Northeastern University

CIC Five Year Report

May 2025

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A letter from Carla E. Brodley

Professor, Khoury College of Computer Sciences
Founding Executive Director, The CIC
Dean of Inclusive Computing
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Dear Colleagues and Friends,

It is with deep gratitude that we share this five-year report. The CIC has been honored to do the work summarized here with all of you. Thank you for your collaboration and insights.

The CIC was launched in 2019 as a five-year effort to demonstrate "best practices" in increasing the representation of women earning computing degrees. Through trial and error, data analysis and research, we have identified a set of interventions that make computing education more accessible and welcoming for ***all*** students. In this report, we explain these systemic interventions and the research that backs them. We also present a number of case studies that illustrate how different schools have implemented the Interventions and the changes computing departments have observed.

Today, we are proud to count as Partner Schools 103 of the largest computing departments in the U.S. These Partner Schools accounted for 24% of all those earning undergraduate computing degrees and 23% of those earning graduate degrees in Fall 2023.

The interventions we support improve outcomes for all students to discover, persist and graduate in computing. For example, at the 21 Partner Schools that have been implementing changes at the undergraduate level for at least 2 years (Figure 1):

1. There were 5,039 more women computing majors in Fall 2023 than in Fall 2019.
2. Over that period, the percent increases for women outpaced men in every category except for non-resident alien.
3. Over that period, the percent increases for students from races historically marginalized in tech outpaced those of historically overrepresented populations (Figure 1).

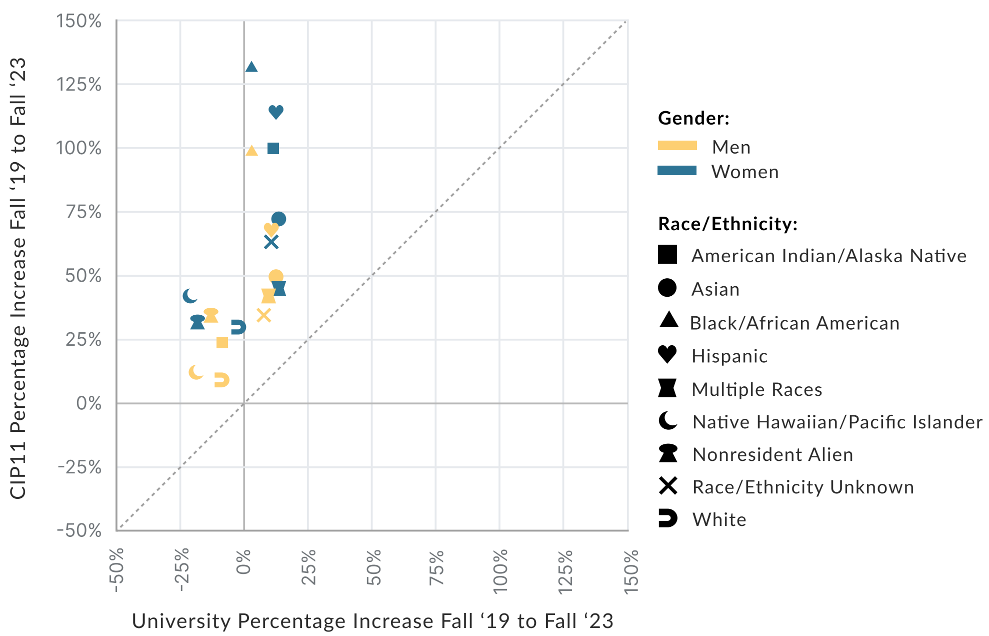


Figure 1. Change in representation of students pursuing CIP11 degrees relative to changes in university population.

The data shows that learners from all backgrounds are able to discover and pursue computing at our Partner Schools, and that schools were able to achieve these changes even as they managed strong growth in demand for computing degrees.

We are just starting the process of understanding what is new/different in the context of AI and how to scale interdisciplinary computing majors. These questions—along with the ongoing support of all Partner Schools as they continue to implement and learn—is the work ahead. Onward!

A letter from Renee Wittemyer

Vice President of Program Strategy
Pivotal Ventures

Pivotal is committed to advancing women's power around the world. As part of this commitment, we are proud to support the creation of the Center for Inclusive Computing (CIC) in 2019.

When we embarked on our journey to determine how to increase women's power and influence within the tech sector, experts already understood the changes that were needed to provide equitable access to computing education. The problem was that few institutions had adopted them. Dr. Carla Brodley had a clear vision for how to get those best practices implemented and open the doors of the field to everyone. Now, thanks to five years of systems-change work by the CIC, more women are graduating with degrees in computing than at any other time in history. That will translate into more women getting good jobs in tech and eventually moving into innovation and leadership positions, where they will drive both equity and innovation. By promoting sustainable changes to the structure and delivery of computing education, the CIC and the universities it partners with have shown what can happen when we remove barriers that keep students from discovering, thriving in, and persisting in computing.

It is particularly exciting that the CIC has proven that it's feasible to improve access to computing education even as the field is growing and changing rapidly, a lesson we will continue to apply. In an era of AI, it is more important than ever to bring a wide range of perspectives to bear in the development technologies that will fundamentally reshape the world.

The CIC's impact has exceeded our expectations. To date, they have worked with four times the number of schools originally projected, engaging with departments that reach one-quarter of all computing undergraduates in the country. Furthermore, they have identified a suite of low-cost, replicable interventions that schools can adapt to their specific contexts. Finally, they have made significant contributions to CS education research through their own work and in collaboration with faculty at their partner schools.

Above all, we are impressed with the CIC's steadfast focus on systemic change that will transform CS education and help students for decades to come. With help from the CIC, the United States has made amazing progress in equity in computing education. As AI continues to have an increasingly outsized impact on society, not only sustaining but also accelerating that progress is essential.

We want to continue to see more women building the future of tech, because it's good for women, good for tech, and good for society.

The Opportunity

> ***The CIC's mission is to partner with university computing departments to identify and remove the barriers that prevent students from discovering and thriving in computing."***

The CIC was established at Northeastern University in the summer of 2019 with the goal of working with computing departments to identify and remove barriers that prevent students from discovering and thriving in the discipline.

We were created in response to research by Pivotal Ventures and McKinsey and Co., which was summarized in the 2018 report "Rebooting Representation." The research indicated that, while there appeared to be good overall consensus on what the best practices for Broadening Participation in Computing (BPC) were, the uptake of these practices was slow.

McKinsey and Pivotal hypothesized that university computing departments lacked sufficient resources to implement changes and saw in this "paradox" an untapped opportunity for impact.

The CIC was therefore established to help bridge the "best practice-to-implementation gap." The goal was not to develop new best practices but rather to remove institutional frictions that prevent the adoption of evidence-based interventions.

To date, we have worked with over 100 computing departments at mostly large, public universities. Through these engagements as well as through extensive data collection and analysis, and significant research (see Appendix B for our Publications), we now know which changes to the academic infrastructure—to the curriculum, to student support and to the major itself—lead to a material narrowing of the difference between who attends university and who studies computing. In other words, we can confidently "diagnose" which Systemic Interventions will work in which institutional context.

> ***Think about how tech interacts with just about all things. Why would we deny opportunity to all of our society to come in and be part of that?"***
>
> **- Public university CS teaching professor**

Since launch, we have focused on three methods to support Partner Schools:

1. Grants
We provide multi-year grants to schools to cover the cost of implementing systemic changes. Grants range from $60,00 to work on a discrete project such as collecting and analyzing intersectional data up to $1M+ to implement multiple interventions at once. To date, we have provided $27M+ in funding.

2. Technical Assistance
Each Partner School is assigned a ***Program Manager***, a computing faculty and BPC expert, who works with them as coach and thought partner. Schools also have access to CIC ***Technical Advisors***—experts with deep expertise in a particular area such as equitable grading, computing in context, or admissions for interdisciplinary computing majors.

3. Data
The CIC supports each Partner School to collect the data needed to understand the school's context and track the impact of interventions. Data collected include: enrollment and pass/fail/withdraw outcomes in the intro course sequence; declared computing majors; and computing degree completions. Data are disaggregated by gender, race/ethnicity (as defined by IPEDS), as well as major and transfer status (internal and external).

Two overarching tenets guide all we do:

Systemic *("Fix the system, not the student")*. All of the CIC's interventions focus on changes to the department. The aim is to reduce the burden on students to do more or do "different" in the face of institutional barriers.

Sustainable *("Fix the system, don't feed the beast")*. We focus on changes to the system that can be made through a one-time investment, without adding a significant ongoing cost to the department's budget.

CIC Timeline

Fall 2019
CIC launches. Pivotal provides funding for 5 years with initial goal of partnering with 25 schools

Spring 2020
CIC launches the Implementation Grant (IG) Portfolio. 6 Schools receive funding in “Round 1”

Fall 2020
6 “Round 2” Schools join IG portfolio; CIC introduces the Diagnostic Grant to support data collection and analysis

Spring 2021
6 “Round 3” Schools join IG portfolio

Fall 2021
4 “Round 4” Schools join IG portfolio. CIC assumes leadership of the MS Pathways to Computing Consortium

Spring 2022
CIC provides start-up funding for 9 Partner Schools to build “bridge to MS” programs and join the Consortium

Fall 2022
CIC receives NSF funding for 2 new initiatives: i) “Bridge to Cyber,” a 3-year effort with CyberCorps; and ii) BPC Alliance “DAPPIC” with CRA CERP

Spring 2023
4 “North Texas” Schools join IG portfolio, the CIC’s first geographically-focused cohort

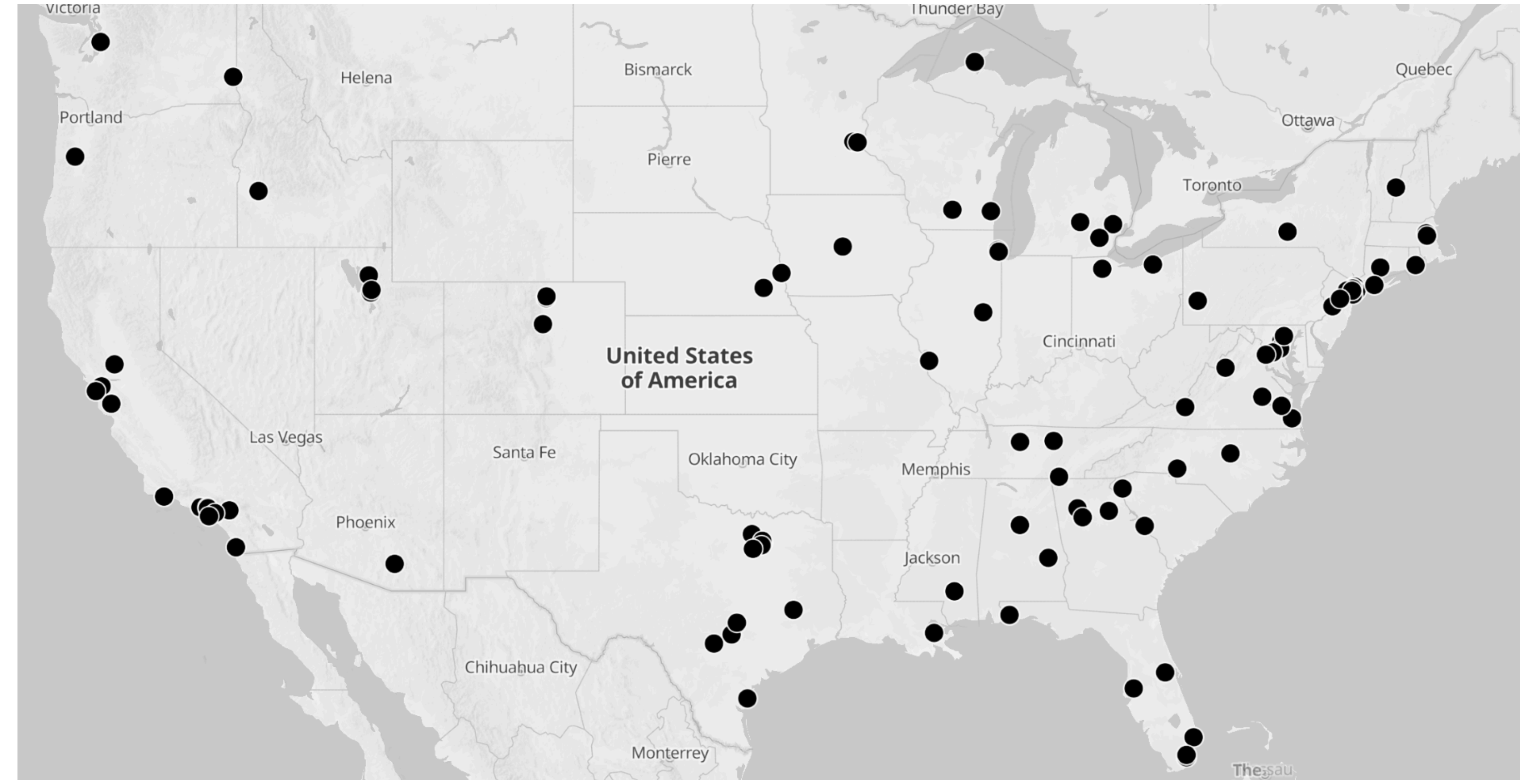
Fall 2023
CIC launches the Transfer Pathways (TP) portfolio and funds 3 Community College + 4-Year Partnerships; CIC provides start-up funding to 7 Schools to develop “bridge to MS” programs and join the Consortium

