Upward Mobility for Underrepresented Students: A Model for a Cohort-Based Bachelor's Degree in Computer Science

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ABSTRACT

CSin3 is a cohort-based, three-year computer science bachelor's degree program that has increased graduation rates of traditionally underrepresented computer science students. A collaborative effort between a community college and a public university, CSin3 provides a clear pathway for upward socio-economic mobility into the high-paying technology industry. CSin3 students are 90% from traditionally underrepresented groups, 80% first-generation, 32% female, and have a three-year graduation rate of 71%, compared to a 22% four-year graduation rate for traditional computer science students. Upon graduation, CSin3 students score similarly on a standardized exam of computer science knowledge as compared to traditional students who graduate in 4 years or more. The first graduates had a job placement rate of 78% within two months of graduation, including positions at large technology companies like Apple, Salesforce, and Uber. By implementing a cohort-based learning community, a pre-defined course pathway, just-in-time academic and administrative support, comprehensive financial aid, and a focus on 21st century skills, the CSin3 program has demonstrated promising results in addressing the capacity, cost, quality, and diversity challenges present in the technology industry.

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1 INTRODUCTION

Over half of all Latino and African-American undergraduates begin at community colleges [17]. However, only 14% of degree-seeking community college students obtain a bachelor's degree within six years [14]. Traditionally underrepresented students, already "stuck in the shallow end" due to limited access to computing in K-12 [16], face a stark reality in their attempts to access high-paying computing careers via a higher degree. Even if these students do persist to graduation, longer time-to-degree results in increased tuition costs, including potential loss of financial aid, as well as lost wages [11].

What causes computer science students at community colleges to struggle with transfer and graduation? Unclear transfer pathways and inconsistent academic advising add difficulties to an academic journey already stressed by financial need and the need for remediation [15]. Even when transfer students graduate, they are less likely to have participated in impactful experiences like internships and learning communities [18].

California State University Monterey Bay (CSUMB), a state university, and Hartnell College, a community college, formed a partnership to implement an innovative pathway that serves students from the Salinas Valley in California: **an accelerated bachelor's degree coupled with significant student support structures and financial assistance**. At the core of this program is a commitment from CSin3 staff to take full responsibility for navigating institutional complexity, allowing students to focus on academics and career readiness. The program includes:

- An accredited three-year Bachelor of Science degree program in which students complete the first 18 months at Hartnell and the final 18 months at CSUMB
- Student cohorts that follow a pre-defined pathway from enrollment through transfer and graduation
- A preparatory math intensive program and a summer bridge program to improve college-readiness of students
- Ongoing academic support through identification of academic needs and provision of support services
- Career development support through internship and job preparation workshops
- Scholarship support that eliminates the need for students to seek outside employment

2 RELATED WORK

Many efforts have been made to support traditionally underrepresented minority students in computing, but few interventions address the spectrum of these students' multifaceted needs across the entirety of their degree. One notable example is a cohort program for first-year computing students at Rochester Institute of Technology [12]. Students are take a subset of classes together, practice active learning, have access to staff who manage institutional complexity, and build a culture of professionalism.

The concept of a three-year bachelor's degree has gained popularity over the last decade, largely in the pursuit of lower costs [13]. Three-year degrees typically offer students a course pathway, but vary in the amount of support they provide or the amount of prior preparation they demand. Some education advocates claim that accelerated degrees are only appropriate for exceptionally well-prepared students [13], while others see three-year degrees as an opportunity to jump-start reform by requiring efficiency from institutions of higher education [26].

3 SETTING: THE SALINAS VALLEY

Despite its location 70 miles south of Silicon Valley, the Salinas Valley is known for agriculture, not information technology. Called the "salad bowl of the world", the Salinas Valley is home to a $4 billion agriculture industry primarily based on crops that must be manually harvested, like lettuce, strawberries, and broccoli [6].

The population of the 1,000 square mile Salinas Valley is 75% Latino. The overall poverty rate is higher than the state and national averages at 20%, with about 50% of Salinas Valley families classified as low income [5]. Languages other than English are spoken in 68% of area homes. More than 40% of Salinas Valley residents did not graduate from high school. For Latinos, the situation is more serious with 55% having less than a high school education, and only 5% having a bachelor's degree [5].

