuminating Pathways**

Individually impressive, the BPC Alliances collectively are more than the sum of their parts. The Alliances are too often seen as works-in-progress—too young in their developmental cycles to have yielded robust quantitative evidence of student achievement of computing degrees. But this understates their common goal of cultural change—how computing is taught in middle and high school, in college, and in graduate programs that convey expectations of student performance but sometimes lack the connection to practical application and future needs. There is unmistakable evidence here of progression in changing computing content, approach, and participation. Looking across storylines, what can we ultimately say about BPC as a program?

If our focus is on the trajectory, not the magnitude of change in computing nationally, then we should behold the promise of the pathways illuminated. This program is not about “quick fixes.” Rather, it seeks what is sometimes called “systematic” changes. This demands a longer time horizon and metrics that capture context as well as content. Below we illustrate with empirical data how some of the Alliances are changing the trajectory of participation in computing for students at various stages of development. These are 4-5 year snapshots of what has been transformed from “the possible” to “going concerns.”

**A4RC**

From the 2006-07 academic year when A4RC began to the 2009-10 academic year, the Alliance’s combined HBCU CS enrollment increased at the undergraduate and graduate level from 555 undergraduates and 131 graduate (Masters) students to 645 undergraduates and 175 graduate

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7 The following section is based on two sources: 2009 annual reports submitted by the Alliances PIs, and data updates sent to BPC Program Officer Cuny in response to her solicitations in late 2009 and early 2010. In combination with the third-party reports above, these self-reports are intended to complete a narrative that can be animated both by participant quotes and quantitative data.
students (gains of 16% and 34% respectively). These trends exceed undergraduate enrollment gains and contradict declines in MS enrollments nation-wide. A4RC partners have grown from six colleges & universities (3 HBCUs) to 20 colleges & universities (13 HBCUs and 1 Tribal University) serving 1790 undergraduates and 486 graduate students. Currently, there is one A4RC Ph.D. candidate at Virginia Tech, 5 PhD applicants that are awaiting decisions at partnering A4RC universities, and 5 students who are anticipating Ph.D. applications. Simply put, this one Alliance is contributing disproportionately to the national pool (according to the Taubbee Survey, 2007-08) that shows CS PhDs awarded to only 22 African or African-Americans).

**Into the Loop**

The Alliance has created an innovative pre-AP CS project-based college preparatory curriculum, Exploring Computer Science (ECS). It has piloted ECS in 20 LAUSD high school classes, with over 900 students, predominately Latino/a and African Americans enrolled. Furthermore, the Alliance has designed and implemented a model of CS teacher summer professional development, in-class room coaching system, and inquiry groups for 25 current LAUSD computer science teachers around Computational Thinking/CS instruction. On the local policy front, it has successfully petitioned the University of California President’s Office for college-admissions credit for ECS, establishing the first non-AP CS class to receive college admissions credit. National impact is also apparent: ECS is available on the CSTA website and *Into the Loop* leadership has assisted in the planning/adoption of the curriculum in New York State, New Jersey, Wisconsin, other locations in California, and in Supercomputing centers located in San Diego, Pittsburgh, and Chicago.

**CAITE**

“*Enrollment in CAITE partner community college IT programs has grown by 56% since CAITE began in 2006...”*

The Commonwealth Alliance for IT Education (CAITE) is the only NSF BPC Alliance to address community colleges where many first-in-the-family college-goers and working students with families begin their college careers. Enrollment in CAITE partner community college IT programs has grown by 56% since CAITE began in 2006, and enrollment in 2- to 4-year college transfer programs has grown by 66%, with the vast majority females and URMs. Alliance institutions enroll over 170,000 students. For the ten institutions where we have complete data for fall 2009, 3% are
enrolled in IT programs (3300 majors), a number that is 50% greater than the national average for computing/IT majors as a percentage of enrollment at colleges and universities. Commensurate with the national trends, CAITE saw a decrease in CS/CIS graduates for the period 2004-2008. Since then, CAITE partners are seeing a substantial turnaround: enrollment in IT majors has increased 40% since 2006 when CAITE began, with women increasing by 60% in two-year colleges and 19% in four-year programs. URM majors have grown by 88% at community colleges and 60% overall among CAITE institutions. CAITE has also developed information resources, articulation agreements, advising structures, and curricula across its 15 institutions designed to ease transfer and support and retain students. Strikingly, at UMass-Amherst, half (5/10) of the fall 2009 computer science deans list students are community college transfers and half (2/4) of the computer science Yahoo! Outstanding Graduates are community college transfers. CAITE’s extensive outreach programs in four regions (Boston, southeast Massachusetts, greater Springfield area, and Lowell/Worcester) have reached more than 8000 students and more than 500 educators at 100+ events and activities.