Spring 2024
CIC launches Interdisciplinary Computing Majors (ICM) portfolio with 10 Partner Schools. 8 “Round 5” Schools join IG portfolio, and 3 Partnerships join the TP portfolio

Fall 2024
CIC receives funding from NSF to conduct research on ICMs with 10 Partner Schools; CIC receives new funding from Pivotal to continue work, expand portfolio, invest in research and add focus on AI

Spring 2025
CIC is working with 103 unique schools and has distributed over $27M in funding

CIC Reach



The CIC works with Partner Schools through six different portfolios:

ICM	TP	B2C	DG	MS	IG
Interdisciplinary Computing Majors	**Transfer Pathways**	**Bridge to Cyber**	**Diagnostic Grant**	**MS Pathways Consortium**	**Implementation Grant**
Total: 10	Total: 11	Total: 15	Total: 34	Total: 36	Total: 36

ICM	TP	B2C	DG	MS	IG	School
		●		●		Augusta University
					●	Barnard College
			●			Boise State University
				●		Bowie State University
				●		Bowling Green State University
	●				●	California State University, Fullerton
					●	California State University, Long Beach
	●		●			California State University, Los Angeles
		●	●	●		Carnegie Mellon University
	●					City College of San Francisco
				●		Clemson University
●					●	Cleveland State University
			●	●		Colorado School of Mines
	●				●	Colorado State University - Fort Collins
				●	●	Columbia University
			●			Cornell University
			●		●	CUNY Baruch College
			●			CUNY Brooklyn College
			●			CUNY Hunter College
			●			CUNY NYC College of Technology
			●			CUNY Queens College
	●					Dallas College Richland Campus
			●			Dartmouth College
				●		DePaul University
	●					East Los Angeles College
			●		●	Florida Atlantic University
●	●			●	●	Florida International University
		●				Fordham University
	●					Front Range Community College
			●	●		George Mason University
		●		●		George Washington University
				●		Georgia Institute of Technology
●		●	●	●	●	Georgia State University
				●		Iowa State University
					●	James Madison University
			●	●		Kennesaw State University
		●				Marquette University
			●		●	Metropolitan State University
	●					Miami Dade College
			●			Michigan State University
				●		Michigan Tech University
					●	New Jersey Institute of Technology
		●				New York University
			●			North Carolina State University
				●		Northeastern University
		●				Oakland University
		●				Old Dominion University
			●			Oregon State University
				●		Quinnipiac University
				●		Rider University
				●		Roosevelt University
					●	Rutgers–New Brunswick
		●				Sam Houston State University
			●			San Diego State University
	●				●	San Francisco State University
					●	San Jose State University
					●	Southern Methodist University
					●	Stony Brook University
		●				Tennessee Tech University
				●		Texas A&M - Corpus Christi
			●			Texas State University
				●		The University of Southern Mississippi
		●				The University of Tenn. at Chattanooga
					●	The University of Texas at Arlington
●					●	The University of Texas at Austin
					●	The University of Texas at Dallas
●			●		●	The University of Texas at San Antonio
					●	The University of Utah
			●			Towson University
				●		Tufts University
				●		Tulane University
		●				Tuskegee University
		●				University of Alabama at Birmingham
			●		●	University of Arizona
			●			University of California-Santa Barbara
					●	University of California, Berkeley
				●		University of California, Davis
			●			University of California, Los Angeles
●				●	●	University of California, Riverside
					●	University of Central Florida
			●			University of Georgia
●				●	●	University of Illinois Urbana-Champaign
				●		University of Maryland, Baltimore County
					●	University of Michigan
●					●	University of Minnesota - Twin Cities
			●		●	University of Nebraska Omaha
			●			University of Nebraska-Lincoln
			●		●	University of North Carolina at Charlotte
	●			●	●	University of North Texas
				●		University of Pittsburgh
		●				University of Rhode Island
●				●	●	University of South Florida
					●	University of Washington - Seattle
			●			University of West Florida
●					●	University of Wisconsin-Madison
				●		Vanderbilt University
				●		Virginia Commonwealth University
				●		Virginia Tech
			●			Washington State University
				●		Washington University in St. Louis
			●			Weber State University
			●			Western Governors University
				●		William and Mary College
10	11	15	34	36	36	**<Totals**

CIC by the Numbers

103

Partner Schools

$27M

Awarded to Partner Schools

42

Partner Schools making changes at the undergraduate level

73

All-day site visits, working with computing departments to identify and implement systemic changes

6

Transfer Partnerships strengthening community college computing pathways

10

Partner Schools implementing interdisciplinary computing majors

65

Schools participating in the CIC's Data Program

36

Members of the MS Pathways to Computing Consortium

15

Partner Schools building bridge programs to the MS in Cybersecurity

Change in Representation of Computing Majors

To determine whether the Systemic Interventions are having an impact on who is studying computing, we look at a number of indicators: enrollment and outcomes in **CS1**, continued enrollment into **CS2** and **CS3**, **Enrollment in the Major**, and then, finally, **Graduation**. While graduation is arguably the most important indicator, it also lags the most; even for our first Partner Schools, it is still too early to assess the CIC's impact through graduation data. As such, our top KPI is **Enrollment in the Major**. Rather than ask, "Is the representation of majors changing?" (which may only tell a story about enrollment in the university) we ask "Is the representation of majors changing faster than that of the university?" I.e., is the computing department 'outperforming' the changes in the university population overall? The answer, shown in Figure 1, is an unqualified yes.

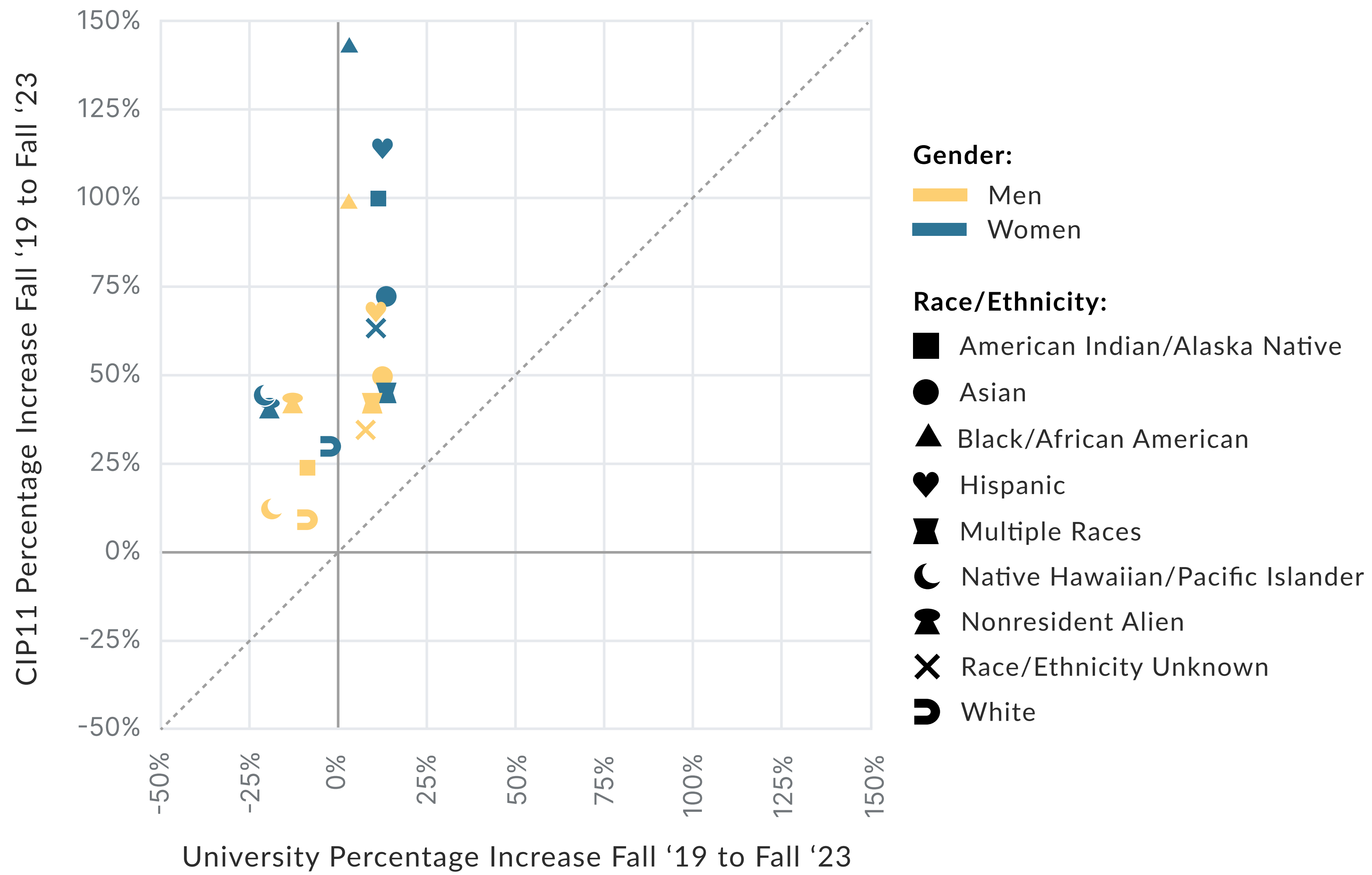


Figure 1: Change in computing majors compared to change in university population. We compare the change in representation in computing majors (y-axis) and the change in representation in the university (x-axis) at the 21 schools that have been in the CIC portfolio for 2+ years. Any data point above the y=x reference line indicates an outpacing. We see that the growth in computing majors is more than the corresponding change in university enrollment for all populations (even for populations that are experiencing declines in university attendance).

CS1: Change in Enrollment in the First Programming Course

The enrollment and outcomes of students in CS1 are important leading indicators, as they point to changes in who is trying computing and how they fare. Here we provide three different ways of looking at CS1 data from 2019 and 2023 for the 21 Partner Schools that have been implementing for 2+ years.

Figure 1. Change in the number of students enrolled in CS1 between Fall 2019 and Fall 2023, by gender.

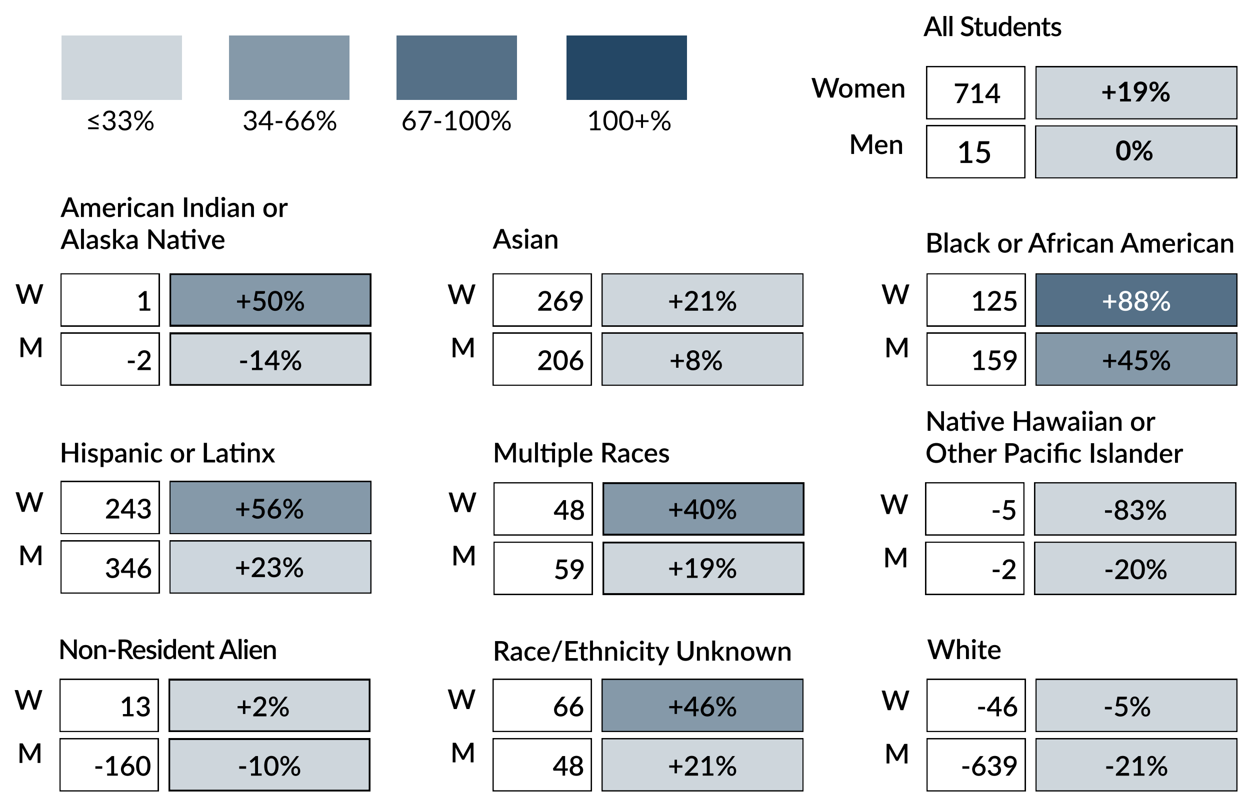


Figure 2. "Heat map" showing the change in the number of students enrolled in CS1 between Fall 2019 and Fall 2023, by gender and race/ethnicity. The darker the box, the greater the percentage growth.