The Salinas Valley is served by Hartnell Community College, an open access institution that enrolls nearly 17,000 students. The closest four-year institution is California State University Monterey Bay, located 12 miles west. CSUMB offers bachelor's and master's degree programs for a student body of over 7,000 students.

4 THE CSIN3 PROGRAM

4.1 Partnership between CSUMB and Hartnell

A small team consisting of faculty and staff from both CSUMB and Hartnell developed the CSin3 program and manage its day-to-day operations. The close working relationship and shared team vision, as well as the broader commitment from the institutions to the cohort-based pathway, made it possible to establish a truly multi-institutional program.

4.2 Three-year, year-round pathway

A recent study of computer science transfer students found 1,213 distinct pathways to graduation with a Bachelor's degree, of which only 1% involved two years at community college and two years at university [22]. A companion study found that these students lack knowledge about transfer and graduation requirements, as well as computer science course content and industry expectations [15]. This paucity of information can lead to poor course choice and career preparation.

To ensure that students are well-prepared while making efficient progress to degree, CSin3 provides a pre-defined course pathway, with guaranteed capacity for each student. Students do not need to spend time deciding on courses, designing a schedule, or resolving waitlist or course conflict issues.

Developed collaboratively by faculty at CSUMB and Hartnell College, the course pathway efficiently meets degree requirements while maintaining a reasonable workload. Students take classes year-round, including winter and summer sessions. Besides decreasing time to graduation, continuous engagement has been associated with increases in both retention and graduation rates [3, 7].

Computer science skills alone are not enough for success as a computer scientist or software engineer [19]. Pathway electives are chosen in order to develop specific 21st century skills [24], e.g. a public speaking course to improve communication, and three English courses to develop critical analysis.

Students complete their first three semesters primarily at Hartnell and the final three semesters primarily at CSUMB. However, students are integrated into the university environment early, as they take one course at CSUMB each semester before transfer.

4.3 Financial aid and low tuition costs

Full engagement with academics and professional preparation demands minimal distractions. Since traditionally underrepresented students are more likely to work to support themselves during college [10], addressing financial needs of students is critical.

The transfer pathway through a community college results in tuition costs under $15,000 for the entire CSin3 program. Through a partnership with a local philanthropic foundation, CSin3 students in the first five cohorts received $30,000 scholarships, allowing them to focus full-time on academics and career preparation. While it is an incentive to remain on track with the program, this kind of finaincial support alone it is likely not sufficient to ensure graduation.

4.4 Tightly-knit cohorts

CSin3 students are organized into cohorts of 32-35 students. Each cohort attends classes and enrichment activities together throughout the three years of the program. While computer science students from underrepresented backgrounds are often minorities in university departments, cohort students are constantly surrounded by people they know, often from similar backgrounds. CSin3 students are 90% from traditionally underrepresented groups, 80% first-generation college students, and 32% female.

Cohort members form a community of learners [21], supporting each other in their academic and professional goals. This support isn't only social and emotional, but also informational. As one cohort member discovers useful knowledge, such as how to get started on a resume-worthy side-project or what to expect during a certain company's behavioral and coding interviews, this information is shared among the cohort, as well as passed between cohorts.

Cohorts are efficient from the institution's perspective. Communication is straightforward: information spreads quickly through the close-knit community, and cohort students are usually in the

same place. Scheduling a cohort's classes can be done at once, in bulk, in an automated fashion.

4.5 Supportive yet driven culture

CSin3 explicitly builds a cohort culture, based on key ideas:

- Computer science careers are an option for anyone, and understanding computer science is something anyone can do if they put in continuous effort. Growth mindset [9] is taught explicitly.
- Grit is key to success. Students view Angela Duckworth's TED Talk, which defines grit as "passion and perseverance for very long-term goals...and working really hard to make that future a reality" [8]. Grit in the CSin3 context is described as studying long hours on campus, day after day.
- No one gets left behind. Cohort members provide help when others are struggling, academically and non-academically.