**Georgia Computes!**

This Alliance has confronted the challenge of broadening participation in computing across the entire K-16 range, getting kids interested before high school, preparing them well and sustaining interest in high school, and helping them achieve success in undergraduate years. “Georgia Computes!” touches all those levels at once, across the entire state. The number of high school students taking AP CS in Georgia has increased since inception of the Alliance in 2006, with particularly high increases among women (57% increase) and Hispanic students (300% increase). The number of high schools offering AP CS has increased by 68%. Georgia now has the highest percentage of high schools that have passed the AP CS audit in the Southeast. From running Girl Scout workshops and summer camps (over 3000 kids, at over 10 locations around the state), to training high school teachers (over 328 teachers representing over 60% of all public high schools in Georgia), to improving the undergraduate curriculum to be more engaging and inviting (over 25% of universities in Georgia have now updated their curriculum with NCWIT-approved best practices), “Georgia Computes!” is successfully broadening participation across the state with a significant minority demographic and abundant economic opportunity.

**STARS**

The STARS Alliance was formed in 2006 with 10 initial member colleges and universities and extended in 2008 with 10 additional members. The STARS Celebration is an annual student leadership conference to induct
students into the STARS Community by participation in year-long team-based leadership projects in concert with regional partners. Four STARS Celebrations have built a BPC-wide community engaging 775 attendees. Over 67 college faculty and staff have engaged in BPC projects through SLC, building partnerships with 80 organizations, implementing the SLC at 20 colleges and universities, and integrating Pair Programming into 16 classes with over 400 students. The SLC has engaged 697 college students in computing outreach, research, and service, as a national corps of BPC change agents. These students have conducted outreach to over 18,000 K-12 students. Participating in the SLC results in statistically significant increases in key indicators of retention (computing efficacy, social relevance of computing, commitment to computing, and GPA). Between 2006-2008 STARS institutions’ enrollment and graduation trends exceeded the national average, e.g., graduate enrollment increases of 33% vs. 2.2% decline nationally, and graduate degree increases of 23% for the Alliance vs. a 1% decline nationally.

**CAHSI**

This Alliance mainstreams mentoring, while building structured academic networks for Hispanic students through intensive academic initiatives that support undergraduates from entry-level computing coursework through graduate school and beyond. By 2009, CAHSI had served 2,634 students with semester-long, academic initiatives, 62% of whom were Hispanic. Peer-Led Team Learning (PLTL) has provided 17,580 contact hours of student-centered, collaborative instruction in critical gatekeeper courses. All students are passing these computing courses at greater rates since PLTL began, leading to shorter time-to-graduation and increased retention in the major. Course completion rates of Hispanic students have increased by 13% since PLTL was implemented. Undergraduate students who work in CAHSI Affinity Research Groups (ARG) have (co)authored journal articles at twice the rate (13%) of a large, diverse national sample of Research Experiences for Undergraduates (REU) students. Since 2005, undergraduate bachelor degrees in computing declined by 32%, while the seven initial CAHSI schools increased their undergraduate degrees by 2%. Through strong collaborations with over 20 corporations, non-profits, and institutions, CAHSI continues to leverage participation in computing.

**AccessComputing**

*AccessComputing* tracks the progress of a sample of participants through critical junctures—including graduating from high school, transitioning to college, majoring in a computing field, transitioning from a two- to a four-year college, earning a degree, and transitioning from college to a computing career or graduate school. Almost every one of the 125
participants followed thus far has experienced interventions (e.g., mentoring, internships, advising) that facilitate movement in a timely manner and much more successfully than individuals with disabilities represented in national data. Our participants completed a total of 72 computing internships, 98 were mentored, 85 received peer support, and 80 were individually advised. *AccessComputing* interventions promote systemic change as well. For example, the Alliance reviewed the accessibility of images on computing department websites nationwide: departments were given suggestions for making image content accessible to visitors who are blind and using screen-reader technology; pre-post measurements revealed that the percentage of images that had alternative text grew from 53% in 2006 to 76% in 2010; and resources and programs were made more welcoming and accessible to students with disabilities. Questions and answers, case studies, and promising practices reported in the *AccessComputing* Knowledge Base now receive 45,000 hits per month.