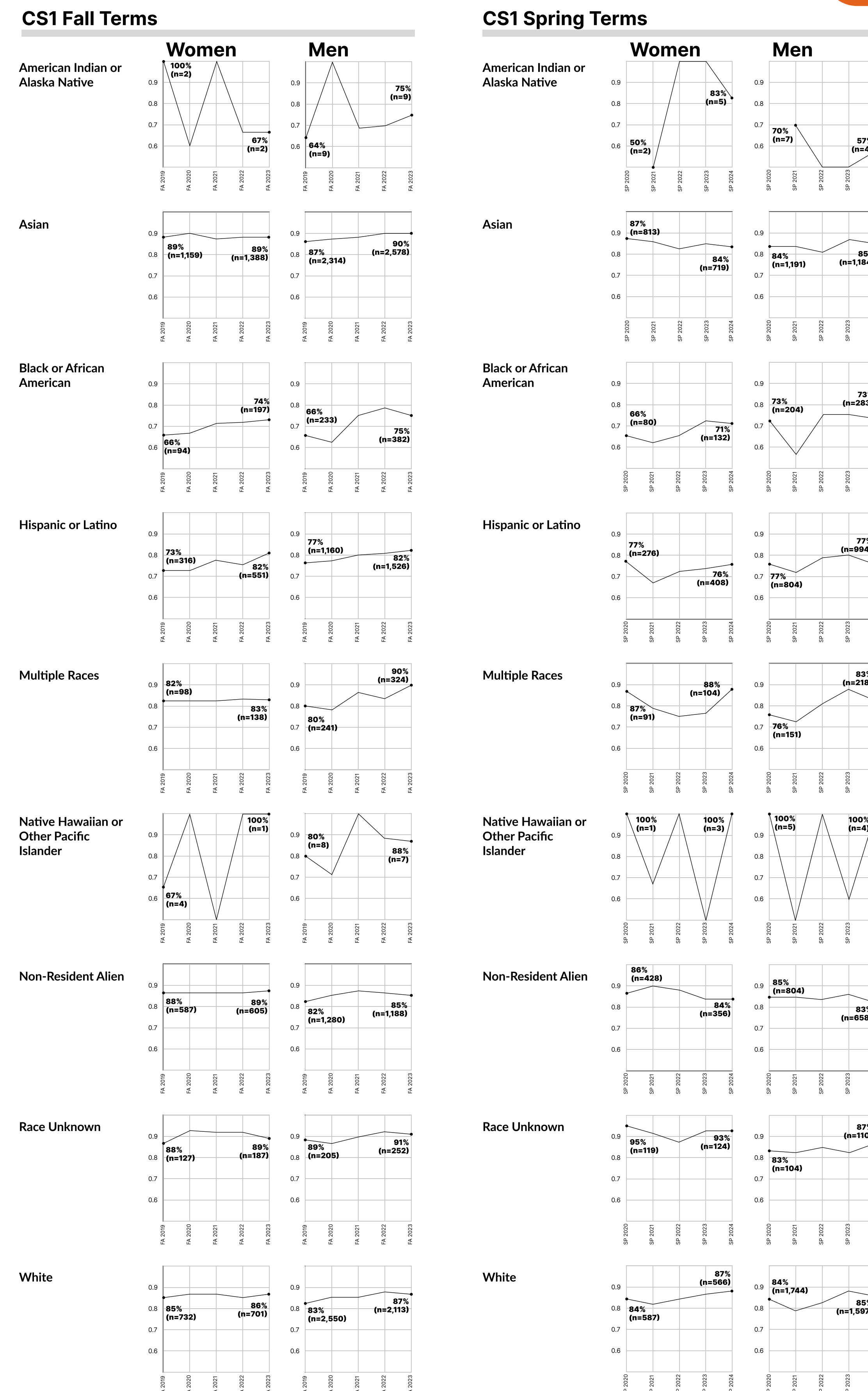


Figure 3. CS1 pass rates by academic term, 2019-2023, by gender and race/ethnicity. Overall, we see consistent increases in pass rates—although data for smaller populations is noisy. We show fall and spring separately as they often enroll different populations (e.g., majors vs. non-majors).

CS2 and CS3: Retention Through the Intro Sequence

Building on what we see in CS1, we look to the second two classes in the intro sequence to see whether students are persisting. For each class, we first show total enrollment for Fall 2019 as compared with Fall 2023, and the change in representation by gender. Then, we show the net increase in students both in terms of number and percentage, by gender and race/ethnicity. As with the prior page, the darker the box, the greater the percentage growth.

CS2:

Figure 1. Number and representation of students enrolled in CS2 in Fall 2019 as compared with Fall 2023, by gender.

≤33% | 34-66% | 67-100% | 100+%

All Students

	Number	% change
Women	1,177	+65%
Men	2,005	+34%

Race/Ethnicity		Number	% change
American Indian or Alaska Native	W	0	0%
	M	6	+120%
Native Hawaiian or Other Pacific Islander	W	-1	-50%
	M	-3	-27%
Black or African American	W	70	+91%
	M	87	+40%
Asian	W	483	+71%
	M	1,024	+63%
Multiple Races	W	15	+19%
	M	110	+51%
Race/Ethnicity Unknown	W	38	+43%
	M	76	+39%
Hispanic or Latinx	W	207	+107%
	M	331	+36%
Non-Resident Alien	W	138	+47%
	M	226	+26%
White	W	227	+58%
	M	148	+8%

Figure 2. Net increase in the number students enrolled in CS2 from Fall 2019 to Fall 2023 and the corresponding % change, broken out by gender and race/ethnicity.

CS3:

Figure 3. Number and representation of students enrolled in CS3 in Fall 2019 as compared with Fall 2023, by gender.

≤33% | 34-66% | 67-100% | 100+%

All Students

	Number	% change
Women	749	+41%
Men	1,226	+21%

Race/Ethnicity		Number	% change
American Indian or Alaska Native	W	0	0%
	M	-1	-11%
Native Hawaiian or Other Pacific Islander	W	-1	-20%
	M	2	+67%
Black or African American	W	71	+145%
	M	99	+58%
Asian	W	363	+51%
	M	654	+37%
Multiple Races	W	13	+21%
	M	57	+30%
Race/Ethnicity Unknown	W	55	+62%
	M	30	+16%
Hispanic or Latinx	W	147	+101%
	M	239	+30%
Non-Resident Alien	W	54	+15%
	M	205	+21%
White	W	47	+12%
	M	-59	-3%

Figure 4. Net increase in the number students enrolled in CS3 in Fall 2023 as compared with Fall 2019 and the corresponding % change, broken out by gender and race/ethnicity.

The Major: Change in Representation in Declared Majors

Major declaration varies by school with some requiring students to apply to the major during admissions, while others require students to identify their major at the end of their second year of university.

In Figure 1, we report the change in the number of majors in Fall 2019 and Fall 2023. We see that the number of majors grew dramatically during this time period to a total of 38,644 men and 12,977 women. We also show the corresponding change in overall representation which went from 22.1% women to 25.1% women majors across the portfolio from 2019 to 2023.

In Figure 2, we show the changes for each group both in terms of net new majors from 2019 to 2023 and the percentage increase. In this heat map graph the darker the box the larger the percentage growth.

Figure 1. Change in the number of students majoring in CS (CIP 11) between Fall 2019 and Fall 2023, by gender.

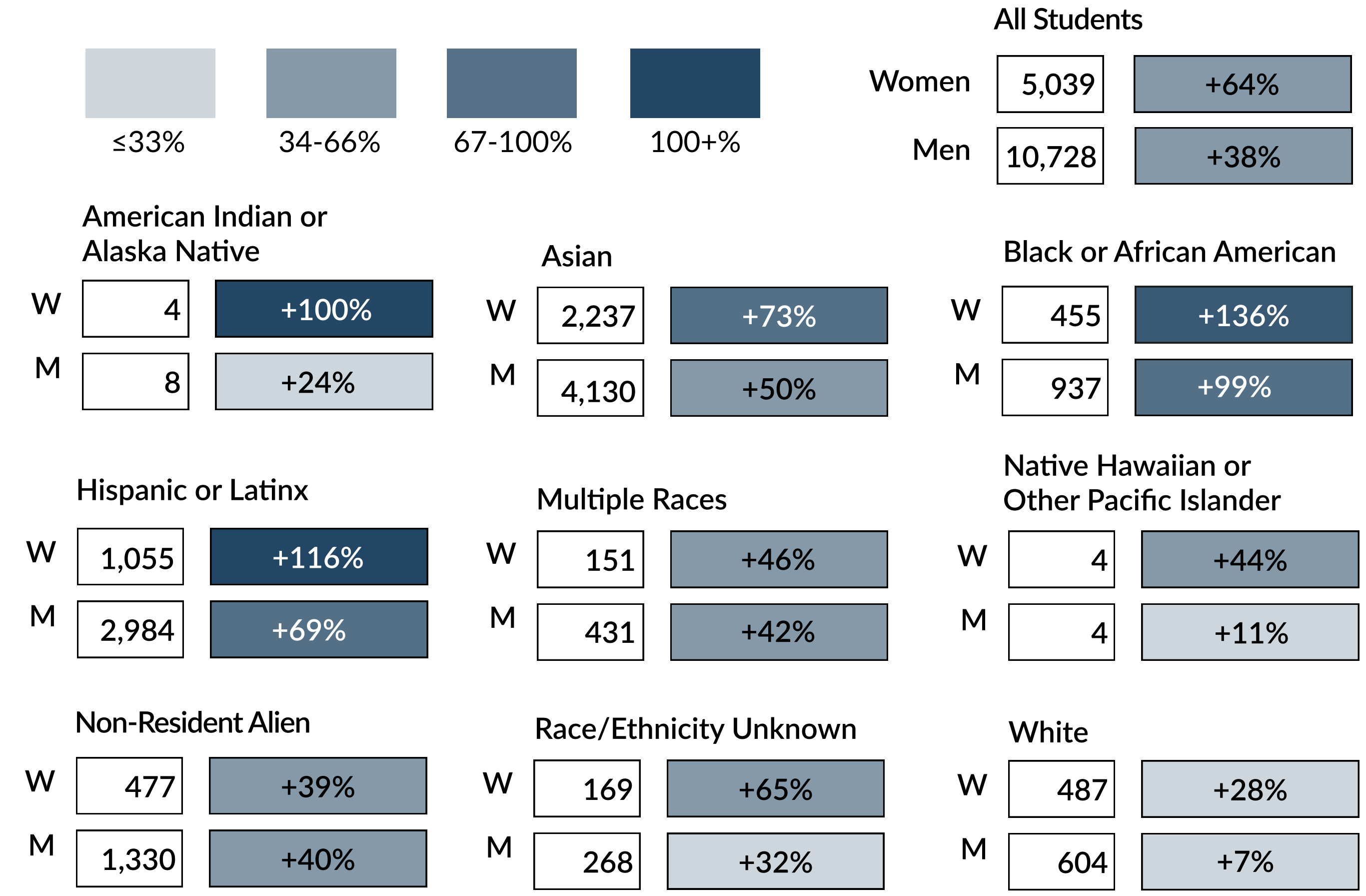


Figure 2. Change in the number of students majoring in CS (CIP 11) between Fall 2019 and Fall 2023, by gender and race/ethnicity.

How We Work

Methodology:

Request for proposals:

We issue RFPs, announcing the availability of CIC funding and solicit proposals from eligible schools. To date, we have issued 12 RFPs and received close to 200 applications.