4.6 Admissions focused on dedication to cohort

4.6.1 Recruitment. Recruitment is targeted at all areas of the Salinas Valley, including rural southern Monterey County. Outreach activities include high school classroom visits, contact with school counselors and teachers, presence at Hartnell college events, and increasingly, word of mouth.

Recruitment efforts emphasize the large number of high-paying computing jobs and stress that not all college majors provide the same opportunities for employment. Computer Science is framed in terms of its real-world impact, and examples demonstrate how computing enables progress in many fields, like creating educational solutions for blind children or fighting forest fires [20]. Presentations honestly address typical graduation rates, and CSin3 is described as a low-cost, effective option for students willing to put in significant effort. .

4.6.2 Eligibility. CSin3 applicants may be seniors in high school, may have completed some college, or may be going back to school after time off. A 3.0 high school GPA is the stated requirement, however, students with lower GPAs are admitted if they demonstrate high levels of motivation and grit. Prior to starting the pathway in fall, students must be ready for calculus and college English (see summer preparation, below).

4.6.3 Application. Students complete an online application via the the program web site[1] that includes a 1000 word personal statement, transcripts, and a letter of recommendation. Applications open in September and the cohort is typically filled by January.

4.6.4 Selection. CSin3 has rolling admissions, based on the idea that any student who meets admissions criteria and is passionate about CSin3 should be considered, regardless of their relative qualifications. Qualified students interview with a small panel of faculty and staff, which provides an opportunity to ensure applicants understand how CSin3 differs from a typical college experience and to ensure that students are truly interested in computer science.

Cohort members are conditionally admitted and required to attend Math Intensive classes, regardless of prior math preparation. Active participation in Math Intensive is a secondary selective measure for grit and dedication to CSin3.

[1] https://www.csumb.edu/csin3

4.7 Math Intensive and summer preparation

The need for supplemental support to become math- and English-ready became evident from the very first recruits into CSin3. This need for remediation is in line with national trends, which show that as high as 60% of college students need math remediation and 28% need English remediation–rates nearly twice as high as those at four-year public institutions (32% and 10% respectively) [25].

During spring semester, a high school mathematics teacher and undergraduate tutors conduct weekly Math Intensive sessions Saturdays at Hartnell College. Students work through Khan Academy's adaptive online curriculum [1]. Instructors monitor student progress via an online dashboard, and students are required to complete a certain number of hours each week or risk their spot in the cohort. Math Intensive supports a shift in expectations towards the full-time college workload of CSin3.

4.8 Summer Bridge

Summer Bridge takes place a few weeks before the start of CSin3 students' first semester in the program. Led by faculty and staff from the CSin3 team, the focus is on building cohort culture, setting expectations about coursework, and giving students a soft introduction to programming and computer science. A letter advising parents of the heavy time commitment of CSin3 is distributed in both Spanish and English.

4.9 Study Time and physical environment

Comfortable study space on campus is crucial for CSin3 students, who typically live at home and lack a quiet study environment there. Mandatory "Study Time" of 5-8 hours per week builds the habit of studying on-campus.

4.10 Access to and relationships with staff

Typically, institutions wait for students to reach out for help, and they expect students to know where to go among many distinct departments. First-generation college students not only face more difficulties understanding the type of help they need, but are also more likely to attend institutions with higher ratios of students to staff.

In CSin3, staff members serve as an API layer on top of the institution, listening to student issues and then guiding students or directly communicating with the correct department for support. This "one-stop-shop" approach takes responsibility for supporting all student queries, whether financial, administrative, or academic. Student issues are never "someone else's problem."

There are two primary staff members who spend significant face time with students each week (e.g. during Study Time), providing mentorship, encouragement, and advice. The *CSin3 Program Coordinator* manages CSin3 student enrollment and registration, distributes financial aid, manages payroll for tutors and faculty funded by related grants, and leads recruitment. The *Computer Science Education Coordinator* provides academic support throughout the pathway, tracking the academic progress of CSin3 students,

managing academic interventions such as tutoring assistance, and leading enrichment sessions.