**NCWIT**

NCWIT has energized segments of the computing community and built the organizational capacity of both member and non-member organizations. Data provided by the PhD-granting institutions in the NCWIT Academic Alliance show a clear positive relationship between membership and improved representation of undergraduate women. At the same time that women’s graduation rates in computer science decreased nationally (see orange line for representation of Taulbee data in Figure 3), women’s share of enrollment among NCWIT Academic Alliance increased. Every cohort increased its percent of women enrolled since the year it joined NCWIT. The evidence is encouraging: NCWIT is “moving the needle” on participation. With it, NSF’s legacy in computing through investments in broadening participation has been enriched.
A Program Greater Than the Sum of Its Experiments

One way of reading the highlights presented above is that of isolated programs funded by a single sponsor that have enjoyed success due to concentrated efforts by a few dedicated CS professionals. That inference, however, would be the weakest and most ill-considered among alternative explanations for what BPC has galvanized. For change comes not only through impacts on individual students and educators, but also as institutions adjust their approaches, structures, and practices to enhance the teaching and learning of computing, and re-dedicate to the development of talent. The experiments represented by the BPC Alliances embody wholesale, goal-directed change. As interventions, they must be measured in new partners and agreements that have longevity to support succeeding cohorts, not just those in the right place at the right time.

“...change comes not only through impacts on individual students and educators, but also as institutions adjust their approaches, structures and practices...”
If we were to sum across the enrollments and degrees awarded by BPC Alliance institutions, we would observe—based just on the sampled data captured above—alterations of the educational landscape that promise to change the face of computing for generations. Based on 4-5 years of data, the results are irrefutable: without BPC, computer science would remain a bastion of white, male, and foreign talent; with BPC, it is an arena investing in all student talent, but particularly those historically on the margins as future professionals preparing for careers in computing and information technology.

To be specific, the NSF Broadening Participation in Computing Alliances, 11 projects that have blanketed computer science with alternatives for diversifying participation in computing careers, has yielded the following:

- **A web of national, interlocking networks** (*ELA, STARS, AccessComputing, CRA-W/CDC, NCWIT*) that socialize computer science students at all levels, and provide students and educators alike with opportunities to share experiences and develop various professional skills and knowledge for all students, not just those that represent the academic research pinnacle of the computer science world).

- **An array of partnership models** (*CAHSI, CAITE, A4RC, ARTSI, Into the Loop*) that bring together institutions alike and unlike in mission, student population, and location to promote aspirations and success by students underrepresented in computing. These models feature novel research collaborations, team learning, and multiple educational pathways through a terrain beset by financial and administrative obstacles to careers formerly unimagined and/or out of reach.

- **New conceptions of talent pool formation and facilitation** that recognize impediments surfacing early in K-12 experiences (*In the Loop, Georgia Computes!, CAITE, STARS, NCWIT*). This recognition requires in response intervention and negotiation by savvy higher education professionals working in conjunction with colleagues in public schools, local and state government, and business/industry leaders. They are doing nothing less than constructing a “parallel universe” to huge unwieldy K-12 districts that illuminates an ecosystem of STEM disciplines, pathways, and institutions, affording opportunities to teach and learn computing as a career option where only shadows were once visible.
The Pathways Ahead

With its inception, NSF's Broadening Participation in Computing program declared “open season” on participation in computing. The discipline’s record on who participates was appallingly homogeneous. Students were gravitating elsewhere at a time when the frenzy over digital tools should be luring students to computer science. BPC invited a competitive community to: choose a segment of the educational pathway, define a particular demographic group(s), select a methodology that demonstrated the efficacy of one’s intervention design, and produce in three years evidence that BPC Alliances—coalitions of organizations (some virtual)—can make a difference in the rates and quality of participation by U.S. citizens in computing education and employment. This was a bold and audacious undertaking for a discipline (a) overwhelmed by foreign students at the graduate level who compensate for an artificially depleted pool of U.S. citizen talent at the undergraduate level, and (b) challenged by an emerging information technology market dominated by sub-baccalaureate credentialing on the one hand and the rise of part-time study offered by for-profit institutions on the other. For all its achievements in digitizing our lives, the culture of mainstream computer science created the problems. Could BPC impel it to develop solutions as well?