▼

Screening:

We screen applications for key criteria such as university leadership and faculty buy-in and determine whether the school advances to a site visit.

▼

Site visit:

A site visit is in-person (~5 hours) and consists of meetings with: i) the project team; ii) faculty; iii) teaching assistants; iv) academic advisors; v) students, and vi) the dean. The purpose of the site visit is to hear from all stakeholders, diagnose barriers, and assess the potential for systemic change.

▼

Site visit report:

We write up findings in a memo that names the themes and connects them to evidence-based interventions, pattern matching to other schools with similar institutional context. We invite the school to reply to the report, iterating until the report is final and can be shared with the dean.

▼

Work plan and budget:

Selected schools then develop a work plan and budget, using the site visit report as guidance, and organizing around interventions rather than activity type (e.g., salary, travel). The final workplan and budget are added to the contract. Budgets include funding for data collection and 15% overhead.

▼

Implementation:

Schools implement the agreed-upon plan over multiple years, adjusting as needed in consultation with their Program Manager and the CIC. Schools meet regularly with their Program Managers and submit annual reports to the CIC. The CIC invites schools nearing the end of their grant term to identify remaining systemic changes they would like to make, and request additional funding.

> ***The CIC data collection practices and the data visualization portal are incredible. [The] CIC's work allowed us to transition from an anecdotal evidence-based department to a data-driven department."***
>
> **-Public university CS professor**

Alongside the CIC's methodology, we highlight other key aspects of our work:

1. Program Managers and Technical Advisors:
The CIC assigns each Partner School a Program Manager, a senior CS faculty with administrative experience who will serve as the coach and trainer for the project team during implementation. In addition to assigning a Program Manager, the CIC will often connect schools to other Technical Advisors, consultants with deep expertise in specific areas.

2. Data Program:
Every CIC Partner School receives funding to support the collection and submission of demographically disaggregated enrollment, retention and persistence data. The data is visualized across nine Tableau dashboards. Schools can also benchmark against peer groups.

3, Codification and Research:
The CIC studies trends and patterns across the portfolio. This analysis has led us to identify the specific interventions we think are most effective for BPC. For example, research to date has yielded insights such as:

a. The **curricular complexity** of a CS degree is correlated with the representation of women. Schools with high curricular complexity (an overabundance of pre- and co-requisites) have lower representation of women computing graduates.

b. There is no consensus among CS departments as to **which math classes should be pre- or co-requisites to which CS classes**. In some programs, students' progression in computing courses can be held up by their progression in the required math courses.

c. An analysis of 2,000 students in Northeastern's Align program shows that **bridge students, including those with non-STEM backgrounds, perform comparably to direct-entry MS students in terms of GPA.**

All CIC publications are summarized later in this report.

Systemic Change Interventions

Changes to the intro sequence

Manage distribution of prior experience
CS is only offered in 57.5% of high schools in the U.S., usually as an elective. This means that university departments have a big opportunity to promote the discovery of computing in college. To do that, they need strategies for managing the distribution of prior experience.

Common assessment
Shared assignments and exams (not just common objectives) across sections of courses in the intro sequence are essential to an inclusive environment. Common assessment ensures that all students achieve the course's learning goals and can advance to the next class—regardless of prior experience.

Computing in context
By "contextualizing" the computing curriculum in different domains, faculty show students its applicability to real-world problems and other disciplines. This has been investigated extensively by the CS education research community but there is still room for wider adoption.

Make CS0/CS1 fulfill a GenEd
Having a great first CS class fulfill a university general education requirement promotes discovery among a wide group of students.

Changes to student support

Centralize teaching assistant recruiting, training, and evaluation
Increasingly, computing students receive much of their face-to-face instruction from TAs. Often, however, TAs receive little to no training on how to teach and how to work with students who arrive with differing levels of prior experience.

Align co-curricular supports
As schools make changes to their intro sequence and degrees, it is essential to update and align core co-curricular supports and to empower advisors to help students navigate pathway options.

Present clear degree maps on website
Many students will first be exposed to the major via the degree plan on the website. As such, it is imperative that it be both accurate and welcoming. The CIC supports schools in making sure their websites contain multiple sample plans of study to meet students where they are, including, for example, an option that does not assume calculus readiness.

Changes to the major

Right-size degree requirements
Departments need to consider whether the number of required courses and prerequisite structure in their CS courses are reasonable. They also need to ensure there are workable plans of study for on-time graduation for all students, including transfer students and students who are not calculus-ready when they start university.

Remove departmental barriers to major declaration
There is growing evidence that GPA-based caps for declaring a computing major (based on their performance in CS1 and CS2) favor students that enter university with prior coding experience. There are other strategies that can meet the department's needs to manage demand.

Interdisciplinary computing majors
Often referred to as CS+X in the literature, interdisciplinary computing majors (majors built at the intersection of computing and another field of study) are a powerful strategy for broadening participation in computing.

Building a Bridge to Graduate Studies

Changes to the curriculum

Build a curriculum that aligns with the MS degree
Bridges are intended to be compressed, accelerated pathways to an MS—not a second bachelor's degree. Rather than asking students to "catch up" to your typical BSCS student, schools should design a new curriculum that maps directly to the required competencies for the MS program. The bridge is critical for students' success in the upstream coursework.

Provide multiple starting points to accommodate prior experience
Students will come from a wide array of professional and academic backgrounds. Some may have coding experience, and others will not. Schools can consider the use of course waivers, placement tests, etc. to help students determine the best starting point.

Build a pathway to a PhD and research careers
Bridge students bring an entirely different perspective to research than a CS degree holder; they may even have prior experience in research from a different discipline or from a work context. Providing opportunities for them to engage in research is an often untapped pipeline for the PhD.

Changes to student support

Support differing levels of math proficiency
Bridge students may include career changers, students who are returning to school after a long break, and non-STEM majors with limited prior experience in college-level math. Providing additional practice resources and support for math-focused coursework in the bridge are key components for their success.

Create community within the bridge student population
Bridge students are neither undergrads nor traditional grad students; they will have most in common with fellow bridge students. Creating opportunities for them to connect with and support one another increases retention.

Enhance advising and faculty training
The needs of bridge students are different from undergrads and traditional grad students. It's important for faculty and advisors to shift their mindset and practices to incorporate adult students, including those who are true beginners to computing.

Changes to administration

Update marketing to welcome non-CS majors
Marketing materials should reflect—both in language and visually—the population a school wishes to attract. Marketing should be judicious with technical language, and avoid framing the bridge courses as remedial or as prerequisites.

Create a clear admissions pipeline and process, including student enrollment status
Ensure marketing and advising materials transparently explain whether bridge students will be considered matriculated or not, and if financial aid can be used to cover the cost of bridge courses.

Be transparent about MS admissions
Ideally, students will be offered automatic admission to the MS degree upon successful completion of the bridge. If this is not true, then schools should clearly explain exactly what needs to happen to be admitted to the MS in marketing materials and via advising once enrolled in the bridge.

Takeaways from the First Five Years

1. Retention first...then attraction
There is no sense inviting students to discover computing if it is, as one student memorably said, "a pit of alligators." This is why the CIC always focuses on retention first. However, schools can only move the needle so much by fixing retention issues; students also need great ways to discover computing once they are already at university.

2. Institutional context matters
Interventions will be more or less effective per institutional context, e.g.:

1. When reducing the curricular complexity, project leaders can anticipate significant political resistance if a degree is ABET-accredited,
2. The university's budget model is relevant to the implementation of interdisciplinary computing majors. If the budget is (seen as) zero-sum, departments will feel competitive and less motivated to collaborate.

3. Culture eats strategy for breakfast
The reality that culture can make or break an intervention is as true in academia as it is in the business world. While money and a well conceived work plan are important, sometimes the enabling environment isn't there. Insisting that the department chair be a member of the project team and that the dean be kept abreast of the work are just two ways to manage this risk. These leaders can address concerns with individual faculty members and build the buy-in needed for the project to be successful.

4. GPA-based enrollment caps are likely a deal breaker
Our experience is that there is almost nothing that can be done to move the needle on representation if GPA-based restrictions on who gets into the major, especially if requirements aren't transparently communicated.

5. Tranche the funding
By tying the funding installments to milestones (i.e., versus time), we are better able to hold leadership's attention throughout the project's implementation.

6. Making the department more inclusive doesn't have to be expensive
Because the fixes we espouse are "systemic," much of the work entailed falls within the existing job descriptions of the chair, the dean, and/or the curriculum committee. That said, we know that there are many competing demands on departments and faculty leaders; providing funding helps faculty and staff stay engaged.

7. Systemic changes can still be undone
Anything done can be undone. In every engagement, we work with project teams to identify specify strategies and actions to make the work durable.

8. Academics love data (and they are competitive)
While many stakeholders that we meet with are motivated by the issues of equity in computing, others need data to get onboard. It has been wonderful to share portfolio data with our schools and show them that what they are doing is working! Similarly, the peer comparison groups motivate project teams to want to meet (and beat) their peers.

9. MS Bridge students perform well relative to peers with prior CS degrees
An analysis of the 2000+ students enrolled in Northeastern's Align program shows that bridge students, including those with non-STEM backgrounds, perform comparably to direct-entry students in terms of GPA and job outcomes.

10. Academics love innovation but also appreciate a blueprint
We purposefully structured the CIC to be complimentary to the National Science Foundation, which focuses on research and promoting innovation. We have heard from department leaders that they appreciate a systemic change playbook they can follow that doesn't risk reinventing the wheel.

What's Next?

Grow portfolio impact
The CIC will maintain a strong focus on the interventions that Partner Schools are implementing. Wherever possible, we try to **extend schools' impact**, whether through additional funding for continued implementation or through ongoing participation in the CIC Data Program.

As we continue to learn from Partner Schools' implementation of evidence-based interventions, we need to continue to experiment, collaborate and better understand the best ways to support systemic change in **computing transfer pathways**. We have done some work in this area and applaud the efforts of the Transfer Partnerships we have been able to support. But the work is complex and the changes are often stymied by underfunding and politics, so more research and experimentation is needed.

Finally, starting in Fall 2025, we will begin to see data that sheds light on the early efforts of the 10 schools we are working with on implementation and study of **Interdisciplinary Computing Majors** (ICMs). Through this collaborative effort, we will assess the administrative feasibility of ICMs in different institutional contexts, and also demonstrate their capacity to attract students from non-computing disciplines.

Lead with data, evidence and research
The CIC is committed to providing ongoing financial assistance to Partner Schools to support the **continued collection of data**. Given the current uncertainty with regard to national data collection efforts, this commitment feels more important than ever.

In parallel, we will continue to improve the data analysis tools we offer Partner Schools, including but not limited to the Tableau dashboards, Peer Comparison Groups, and In-Class Surveys.

Finally, we will continue to invest in our partnership with the **National Student Clearinghouse's Postsecondary Data Partnership** to explore long term data collection and visualization options that allow higher ed to track domain-specific trends in enrollment, persistence and graduation.

In terms of research, as of this writing, we have **launched a new database** that will allow us to examine—with much greater efficiency—the relationship between the implementation of different Interventions and changes in student enrollment, retention, persistence and graduation.

This efficiency clears the way for us to **double down on our research activities** and accelerate progress toward our two key research goals, which are: 1) to better understand how computing is offered in the U.S and strengthen the shared understanding of best practices; and 2) to contribute materially to BPC research through rigorous data collection and analysis.

Ensure equitable access to artificial intelligence
As of this writing, the CIC team is launching a **national landscape study of AI curriculum**, programs and requirements at the undergraduate level, with the goal of identifying trends and "best practices" in how AI is being integrated into computing programs around the country. We look forward to sharing this information widely with computing departments to inform the development, design/re-design of program offerings.

Subject to the results of the landscape study, in the coming year, the CIC anticipates issuing new Requests for Proposals to support schools in developing/enhancing: AI tracks/concentrations; first year "AI+X" courses; Bridge to MS in AI programs; and "AI-viable" community college-to-bachelor's pathways. An essential and overarching objective to this anticipated work is ensuring that the urgent adoption of **AI is an invitation and opportunity for all**, not just select groups. As just one example, early research indicates that learning to code with gen AI might further the divide in the CS intro sequence between students with and without prior coding experience. We are paying close attention to this area of CS Ed research so we can help to disseminate learnings and best practices as soon as they emerge.