4.11 Tutoring and Peer-Led Team Learning

Tutoring for challenging courses provides another layer of academic support for CSin3 students. Tutors are hired through the tutoring centers at Hartnell and CSUMB, and directed to hold hours at times and locations convenient to CSin3 students. Attending tutoring is not mandatory, although it becomes so if a student is at academic risk. To improve both their general tutoring skills and pedagogical content knowledge about how to tutor their topic, tutors participate in weekly training sessions overseen by the CS Education Coordinator.

Because of the importance of building foundational programming skills early on, a more robust academic support structure has been created around the first two programming courses in the CSin3 pathway. The core of this structure is Peer-Led Team Learning [23], where students in more senior cohorts are trained as Peer Leaders by the CS Education Coordinator, and guide first-year students through collaborative problem sets for 1.5-2 hours weekly.

4.12 Enrichment activities

What happens in classes alone is not enough to prepare students for industry, both academically and professionally. CSin3 students attend a weekly three-hour Friday Cohort Enrichment session in their first year. In the first semester, this session covers cohort culture, incorporates team-building, reviews CS1 programming fundamentals, and develops study skills like time management and test-taking strategies. In the second semester, this session covers more CS1 programming fundamentals, as well as career exploration exercises, resume information, and a walk-through of a sample side project. In the second and third years, CSin3 students attend weekly Above and Beyond Computer Science sessions, located at CSUMB, which cover professional preparation skills like resume-building and technical interview preparation. These enrichment sessions are open to all CSUMB computer science students.

4.13 Internship

Having an internship is a key qualification for many computing jobs, however, first-generation college students, traditionally underrepresented minority students, and transfer students are less likely to complete an internship than their peers [18]. Because of this, the importance of an internship and the timeline for obtaining one must be communicated early and often, and adequate support and preparation must be provided.

For CSin3 students, completing an internship over the second summer is a requirement of the program. This looming internship requirement sets real-world expectations, and while daunting, gives students a clear goal, motivation for career prep like resume-building, and an authentic reason why coursework (both in and out of computer science) is important.

To meet the deadlines of major technology companies, students must be ready to apply for internships in the fall of their second year. CSin3 students' association with a four-year university and their in-progress plan for earning a bachelor's degree is often considered a positive by these companies. Students who are not successful with the initial round of applications typically apply to smaller or local companies and/or research experiences in the spring semester.

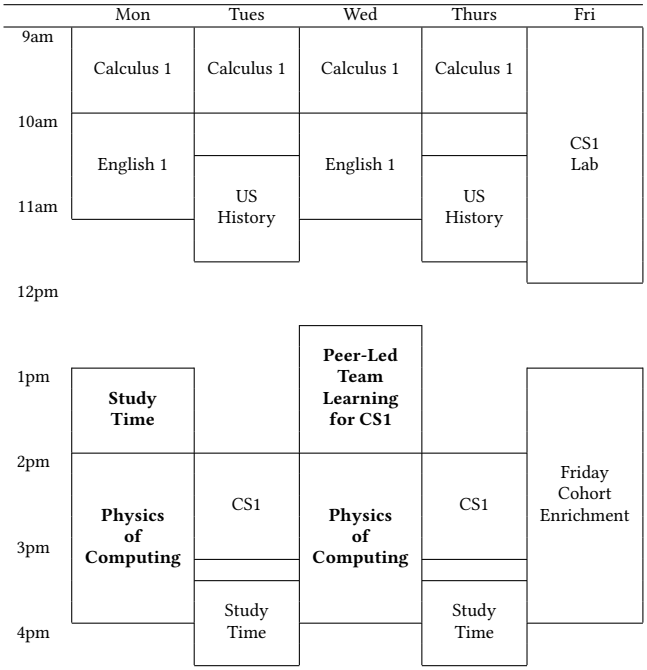

Table 1: Weekly schedule for CSin3 students' first semester (sample, Fall 2015). Bolded activities take place at CSUMB.

Unlike some college internship programs, CSin3 students do not have guaranteed placements, although faculty often help connect CSin3 and other CSUMB students with employers. Students' success at obtaining internships and the feedback from their employers is a valuable feedback mechanism for CSin3 faculty and staff.

CSin3 students, along with other CSUMB computing students, present posters about their summer internship work at a symposium in the first week of each fall semester. This event helps sustain connections with industry, is an opportunity to invite recruiters to campus, and inspires other CSUMB computing students to begin thinking about internships early in their college careers.