What does the collection of these ten or eleven Alliance projects say about student-centered reform of computing education? By their very response in the categories we have detected—reforming statewide systems, focusing on undergraduates, connecting unlike institutions, and building national networks—they spoke loudly. To their credit, the Alliances took on the biggest challenge facing STEM disciplines: how to attract the student demographic now majority female and soon majority minority to a field seen as arcane and remote from the daily needs and interests of the general U.S. population?

BPC is changing all this: yes, the importance of computer science (CS) to non-CS disciplines is often understated and therefore under-appreciated. But CS serves as a foundation to any number of significant discoveries in other disciplines. The increased power of supercomputing in all complex quantitative disciplines, both applied and theoretical, is an obvious application of advanced CS. The increased role of CS in modeling and imaging applied to physical, medical, social, economic, and behavioral sciences is another example of ever increasing interdisciplinary use of CS

“NSF’s Broadening Participation in Computing program declared ‘open season’ on participation in computing.”
technology. There is virtually no discipline or aspect of our daily lives that is not positively impacted by advances in CS. It has become the backbone of our technologically dependent society. BPC Alliances have made all of this more real, more attainable, for more students.

The Alliances work together! The Pls and many of the senior personnel meet face-to-face, serve on each others’ boards, and communicate frequently. All of them contribute regularly to the BPC Portal (www.bpcportal.org), describing their efforts, listing their events, and disseminating their results. Nearly all Alliances: work with AccessComputing to increase their inclusion of persons with disabilities; send students and faculty to the annual STARS Celebration; and encourage their students to join EL and participate in CRA-W/CDC programs. Many of the Alliances have run or sent faculty to workshops on the CAHSL ARG model, the GeorgiaComputes! computing in context curriculum, or the STARS pair-programming work. Together, they are forming a national infrastructure for change.

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Five years after NSF’s initial investment, computer science has learned much. Whereas skeptics would say there are few definitive findings, others (ourselves included as third-party story-tellers) would suggest that there are plenty of promising signs and concrete indications that changes are taking root, structures are being modified, and computing is reaching out with tangible success. We can quantify some results and describe others only anecdotally. We can elucidate trajectories and satisfactorily demonstrate conventional outcomes, e.g., progression to the next stage rather than simply receipt of the degree. The hope is to catalyze education policy initiatives and state actions that raise the bar for computing and the resources for grasping it. Inasmuch as BPC was conceived as a capacity-building program, interim outcomes should properly focus as much on organizational arrangements, new partnerships, and the structures created to sustain future generations in computing education as on near-term end-products.

The type of collaboration and innovation exhibited by the BPC Alliances is too often underestimated and undervalued by sponsors and under-appreciated by those in other disciplinary communities. Limited resources are being directed at a complex national problem. Considering the multiple stakeholders involved, the importance of cultivating interpersonal
relationships, forging and embracing shared values, and building mechanisms to assess what is making a difference and why, NSF’s BPC program fulfills the expectation of how transformative, even visionary, models of intervention in a discipline look and function.

At the very least, based on national trends, the BPC Alliances seem to be bucking them. More important, they are championing new approaches to student recruitment and preparation, to faculty classroom practice, to disciplinary mission and measures of success. They are changing institutions—and the future face of computing.
ABOUT THE CENTER

The AAAS Center for Advancing Science & Engineering Capacity is a fee-for-service consulting group that provides institutions of higher education with assistance in improving delivery of their educational mission, especially in science, technology, engineering, and mathematics (STEM) fields. Established in August 2004 with a 3-year grant awarded by The Alfred P. Sloan Foundation, the Center is located in the AAAS Education and Human Resources Programs, which has an unparalleled record of achievement in developing, managing, documenting, and evaluating programs to enhance participation, preK-workforce, in STEM careers. The Capacity Center works to improve campus climate and increase recruitment, retention, and graduation of U.S. students in STEM fields, especially those from traditionally underrepresented groups. Details can be found at www.aaascapacity.org.