Case Study: Changes to Undergraduate Programs

Georgia State University

Key Context:
- Large public university in the Southeastern U.S.
- ANNAPISI, PBI designations
- 2512 CS majors in Fall 2023
- Computer Science housed in College of Arts and Sciences

Opportunity:
GSU has two programming courses before data structures. Students new to coding reported that CS1 and CS2 were intimidating, and they were afraid to ask questions because other students said everything was easy. Advisors said that this resulted in students new to coding questioning whether they should be in the major. In addition, the lack of common exams and assignments in CS1 and CS2 meant that students perceived themselves to have differing levels of preparedness for the subsequent class. CS1 had a high fail/withdraw rate, and students and advisors identified CS2 to data structures as a particularly difficult transition point. Finally, because many students are not calculus ready (or even pre-calc ready) when they arrive at GSU, having pre-calc or calc I as a co-requisite to CS1 means these students cannot take CS1 until spring semester. As such, many opt out of majoring in CS because they cannot see a path to completing the degree in 4 years.

Funded Interventions and Results:
The goals of the CIC funding were to: i) update the introductory course sequence to make true beginners feel welcome and allowed to “not know”; ii) streamline the math requirements to allow students to start with CS1 in their first semester and graduate in 4 years regardless of math preparation; iii) implement common assessment across all sections of CS1 and CS2; and iv) create programming assignments that put computing into contexts meaningful and engaging for students.

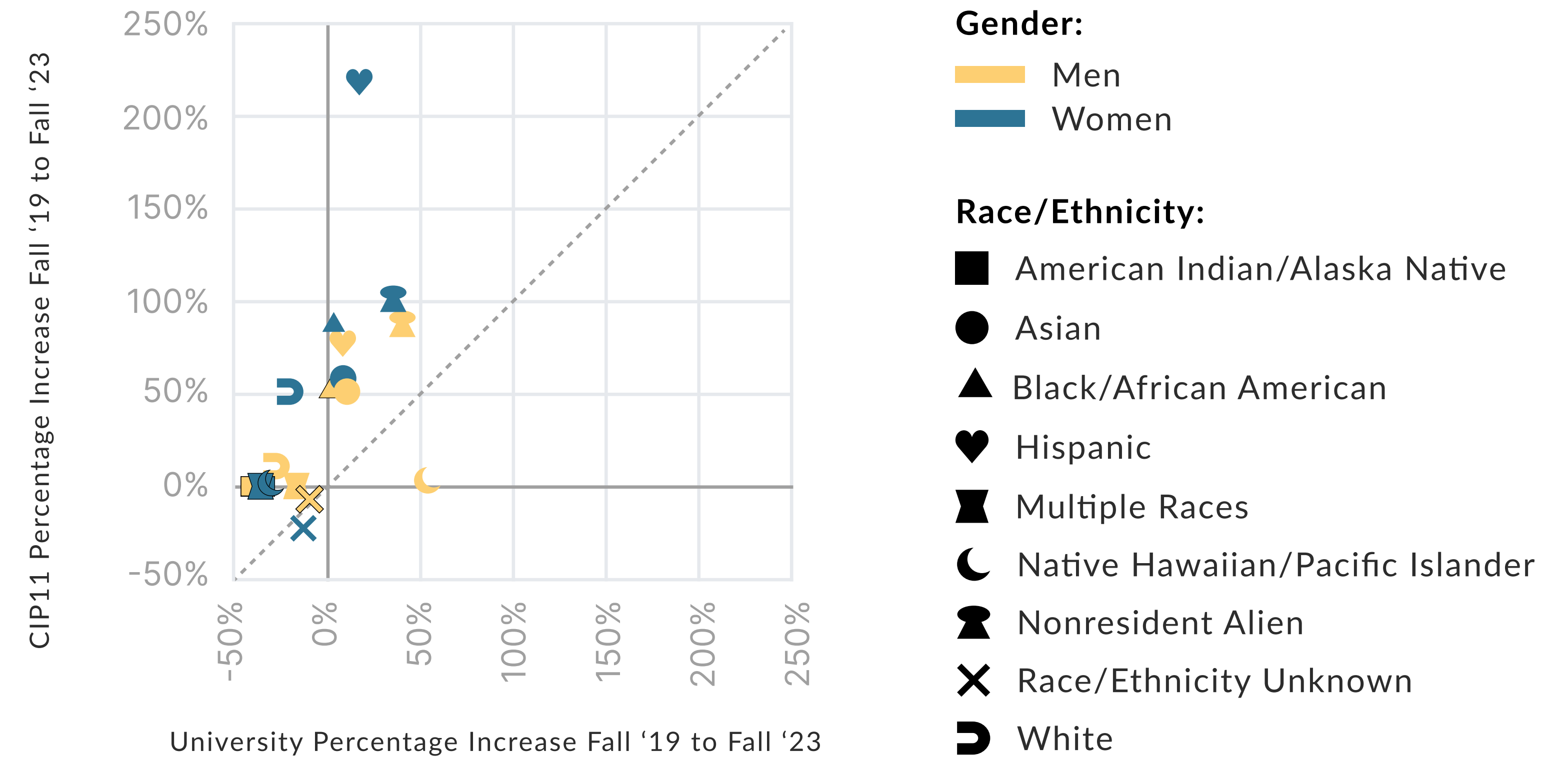


Figure 1: Changes in CS majors (y axis) relative to change in enrollment at GSU overall (x-axis) shown intersectionally. Any point above the dotted line indicates that for that population the growth in CS majors is outpacing any growth in overall enrollment at the university. E.g., enrollments of Black women at GSU grew by 4%, while CS majors who were Black women grew by 89%.

Table 1: Intervention Summary

Status	Intervention	Institutional context
●	Manage distribution of prior experience	GSU separates true beginners and those with experience into different lab sections. Advisors help students select the best section for them.
●	Common assessment	All sections of CS1 and CS2 share common assignments. Exams are created from a bank of possible questions to ensure students are tested on similar concepts across sections.
●	Computing in context	CS1 and CS2 have labs that incorporate relevant context.
◑	CS0/CS1 fulfill a gen-ed	An introductory data science course, although not part of the CS major, exists and satisfies a gen-ed.
●	Centralized TA recruitment and training	TA recruitment/assignment is centralized. Training is required for all new TAs.
●	Student support	Professional advisors in the college have a case load of ~300. Students are required to see advisors at the start of university and if they are on academic probation. In addition to TAs, the department offers tutors, including dedicated tutors for CS1 and CS2, and peer tutors in the corresponding labs.
◑	Website	The prerequisite chart has been updated to reflect removal of math as a pre-requisite to CS1.
◑	Curricular complexity	The BS requires 53 CS credits and is not ABET accredited. The required math classes do not prevent students from trying computing in CS1. Work is ongoing to ensure that math classes do not hinder students from progressing through the intro sequence.
●	No enrollment caps	Major declaration requires a GPA of 2.5 in CS1, discrete math, and their first other math course. To progress in the major, students must earn a C or better in technical courses.
●	Collect and review PFW intersectional data	Data is collected every term, presented to faculty and used for decision making.

Key: ● Fully implemented ◑ Partially implemented ○ Not implemented

Case Study: Changes to Undergraduate Programs

University of Minnesota

Key Context:

- Large flagship university, located in upper Midwest of the U.S.
- AANAPISI designation
- 2512 CS majors in Fall 2023
- Computer Science housed in the College of Sciences and Engineering

Opportunity:
UMN already followed many of the recommended best practices (see Table 1) but had large numbers of students withdrawing from CS1 and, to a lesser extent, from CS2. Prior to CIC funding, UMN had piloted a paired, one-credit, active learning class with CS1. This gave students the ability to practice coding in small groups on whiteboards for two hours a week. The course was optional and ungraded. The department observed that students who opted to take the paired class had better outcomes in CS1 than those who did not (higher grades, fewer withdraws, and higher persistence to CS2).

Funded Interventions and Results:
CIC funded the expansion of the paired class to all sections of CS1 and CS2. The impact has been significant: a drop in the withdraw rate in CS1 from 30% to 10%; a drop in the withdraw rate in CS2 from 13% to 8%; and a big shift in the demographics of computing majors (see Figure 1). This intervention is systemic and sustainable as the department now pays the instruction costs for the paired-classes and the class is in the course catalog. Most students sign up for the paired class, which is still optional and still pass/fail.

Table 1: Intervention Summary

Status	Intervention	Institutional context
●	Manage distribution of prior experience	No CS0. CS1 and CS2 (data structures) are taught primarily in Python, but versions in Java and C++ (for engineering students) are offered. Students are encouraged to start with the Python sequence. Students can start with CS2 if they have AP credit or equivalent. CS3 is advanced programming principles. There is no limit on the number of times students can try a course. CS1-3 have required labs. As discussed, there is an optional, paired, one-credit P/F class for the Python and C++ versions of CS1, and for both versions of CS2.
◐	Common assessment	Common assignments used across all sections of CS1. Common exams are not required and depend on the choice of the instructors. Students can see TAs from any section.
●	Computing in context	Curriculum includes computing in context examples and content.

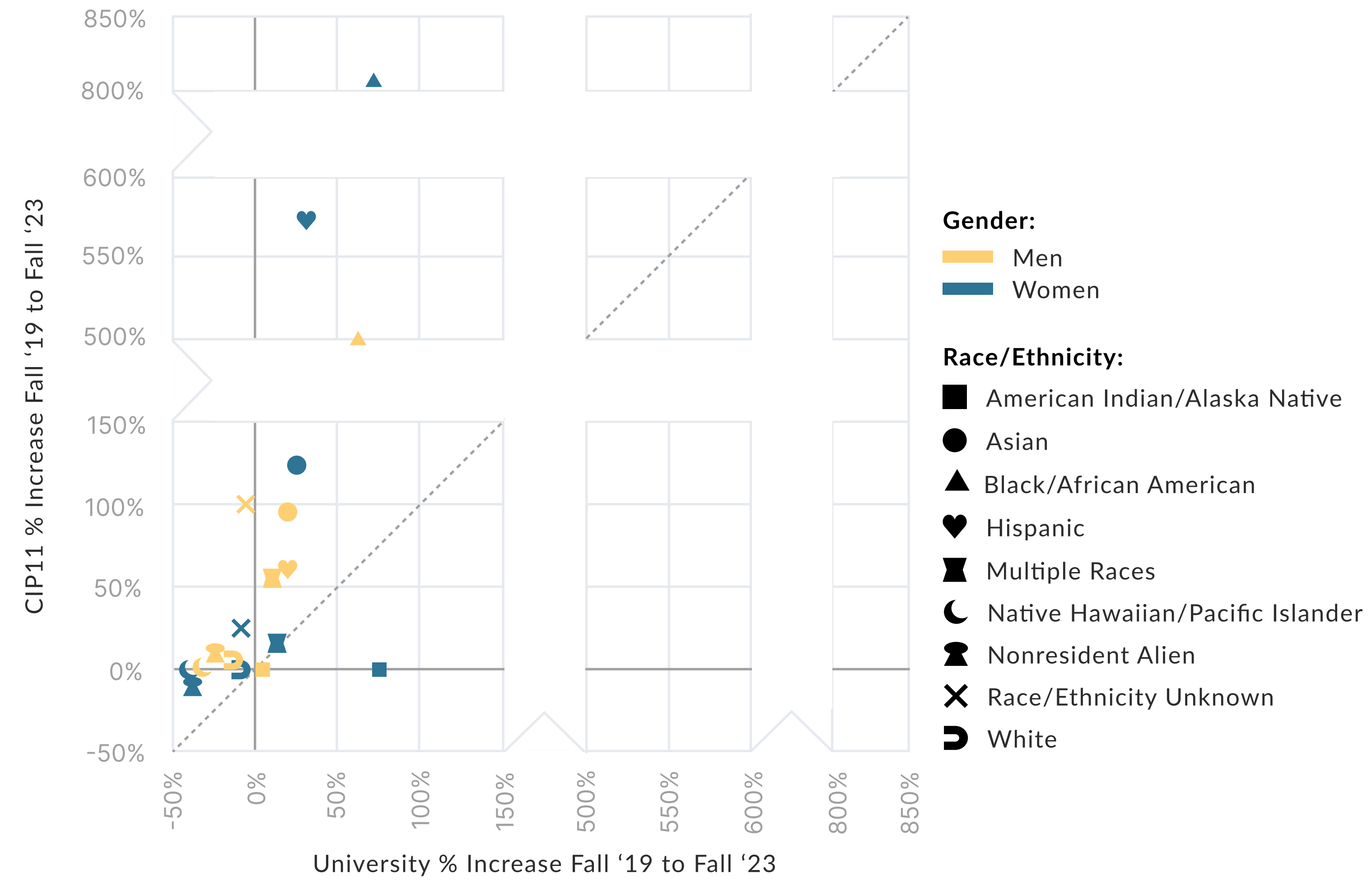


Figure 1: Changes in CS majors (y axis) relative to change in enrollment at UMN overall (x-axis) shown intersectionally. Any point above the dotted line indicates that for that population the growth in CS majors is outpacing any growth in overall enrollment at the university. E.g., enrollments of Black women at UMN grew by 71.5%, while CS majors who were Black women grew by 813.3%.