5 OUTCOMES

5.1 Student outcomes

5.1.1 Transfer and graduation rates. CSin3 enrolled its first cohort in fall 2013, and has enrolled another cohort in each year since. Eighty-five percent (87 out of 102) of CSin3 students transfered to CSUMB after 18 months. Seventy-one percent (46 of 64) of CSin3 students graduated with a bachelor's degree in 3 years. From the first cohort, 79% graduated in 3.5 years.

CSin3 has had a significant impact on the demographic composition of computer science graduates from CSUMB. Prior to launching CSin3 in 2012, CSUMB produced 1/34 of all Hispanic CS graduates from across the CSU system and 1/30 of all female CS graduates. As of May 2017, CSUMB produced 1/10 of all Hispanic CS graduates and 1/13 of female CS graduates across the entire CSU system of 23 campuses and over 400,000 undergraduates.

5.1.2 Job and Internship positions. Of the 46 CSin3 students who graduated in three years (from the first two cohorts), 36 (78%) had secured gainful employment in the technology industry within two months of graduation. Employers include Apple, BlackRock, CIG, Driscolls, Dolby, iFoodDecisions, HeavyConnect, HumRRo, JPMorgan Chase, Kibo, Liberty Mutual, Lyft, Panafold, RedTeal, Salesforce, SSCS, NBC Universal, Uber, and Verizon.

Three cohorts have participated in internships. Internship preparation activities have benefited not only CSin3 students, but also other CSUMB students who attended workshops and interacted with visiting industry professionals. These efforts have resulted in 131 computer science students, 79 from CSin3, completing internship experiences in summers 2015, 2016, and 2017.

5.1.3 Standardized exams of computer science and general critical thinking. During their first semester of college (Fall 2013), 32 CSin3 students from the first cohort and 26 traditional CSUMB CS students took the CLA exam, a measure of general critical thinking skills [4]. CSin3 students scored lower (1061 vs. 1093) on this initial exam. However, almost three years later, these CSin3 students re-took the CLA (Spring 2016) and on average scored higher (1121 vs. 1075) than a group of 100 randomly selected 4th-year seniors from across CSUMB.

CSin3 graduates and traditional graduates also took the ETS Major Field Test for Computer Science, a standardized exam that covers foundational and advanced computer science knowledge [2]. CSin3 graduating seniors took the Major Field Test in spring 2016 and spring 2017, with an average score of 144 (40th percentile) and 146 (43rd percentile), while the other graduating CS students averaged 142 (33rd) and 144 (40th), in the respective years.

5.1.4 Threats to validity. While CSin3 students were initially less prepared than traditional CSUMB students, at least as measured by the CLA exam, perhaps CSin3 has selected for characteristics like motivation and grit, and those internal characteristics are the reason for CSin3 students' success. It is an open question, however, as to whether CSin3 students enter with these characteristics, or whether they are built through the social factors of the program.

Would CSin3 students have chosen to attend or transfer to CSUMB if they were not a part of CSin3? Many CSin3 students had GPAs that would allow them to be accepted at other, more highly-ranked institutions farther from home. Perhaps CSin3 students are not comparable to CSUMB graduates. It is worth noting, however, that low-income students who can attend other institutions may choose to attend college close to home to lower costs [15].

5.2 Institutional outcomes

5.2.1 Partnerships with industry. The visibility of the CSin3 program has led to connections with industry partners, who find access to a concentration of well-prepared graduates from traditionally underrepresented backgrounds valuable. Since the start of the CSin3 program, CSUMB has had campus visits from partners who had not visited previously, including Lyft, Uber, Amazon, Salesforce, Apple, Facebook, and others.

Industry partnerships do not only benefit CSin3 students. While recruiters may initially ask for access to CSin3 students, they are connected with high-performing students from within the entire computer science program.

5.2.2 CSin3 as a test lab and lever for change. The structured nature of cohort model lends itself to a relatively easy introduction of new initiatives that require additional student time. The success of PLTL within CSin3 motivated a re-structuring of CSUMB's CS1 and CS2 labs to build PLTL into the course curriculum. Resume preparation and technical interview practice began as a mandatory CSin3 activity, but was expanded to all CSUMB students.