Table 1: Intervention Summary (continued)

Status	Intervention	Institutional context
○	CS0/CS1 fulfill a gen-ed	Not applicable.
●	Centralized TA recruitment and training	Processes for TA recruitment/assignment and training (in-person and run by the department) are centralized. Training is required and students are paid via their allotted hours for the first week. Professors evaluate TAs and this information is used to make rehiring decisions.
●	Student support	Professional advisors are in the college with case load of ~300. Students are required to see their advisor once per term. An advisor sits on the curriculum committee. College and department tutors are also available.
○	Website	Website does not have a separate plan of study for non-calc-ready students.
●	Curricular complexity	BS has 48-60 computing credits. BA (offered in the College of Liberal Arts) has 45 computing credits. Math requirements are the same for both BA and BS. Calc 1 is required for CS2. Neither the BS nor the BA is ABET-accredited.
○	No enrollment caps	Both BS and BA have a GPA cutoff, which used to be 2.0 then changed to 2.4, and is now 3.0. At present, students apply to the major when they have completed CS1, CS2, Calc 1, Calc 2 and Discrete. They are guaranteed admission if they have a "Technical GPA" equal to or above 3.0 for these classes. If their Technical GPA is between 2.0-2.999, they must apply. GPA is computed from all course attempts. Students can apply to the major twice.
●	Collect and review PFW intersectional data	Data is collected every term, presented to faculty and used for decision making.

Case Study: Changes to Undergraduate Programs

Colorado State University

Key Context:

- Large state university located in the Western U.S.
- 1139 computing majors in Fall 2023
- Computer Science housed in College of Science

Opportunity:

CSU had three inter-related challenges. Students without prior coding experience who had completed CS1 at CSU were receiving lower grades in CS2 than those with prior experience. CSU was also unhappy with the retention rate in the major, due in part to the high load on advising. Just prior to receiving the CIC grant, CSU had revised their entire undergraduate curriculum to allow students to progress in CS even if they needed to take remedial math courses.[1]

Funded Interventions and Results:

CSU received CIC funding to redesign CS1 for students without prior coding experience. Students without experience are in a separate section with additional supports. There is now no measurable difference in performance in CS2 between students who began CS1 with or without prior coding experience. At the same time, the department was successful in having CS0 fulfill a general education requirement, which led to higher enrollment. Another funded initiative was a “retention advisor,” a role that the department was able to convert into a sustainable additional line thanks to the significant impact this role had on student retention in the major. Overall, the results are impressive: an increase from 13.8% (2019) to 19.5% (2023) in majors identifying as women; and gains in the representation of women across all races and ethnicities. In Figure 1 we show the change in who is majoring in CS plotted against the overall changes in the demographics across the university.

[1]Please see Ganesan, et al., 2025 “Does Reducing Curricular Complexity Impact Student Success in Computer Science?” In Proceedings of the 56th ACM Technical Symposium on Computer Science Education V. 1 (SIGCSE TS 2025), February 26-March 1, 2025, Pittsburgh, PA, USA. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3641554.3701915

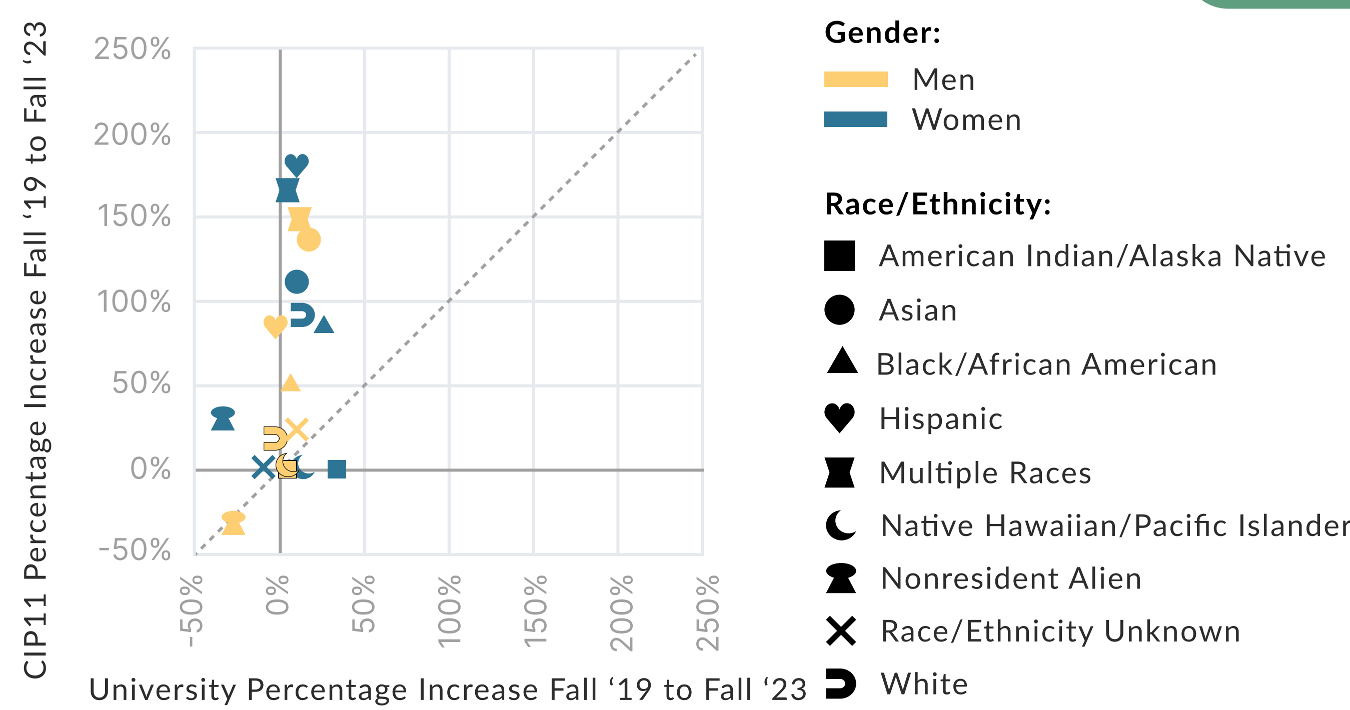


Figure 1: Changes in CS majors (y axis) relative to change in enrollment at CSU overall (x-axis) shown intersectionally. Any point above the dotted line indicates that for that population the growth in CS majors is outpacing any growth in overall enrollment at the university. E.g., enrollments of Hispanic women at CSU grew by 15%, while CS majors who were Hispanic women grew by 171%.

Table 1: Intervention Summary

Status	Intervention	Institutional context
●	Manage distribution of prior experience	CS1, CS2 (data structures) and CS3 are taught in Java and have a required lab. Students can take them unlimited times. Students without coding experience start with CS0, which is taught in Python. Students with AP credit place out of CS1. Students can self-select to start anywhere in the sequence but are strongly encouraged to follow the guidance of their advisor.
◐	Common assessment	Same assignments/exams for CS1 but not for CS2 and CS3. For CS0, CS1, CS2 and CS3, students can see TAs from any section. Online CS1 is synced with on ground version.
●	Computing in context	Curriculum includes computing in context examples and content.
●	CS0/CS1 fulfill a gen-ed	CS0 fulfills a gen ed requirement.
●	Centralized TA recruitment and training	Processes for TA recruitment/assignment and training (in-person and run by the department) are centralized. Training is required and students are paid via their allotted hours for the first week. Professors evaluate TAs and this information is used to make rehiring decisions.
●	Student support	Professional advisors in the CS department with a ratio of ~150 students per advisor. Students are required to see their advisor when they enter, as they reach defined milestones, and if they are on academic probation. Beyond that, students are encouraged but not required to meet with their advisor once per term. There is a required early alert for poor performance in lower-level classes. An advisor is on the curriculum committee.
○	Website	Website does not have a separate plan of study for non-calc ready students.
●	Reasonable curricular complexity	The BS is not ABET-accredited and requires 61 credits (including CS0). Calc 1 is a pre-req for CS3. Degree requires linear algebra and statistics, but not Calc 2.
◐	No enrollment caps	Students are required to have an overall GPA of 3.4, but there are waivers to get this down to a 3.0. The department would like to get rid of this enrollment cap.
●	Collect and review PFW intersectional data	Data is collected every term, presented to faculty and used for decision making.

Case Study: Changes to Undergraduate Programs

University of Washington Seattle

Key Context:
- Flagship state university in the Pacific Northwest
- 1,832 CS majors in Fall 2023
- Computer Science B.S. offered through College of Arts & Sciences
- Uses quarter system

Opportunity:
The University of Washington-Seattle ("UW") already followed many of the recommended best practices (see Table 1) prior to engaging with the CIC. However, students and faculty thought that the introductory sequence should be expanded from two to three quarters because some students come with no prior coding experience and others have significant coding experience. The expansion would let students start where they are comfortable and allow true beginners to be together.

Funded Interventions and Results:
The goal of the CIC Implementation Grant was to fund the expansion of the intro sequence and to support faculty in developing a self-assessment tool for students to use to determine whether they should place into CS1, CS2, or CS3. This has been a huge success with very few students needing to change levels. In addition, the CIC supported updating of TA training materials and integrating societal impacts and culturally relevant assignments into the introductory sequence. With these interventions, the pass rates of the new CS2 and CS3 are high (70-90%) across all populations (the old CS2 - now CS3 - had much lower pass rates, ranging from 45-88%).

In Figure 1 we show the change in enrollments for the major relative to the change in enrollment at the university as a whole and we can see that in all cases except for its Native Hawaiian/Pacific Islander men, enrollment for every group in CS is either the same or outpacing that of the university. Another goal is to roll out the new curriculum in high schools once it had been successfully rolled out at the university. In the past year, UW has completed the transition to the new CS1 curriculum in 17 high schools (meaning UW can now support those schools in implementing CS2), and expansion to other schools is ongoing.

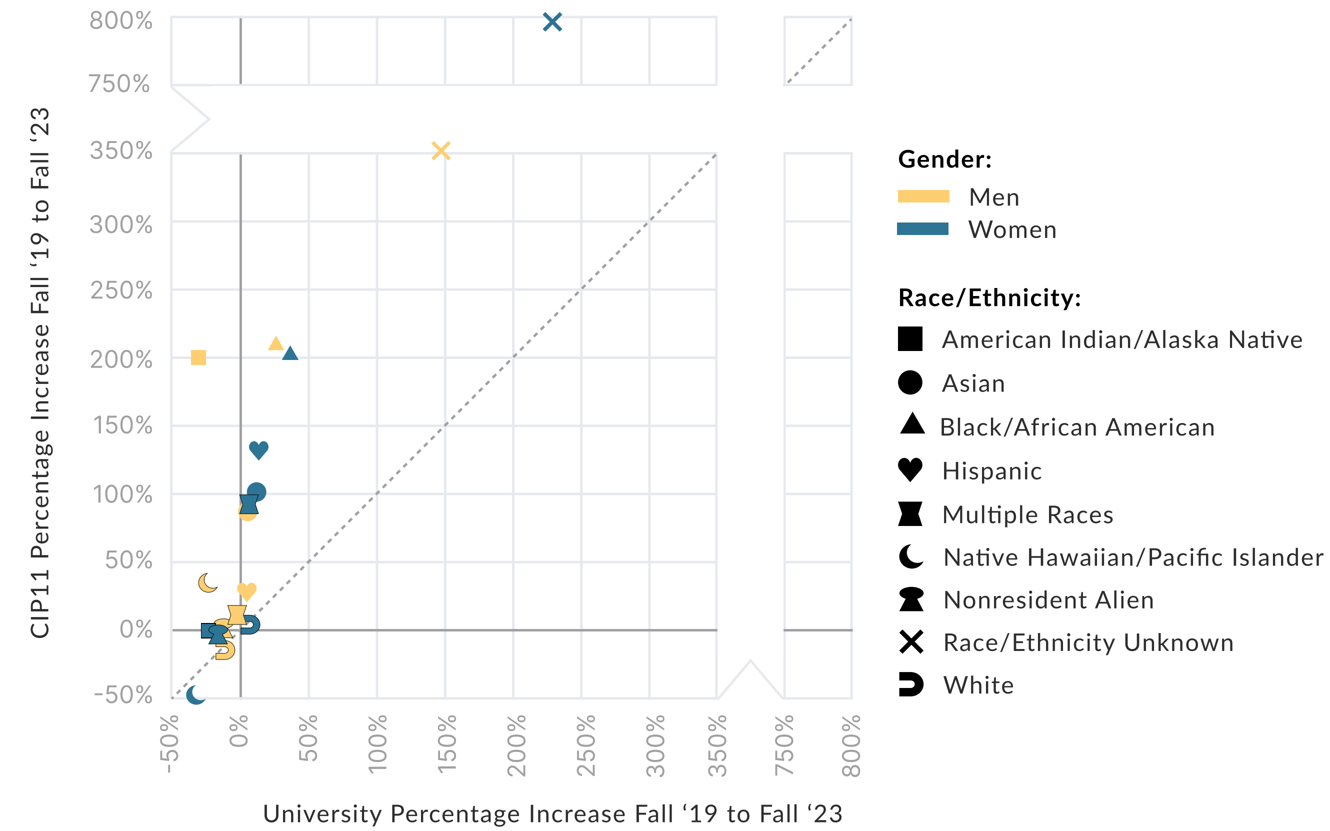


Figure 1: Changes in CS majors (y axis) relative to change in enrollment at UW overall (x-axis) shown intersectionally. Any point above the dotted line indicates that for that population the growth in CS majors is outpacing any growth in overall enrollment at the university. E.g., enrollments of Hispanic women at UW grew by 10%, while CS majors who were Hispanic women grew by 140%.

Table 1: Intervention Summary

Status	Intervention	Institutional context
●	Manage distribution of prior experience	CS1-3 are taught in Java. Students self-select where to start based on a self-assessment tool. Data structures is taught in CS3.
N/A	Common assessment	One instructor teaches one large section for each of CS1-3.
●	Computing in context	The assignments are regularly updated to reflect current context.
●	CS0/CS1 fulfill a gen-ed	Both CS1 and CS2 fulfill a gen ed.
●	Centralized TA recruitment and training	TA recruitment/assignment, in-person training and evaluation is centralized. For first-time TAs, they meet once a week for training by the department and are paid for their time from their allotted hours per week. Professors and students are surveyed to evaluate TAs and the feedback is used in re-hiring decisions.
●	Student support	There are professional advisors in the department (caseload is ~300/advisor) and peer advisors are also available. Students must see advisor at the beginning of the major and if they are on academic probation. An advisor sits on the curriculum committee.
○	Website	Website does not have a separate plan of study for non-calc-ready students.
●	Reasonable curricular complexity	BS requires 65 credits and is not ABET accredited. CS1-3 do not have any math pre- or co-requisites.
●	No enrollment caps	The number of CS majors at UW is restricted by the state. Students are admitted directly to the major and strongly discouraged from coming to UW hoping to switch to the CS major. A few students are allowed to transfer based on a holistic transfer application.
●	Collect and review PFW intersectional data	Data is collected every term, presented to faculty and used for decision making.

Case Study: Changes to Graduate Programs

Old Dominion University

Key Context:

- Public R1 research university located in Mid-Atlantic US
- Degrees are housed in university's interdisciplinary School of Cybersecurity
- Bridge to MS in CY program launched in Fall 2024
- Bridge and MS CY are offered both online and on-ground
- In AY2025, there are ~275 students enrolled in ODU's MSCY

Opportunity:
Old Dominion University (ODU) has offered an MS in CY since 2018. ODU has been a CyberCorps® Scholarships for Service school since 2021. With initial funding from the National Science Foundation and consulting support from the CIC, the project team began development of their bridge in 2023.

Over the years, ODU's School of Cybersecurity has seen increasing interest from career switchers or IT professionals who want to advance in their careers. The department was motivated to be responsive to this demand, and saw this as an opportunity to broaden access to their CyberCorps® Scholarships for Service program to a wider range of students. However, many of these prospective students obtained their degrees years ago and/or have not been sufficiently trained in information security and protection.

Given the identification of this underserved population, ODU wanted to design a bridge to the MS CY that would help students transition to higher demand and higher-paying jobs in cybersecurity, with an emphasis on regional employers and government agencies.

Current Status of Bridge Program:
ODU launched their bridge in Fall 2024. To prepare for launch, the project team conducted a series of focus groups and consultations with cybersecurity professionals with expertise in expanding representation in the field. Informed by these insights, the team developed online training modules tailored to the needs of students who are new to technology. ODU piloted the bridge modules with their existing MS student population, offering them for free as supplemental materials. This "pilot" allowed the team to identify places where courses needed adjusting to enhance accessibility and navigability (courses are asynchronous).

The Cybersecurity Bridge Program is designed to equip individuals with limited technology backgrounds for success in the MS in Cybersecurity program. It comprises three courses: Fundamentals of Linux Systems for Cybersecurity (CYSE 609, 3 credits), Windows Systems for Cybersecurity (CYSE 608, 3 credits), and Advanced Techniques for Cyber Defense (CYSE 602, 3 credits). These courses are integral to the MS in Cybersecurity curriculum and can be applied as restrictive electives within the program. Once students complete the bridge courses, they are automatically admitted into the MSCY degree.

Curriculum outline:

1 semester of bridge courses (9 credits)

Fundamentals of Linux Systems for Cybersecurity
Windows Systems for Cybersecurity
Advanced Techniques for Cyber Defense

2-3 semesters of MS-level courses (21 credits)

CYSE 600
CYSE 603
CYSE 605

\+

4 additional "restricted elective" courses

=

MSCY degree

Case Study: Changes to Graduate Programs

Colorado School of Mines

Key Context:

- Public R1 research university offering STEM degrees in the Western US
- CS@Mines Bridge program launched in Fall 2021
- Modality is in person, synchronous
- Early member of the MS Pathways to Computing Consortium, a collaborative effort administered by the CIC
- 50 students are currently in the bridge or have transitioned into the MSCS

Opportunity:

The Colorado School of Mines has offered an MS in Computer Science for more than a decade, with enrollment surpassing 92 students in 2024. They chose to launch their CS@Mines Bridge program to broaden access to their MS in CS to those with non-computing undergraduate degrees. Specifically, leadership saw the opportunity to serve three audiences that were historically out of scope for the MS in CS: recent college graduates without a CS background, professionals switching careers or enhancing technical skills, and STEM graduates needing foundational CS coursework for advanced studies.

Current Status of Bridge Program:

CS@Mines launched their bridge program in Fall 2021. To prepare for launch, the project team's work plan centered on the following: bridge curriculum development; modification of student advising and mentorship processes and materials; and the development of marketing materials and outreach activities. Students apply through the CS@Mines Bridge Program graduate admissions website. The admissions team assesses each student's preparedness in computing and mathematics, and identifies the appropriate entry point for the student, and any additional support beyond the bridge as needed. If a student has no programming experience, they begin with Computer Science for STEM (CSCI 128, 3 credits) which covers Python programming, file I/O, object-oriented programming, and STEM computing topics. If they have some experience, they begin with Foundational Programming Concepts & Design (CSCI 200, 3 credits), which covers C++, memory management, object-oriented programming, algorithms, data structures, recursion, software engineering principles, and command line programming.

Bridge students also take courses in Systems Programming (CSCI 210), Data Structures & Algorithms (CSCI 220), Software Engineering (CSCI 306), Computer Organization (CSCI 341), and Discrete Mathematics (CSCI 358). Finally, they enroll in a 1-credit seminar course (CSCI 195) run by the Director, exposing them to foundational CS topics, career pathways, and providing opportunities for social gatherings and connections with alumni and industry partners. Once students complete the bridge courses, they are automatically admitted to the MSCS degree.

Currently, work is underway to further streamline admissions and financial aid processes, and to develop different pathway options, including a thesis and non-thesis track. Additionally, in February 2025 the board of trustees approved a new fully-online professional master's degree in CS designed specifically for working professionals. This degree has fewer prerequisites, more flexible course timelines, an applied interdisciplinary curriculum, and specialization options in applied machine learning, cybersecurity, analytics and project management, and advanced software engineering.

Curriculum outline:

2-3 semesters of bridge courses (19 credits)

CS for STEM and Foundational Programming Concepts & Design Systems Programming Data Structures & Algorithms	+	Software Engineering Computer Organization Discrete Mathematics Bridge Seminar

3-4 semesters of MS-level courses (30 credits)

CSCI 561 CSCI 564 Elective Elective	+	Elective Elective Project, thesis, or coursework	+	Elective Elective Project, thesis, or coursework

=

MSCS degree

Acknowledgments

We are profoundly grateful to the team at Pivotal, without whom the CIC would not have come into existence. You inspire us every day with your commitment to creating a better, more inclusive world.

Northeastern University has been our home since inception and we are deeply thankful to the University's President, Joseph E. Aoun, and his senior leadership team for championing this work.

There are many individuals at Northeastern with whom we are fortunate to collaborate on a near daily basis. We extend particular thanks to: Provost David Madigan; Dean Mynatt and the leadership of Khoury College; Diane MacGillivray, Luanne Kirwin, Rob Silk, and Heather Moore in Advancement; Rick Alves and John Crowley in the Office of General Counsel; Sully Baez, Babitha Pathiyanna and Ani Bita in Khoury Finance; Barbara Morris, Craig Mannett, Jake McCall and Lauren Daley in Khoury Grants; and Provost Emeritus Jim Bean.

We are excited to thank CIC team "alumnae" who helped to build the CIC and whose fingerprints are everywhere in this document: Jessica Traynor, Sally Wynn, Talisa Jackson, Laura Herr, and LaToya Shuler.

To our esteemed colleagues who have worked with us over the years as Program Managers and Technical Advisors: words fall short in expressing how lucky we feel to do this work with you.

A special thanks to the CIC's founding Advisory Council: Jamika Burge, Andrea Danyluk, Jeff Forbes, Maria Klawe, John Rice, Lucy Sanders, Judy Spitz, Jodi Tims, and Brenda Darden Wilkerson.

The CIC has been extremely fortunate to have the financial support of many of the nation's leading funders in equitable education. A heartfelt thanks to: the Cognizant Foundation, Hopper Dean Foundation, Google.org, the National Science Foundation, the PIT Infrastructure Fund, the Siegel Family Endowment, and the Shanahan Family Foundation.

We are a small team at the CIC, and this is due in no small part to an amazingly talented group of consultant partners, including: Action Analytics, Grove Collective, Owen Media, the Program Evaluation Group, Sametz Blackstone, Vox, and Yeti Technologies.

We are blessed to work in an ecosystem whose hallmarks are collaboration and solidarity. A particular shout out to the Computing Research Association for their overarching partnership and to Tracy Camp for her thought leadership. We are proud to call the following organizations our friends and allies: ACM-W, Anita B.org, Break Through Tech, Code Path, Momentum, NCWIT, the National Student Clearinghouse, Reboot Representation, Science for America, and so many others. Onward!

Last but in no way least, we want to thank the 100+ schools with whom we have had the chance to work and learn together. Thank you for "being the change."

Appendix A

Intervention Cost and Time

Cost and Time Per Undergraduate Intervention

Through the more than $27m in funding provided to date, we have good insight into the cost and level of effort for each intervention. Cost is dictated largely by faculty time and pay level. To illustrate the cost ranges for each intervention, we used the following data points from CRA's most recent Taulbee Survey:[1]

- The 50th percentile for associate professors' 9-month salary is $144k, thus one month of their summer salary is $16k.
- The 50th percentile for non-tenure-track faculty for 9 months is $98k, thus one month of their summer salary is $11k.

[1]According to the most recently available Taulbee Survey data for 2023: https://cra.org/wp-content/uploads/2024/05/2023-CRA-Taulbee-Survey-Report.pdf

Manage distribution of prior experience

Cost: $ 11k - $48k
Time: 1 - 3 months

Various strategies are available: 1) create a "self placement" tool, 2) different sections of CS1-CS2 with different "pacing"; and 3) different track for true beginners (e.g., 3 course sequence versus 2 course).

Common assessment

Cost: $ 0 - $48k
Time: 1 - 3 months

1 month of summer salary to build out common assessments for each CS1-3 course. There may be an ongoing cost for faculty to serve as "course coordinators."

Computing in context

Cost: $ 11k - $64k
Time: 1 - 4 months

1 month summer salary to build out modules for each CS0-CS3 course as relevant, plus chair/administrator time to present to curriculum committee.

CS0/1 fulfill Gen Ed

Cost: $ 11k - $16k
Time: 1 month

1 month summer salary for faculty to prepare the university proposal plus chair/administrator time to shepherd through committee approvals.

Centralize process for TA training etc.

Cost: $ 11k - $32k
Time: 1 - 2 months

1-2 months faculty time to develop, test, refine and implement. Ongoing cost could be 1 month of summer salary depending on size of program.

Present clear degree maps on website

Cost: up to $10k
Time: 40 - 60 hours

Cost of staff or consulting time to improve/redo the website to include clear degree maps.

Right-size degree requirements

Cost: $ 11k - $16k
Time: 1 - 2 months

1-2 months faculty time to develop, test, refine and implement.

Interdisciplinary computing majors

Cost: $ 300k - $700k
Time: 2 - 3 years

This can be expensive as it involves changes to the department and to university infrastructure. The cost range here is for the design and launch of 3 ICMs.