CSin3 has also inspired the creation of other cohorts. The culture within the first CSin3 cohort immediately motivated the program team to launch a cohort-based four-year program to serve incoming freshmen at CSUMB, called CS++. At the time of submission, there have been four cohorts of CS++ students at various stages of pipeline showing similar promise of engagement and results.

6 CHALLENGES

6.1 Costs and Sustainability

CSin3 has significant upfront costs, especially the salaries of related staff and the financial aid for students. However, the costs of intensive programs like CSin3 must be weighed against the costs of delayed transfer and graduation times, both to students, to the state, and to industry.

CSUMB and Hartnell have been successful at securing grants and foundation support to fund CSin3, but it is understood that such support cannot continue indefinitely. In fact, CSin3 will transition to partial financial support in AY 2018-2019, after a foundation partner completed five years of scholarship support.

The program team is currently spearheading an effort called *Computing Talent Initiative*[2] to build partnerships with other colleges, universities, and industry partners in order to replicate the cohort model.

6.2 Integration with the CSUMB student body

Strong bonds within each cohort are key to creating the supportive, cohort-based learning environment of CSin3. However, these strong bonds can lead CSin3 students to only socialize with each other, and not form new connections with CSUMB students, even after transfer. Differing backgrounds of CSin3 students, who are largely Hispanic and from the Salinas Valley, compared to the larger CSUMB student community, which has fewer underrepresented minority students than Hartnell, may also play a role.

Undoubtedly, students in CSin3 receive personalized attention significantly greater than that a traditional student typically receives. While CSin3 students sacrifice flexibility and time in order to receive this benefit, this attention still has significant benefits. Continuing such attention on cohort program students while addressing perceived favoritism sometimes expressed by traditional CSUMB students is a challenge.

7 CONCLUSION

The status quo of low graduation rates for underrepresented students is not acceptable at a time when computing jobs are in high

[2] http://www.computingtalentinitiative.org

demand and offer a path to upward social mobility. CSin3's innovative design balances several goals related to student success, institutional resources, and industry needs in order to address key factors contributing to these less-than-ideal results. While this paper outlines details of the specific operations and implementation of CSin3, it is not the suggestion of the authors that all components be replicated precisely or in full. Rather, we offer the key principles below as a model for increasing diversity, retention and degree completion rates, and transition to industry in a high-demand field like computer science.

Partnerships that extend beyond institutional boundaries. In order to serve a diverse student body that includes many low-income, first generation students, it is critical to develop a program that meets students where they are and guides them forward. Breaking down silos within and across institutions - particularly the boundaries between community college and university - is necessary for accomplishing that objective.

Organizing students into cohorts. Building a learning community of students and developing expected norms for behavior, engagement, and work ethic reinforces good habits, creates operational efficiencies, and leads to increased student success.

Support that is both close in time and in proximity. Offering a single point of contact (or a small team) who tracks student progress, interfaces directly with every student, and can respond to individual student and cohort needs in real-time, allows students to focus their time and energy on developing the knowledge, skills, and experiences that will keep them on track to graduation and successful careers in industry.

A defined pathway that guarantees graduation in a set time. With ever-expanding catalogs of course options, it is important that institutions identify and advertise clear pathways to degree that don't change year-to-year, are guaranteed to be offered and have space, and will lead to graduation in a predetermined amount of time.

Students having a clear, inspiring post-graduation vision from the beginning. This picture can be painted through close relationships with industry, experiential learning opportunities like internships, examples of and connections with relatable figures, and student reflection on their own goals and ambitions.

By incorporating these elements, CSin3 students reap the benefits of a university affiliation and exposure, while capitalizing on the low costs of a community college; are successful through the development of grit and time on task even though they often enter the program as not the highest achievers; and have access to a socially supportive environment rooted in academic pursuit.

As with most challenges, there is no silver-bullet solution to the capacity, diversity, and quality issues facing computer science in both higher education and the industry. Collaborative, iterative, boundary-pushing ideas and actions are required to move the needle in helping ensure that higher education offers a path to upward mobility for traditionally underrepresented students.

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