Cost and Time to Build a Grad Bridge to CS

Using the same cost drivers from CRA's most recent Taulbee Survey[1] to quantify the costs associated with building a bridge-to-MS program.

Specifically, we use the following assumptions:
- The 50th percentile for associate professors' 9-month salary is $144k, thus one month of their summer salary is $16k.
- The 50th percentile for non-tenure-track faculty for 9 months is $98k, thus one month of their summer salary is $11k.

[1]According to the most recently available Taulbee Survey data for 2023: https://cra.org/wp-content/uploads/2024/05/2023-CRA-Taulbee-Survey-Report.pdf

Develop new bridge courses

Cost: $ 22 - 32k/course
Time: 2 months/course

Create new bridge course including common assessments across sections - 2 months of faculty time per course (note: most bridge programs require multiple bridge courses, so multiply accordingly)

Modify or upgrade existing bridge courses

Cost: $ 0 - $32k/course
Time: 1 month/course

1 month of faculty time to modify each of the courses in the bridge. Multiple iterations may be needed.

Update website for bridge offering

Cost: $ 20 - $40k
Time: 1 - 2 months

Build out website to advertise bridge program offering

Recruitment events for bridge

Cost: $ 1k - $20k
Time: 1 month

Recruitment events e.g. lunches for current undergraduates; information sessions; webinars. These costs will be covered by tuition revenue, but the department may need to cover costs in the first 1-3 years.

Co-curricular programming

Cost: $3k/year
Time: 1 - 3 years

Host monthly alumni or external expert talks for bridge population - $250/speaker

Bridge-specific academic advising

Cost: $ 62.5k/year
Time: 1 - 3 years

Entry-level academic advisor to serve bridge students (recommended when enrollments hit 100+ students). These costs will be covered by tuition revenue, but the department may need to cover costs in the first 1-3 years.

Appendix B
Publications

Publications

An MS in CS for non-CS Majors: Moving to Increase Diversity of Thought and Demographics in CS

Proceedings of the 51st ACM Technical Symposium on Computer Science Education 2020
Brodley, C. E., Barry, M., Connell, A., Gill, C., Gorton, I., Hescott, B., Lackaye, B., LuBien, C., Razzaq, L., Shesh, A., Williams, T. and Danyluk, A.

We have created, piloted and are growing the Align program, a Master of Science in Computer Science (MS in CS) for post-secondary graduates who did not major in CS. Our goal is to create a pathway to CS for all students, with particular attention to women and underrepresented minorities. In this paper, we present our “Bridge” curriculum, which is a two-semester preparation for students to then join the traditional MS in CS students in master’s-level classes. We describe co-curricular activities designed to help students succeed in the program. We present our empirical findings around enrollment, demographics, retention and job outcomes. Among our findings is that Align students outperform our traditional MS in CS students in grade point average. At the time of publication, 137 students had graduated from the program and 827 were enrolled.

CS 0: Culture and Coding

Proceedings of the 51st ACM Technical Symposium on Computer Science Education 2020
Lionelle, A., Grinslad, J. and Beveridge, J. R.

Many universities offer an introductory computing class for non-majors but often this class does not easily or obviously connect to additional coursework or the opportunity to major. The ideal CS0 – from a BPC perspective – is one designed to encourage non-CS majors to discover computing and pursue additional coursework if they find they like it.

Diagnosing why Representation Remains Elusive at your University: Lessons Learned from the Center for Inclusive Computing’s Site Visits

Proceedings of the Annual Conference on Research in Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT) 2021
Brodley, C. E., Gill, C. and Wynn, S.

In this paper, we detail the structure and content of the CIC’s 2021 site visit methodology to enable the leaders in undergraduate computing programs to identify their unique challenges and position themselves to implement well-informed broadening participation strategies.

Broadening Participation in Computing via Ubiquitous Combined Majors (CS+X)

Proceedings of the 53rd ACM Technical Symposium on Computer Science Education 2022
Brodley, C. E., Hescott, B. J., Biron, J., Pekin, M., Maravetz, S. and Mislove, A.

As computing becomes increasingly relevant to all disciplines, interdisciplinary computing degrees become increasingly important. These interdisciplinary majors: 1) address the increasing need for computing knowledge across all disciplines; 2) have the potential to increase a student’s employability and they give employers the opportunity to hire students who are trained in two fields relevant to the company; 3) by reducing the number of requirements for the computing degree, can alleviate some of the pressure faced by CS departments from booming enrollments on the upper-division courses; and 4) broaden participation in computing.

Why Universities Must Resist GPA-based Enrollment Caps in the Face of Surging Enrollments

Communications of the ACM, 65 (8) 2022
Brodley, C. E.

Computing departments face a challenging combination of forces: soaring student enrollments and lagging resources. On the face of it, it seems logical to respond by capping enrollments, and by far the most popular method in the US is to set a minimum grade-point average threshold (calculated for courses in the introductory CS sequence) for entry to the major. Although this might appear like a fair way to determine who gets into the major, it is biased toward students with prior experience in computing. This White Paper explains the ways in which GPA-based caps work at cross purposes with BPC goals, and offers alternate solutions

Expanding the Pipeline: Addressing the distribution of prior experience in CS1

Computing Research Association News, 34 (6) 2022
Brodley, C. E.

The CIC believes that a student should be able to discover computing in college. CS is only offered (often as an elective) in 57% of U.S. high schools – those located in the most privileged and well resourced geographies in the country. Therefore, it is imperative that university computing departments create a pedagogical infrastructure that properly handles the wide distribution of prior experience.

Publications

On the BPC Importance of Advising

CIC White Paper 2023
Alvarado, C. and Brodley, C. E.

As schools make changes to their intro computing course sequence and the degree, it is essential to update and align core co-curricular supports in parallel. Above all, it is paramount that computing leadership include academic advisors in their conversations about curricular and structural changes and empower advisors to help students navigate the different pathways through the computing degree.

Systematizing Solutions to Attrition in University Computing

CIC White Paper 2023
Brodley, C. E.

In this white paper, the CIC draws on the work done with more than 60+ of the largest computing departments in the country (representing 25% of all US computing graduates) and shares observations on what computing department leaders can do to ensure the durability or "stickiness" of the BPC changes they make.

On the BPC Importance of Centralizing TA Training, Recruiting, and Evaluation

CIC White Paper 2023
Brodley, C. E. and Muzny, F.

In this paper we discuss the benefits of centralized training, recruiting, and evaluation, outline and address the main concerns we have heard from faculty about centralizing these tasks, and provide concrete steps toward implementation.

Teaching Assistant Training: An Adjustable Curriculum for Computing Disciplines

Proceedings of the 54th ACM Technical Symposium on Computer Science Education 2023
Muzny, F. and Shah, M. D.

We present an adaptable curriculum for training undergraduate and graduate teaching assistants (TAs) in computing disciplines that is modular, synchronous, and explicitly mirrors the teaching techniques that are used in our classes. Our curriculum is modular, with each component able to be expanded or compressed based on institutional needs and resources. It is appropriate for TAs from CS1 through advanced computing classes.

Collecting, Analyzing, and Acting on Intersectional, Longitudinal Data and Pass/Fail/Withdraw Rates in Computing Courses

Proceedings of the 55th ACM Technical Symposium on Computer Science Education 2024
Muzny, F., Giordano, M., Sommers, E. and Brodley, C. E.

In this paper, we present three case studies grounded in an analysis of the first programming class ("CS1"), demonstrating how an institution can use student outcome data to understand their program and develop interventions that broaden participation in computing.

Visualizing Progress in Broadening Participation in Computing: The Value of Context

Communications of the ACM, 67 (7) 2024
Barr, V., Brodley, C. E. and Pérez-Quiñones, M.

In this paper, we discuss the challenges of using the standard approaches to understanding representation in computer science. We present a series of visualizations that analyze intersectional representation in computing in the context of university demographics across all degrees, and over time. We then turn to examine how well the information-based metrics of diversity used in many other disciplines can serve to analyze demographic diversity in computing.

The BPC Relevance of Common Assessment in the Introductory Sequence

Communications of the ACM, 67 (7) 2024
Brodley, C. E. and Gill, C.

Common assessment (i.e., shared assignments and exams) across sections of the introductory computing sequence is key to creating an equitable learning environment. Students arrive at the introductory computing sequence with wide-ranging levels of prior coding experience. Common assessment ensures students are able to achieve the stated learning goals and advance to the next class. Common assessment also makes it possible for students to choose which teaching assistant they see based on scheduling, learning style, or intersectional identity, etc.

Does Curricular Complexity in Computer Science Influence the Representation of Women CS Graduates?

Proceedings of the 55th ACM Technical Symposium on Computer Science Education 2024
Lionelle, A., Quam, M., Gill, C. and Brodley, C. E.

In this paper we investigate the relationship between curricular complexity and the representation of women earning CS degrees. To do this, we created curricular maps of 60 computer science degrees and calculated measures such as program complexity, course blocking, delay factor, and total math/CS credits. Our results show that degree complexity, blocking factor, and delay factor are all inversely related to the representation of women. We also present the courses that most commonly impede student progress and provide suggestions to improve degree plans.

Publications

An Analysis of the Math Requirements of 199 CS BS/BA Degrees at 158 U.S. Universities

Communications of the ACM, 67 (8) 2024
Brodley, C. E., Quam, M. and Weiss, M.

For at least 40 years, there has been debate and disagreement as to the role of mathematics in the computer science curriculum. This paper presents the results of an analysis of the math requirements of 199 computer science (CS) BS/BA degrees from 158 universities, looking not only at which math classes are required, but at how they are used as prerequisites (and corequisites) for CS courses.

Top Ten List for Making a Great "Major Requirements" Web Page

CIC White Paper 2024
Quam, M.

This "Top Ten" list accompanies the article "Does Curricular Complexity in Computer Science Influence the Representation of Women CS Graduates." In mapping the curricular complexity of 60 CS degrees, the CIC identified the following best practices that departments can follow to make their degree requirements website both accurate and welcoming.

ACM 2023: CS + X — Challenges and opportunities in developing interdisciplinary computing curricula

ACM Inroads, 15(3) 2024
Brodley, C. E., Barr, V., Gunter, E., Guzdial, M., Libeskind-Hadas, R., and Manaris, B.

Interdisciplinary undergraduate computing curricula are of growing interest to students, institutions of higher learning, and employers, and range from single interdisciplinary courses to full majors. In this paper, we survey the range of types of CS+X programs and give recommendations for engaging with the opportunities and challenges in developing such programs.

Does Reducing Curricular Complexity Impact Student Success in Computer Science?

Proceedings of the 56th ACM Technical Symposium on Computer Science Education 2025
Ganesan, S., Lionelle, A., Gill, C., and Brodley, C. E.

In this paper, we present the results of a comparative analysis of curricula before and after a major structural revision. The new curriculum, with a 60% reduction in curricular structural complexity, showed both increased retention of students over the old curriculum (67% to 98%) and an increase in the number of students converting from undeclared to computer science (44% to 69%). Our findings demonstrate that reducing curricular complexity need not compromise program rigor and can benefit students by providing greater flexibility and ensuring earlier exposure to (and therefore retention in) CS.

An MS in CS for non-CS Majors: A Ten Year Retrospective

Proceedings of the 56th ACM Technical Symposium on Computer Science Education 2025
Schmidt, L. W., Kidder, C. J., Akhmetov, I., Bebis, M., Jamieson, A. C., Lionelle, A., Maravetz, S., Rollins, S., and Selinger, E.

For the last 10 years, Northeastern University has offered a two-semester bridge into a master's in computer science for people with undergraduate degrees in non-computing disciplines. The bridge program has over 2,000 currently enrolled students with more than 50% women every year since 2020, and domestic enrollment has increased relative to direct entry master's students. Data show that bridge students, including those with non-STEM backgrounds, perform comparably to direct-entry students in terms of GPA, and that 93% are employed full time with an average salary of $120,000 USD. We attribute the program's sustained success to institutional investment in resources specifically designed to meet the unique needs of bridge students.

Student Application Trends for Teaching Assistant Positions

Proceedings of the 56th ACM Technical Symposium on Computer Science Education 2025
Muzny, F., Suria, A., and Brodley, C. E.

We present a comprehensive analysis of teaching assistant (TA) application preferences, with the goal of identifying whether there are significant differences in the courses students prefer to TA for based on student identity. Focusing on the dimensions of applicant program level (undergraduate versus Master's students), gender, and international versus domestic student designation, we perform an analysis of application patterns. Our results show that program level, gender, and international status all play roles in student application behavior. This work demonstrates that with a centralized TA application system, an institution can gain a comprehensive understanding of application behaviors–leading to informed decisions about where to potentially intervene, especially with an eye toward broadening participation in computing at all levels.

Thank You

Learn more about our work at cic.northeastern.edu