The Benefits of Socially Responsible Computing in Early Computing Courses: A Multi-Institutional Study at Primarily Undergraduate Hispanic-Serving Institutions

ANONYMOUS, Anonymous, Country

Background and Context. Computing is considered a fundamental skill for civic engagement, self-expression, and employment opportunity. Despite this, in our state in the USA, there are significant equity gaps in post-secondary computing enrollment and retention. Specifically, in the Anonymous University System, which serves close to half a million undergraduate students, students identifying as Hispanic/Latino make up a smaller percentage of CS majors than expected from the state's overall population; and, once enrolled, tend to leave the CS major at higher rates than other students.

Purpose. We report on the impacts of a curricular intervention aimed at strengthening the sense of belonging of Hispanic/Latino students in computing, with the eventual goal of improving retention in computing majors for those students.

Methods. Working in an alliance of six universities within the Anonymous University System (five of which are designated as Hispanic-Serving Institutions), we have incorporated socially responsible computing across early CS courses. We aim for alignment between our curriculum and students' communal goal orientations, and for coursework that attends to students' interests, values, and cultural assets. Over a two-year-long study, we collected survey data to learn about the impact of our curricular intervention on students' sense of belonging and perceived learning and agency.

Findings. We found that students generally reported high communal goal orientations and, at the campuses *without* competitive enrollment policies, our intervention had a significant positive impact on students' senses of belonging. This effect was observed between control and treatment terms as well as within treatment terms. We also note that Hispanic/Latino students were more likely than other students to report that non-curricular factors like work and family obligations interfered with their learning, and also appeared to experience slightly stronger benefits from the intervention.

Implications. Our data suggests positive outcomes for integrating socially responsible computing into early CS courses, especially for Hispanic/Latino students at certain PUIs. Unlike much prior research, we found that conducting studies outside of PWIs can provide new insights into the impact of curricular interventions on student experience and retention. Our varying results by campus suggest that factors such as campus population, acceptance rate, and departmental enrollment policies ought to also be taken into account in studies that aim to broaden participation in computing. Would results from prior research on recruitment and retention of Hispanic/Latino students or other underrepresented students look different if such studies were replicated at institutions with different demographics and enrollment policies?

CCS Concepts: • **Social and professional topics → Computing education**; **Computer science education**; **Race and ethnicity**.

Additional Key Words and Phrases: Socially Responsible Computing, Broadening Participation in Computing, Hispanic/Latino students, Primarily Undergraduate Institution, communal goal endorsement, sense of belonging

Author's Contact Information: Anonymous, who@where.what, Anonymous, City, State, Country.

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1 Introduction

Computing has long been considered a fundamental skill for civic engagement, offering opportunities for self-expression, education, civic and critical consciousness, and financial and social mobility [26, 33]. Yet, White and Asian male-identifying students are disproportionately over-represented in computing. Efforts to challenge these gaps are underway. For example, NSF's Broadening Participation in Computing calls on us as CS educators to address the "missing millions—those who are yet to be engaged in the STEM workforce so that it reflects the racial, ethnic and gender representation of the general population". The problem is systemic and requires institutional-level changes.

Attending to this call, our project brings together faculty from six primarily-undergraduate institutions in Anonymous State in the USA. The six institutions are part of the same public University system, which serves close to half a million students. In Fall 2023, 48.3% of these students identified as Hispanic/Latino,[1] but only 25% of the 3704 computer science degrees awarded at the Anonymous University System in 2023 went to students identifying as Hispanic/Latino.[2] While there is work to be done statewide to continue to boost undergraduate enrollment for Hispanic/Latino students, in computing we have an additional burden to attend to the disproportionate enrollment in computing for Hispanic/Latino students.

Within this context, our work is centered on developing socially responsible computing (SRC) curriculum and integrating it into the first two years of post-secondary CS courses, with the goal of supporting students who have been historically underrepresented in computing—that is, those who do not identify as White or Asian men. Despite being part of the same University system, we find that our six sites have significant variance demographically and with respect to departmental and institutional policy. Our work engages with this difference, encouraging curriculum development tailored to each context but with a common thread that emphasizes strengthening students' sense of belonging in computing by (1) developing early computing course materials with clear signaling that computing can be used to benefit society, thereby appealing to students' communal goal orientations [32], and (2) incorporating tenets of culturally relevant pedagogy [30], specifically providing opportunities for students to succeed in course assignments that draw on diverse backgrounds and interests. Engaging with multi-site variations as we work towards a shared goal enables us to identify differences in effects arising from institutional factors such as inclusiveness in terms of admission and major selection criteria.

We address the following research questions (described in more detail in §5):

- **RQ1** What was the level of communal goal endorsement from our CS students?
- **RQ2** How did sense of belonging in computing change with the inclusion of SRC coursework?
- **RQ3** How did SRC curricula affect students' self-reported learning of technical and "social technical"content?
- **RQ4** What other factors impacted students' experiences in early CS courses?

We used surveys given during a Control term (with no curricular additions) and three Treatment terms to measure the impact of curricular intervention on students' sense of belonging in computing. Additionally, we studied students' communal goal endorsements, their perceptions of the SRC curricular additions, and other factors that might have

[1] Anonymized link to Anonymous University System enrollment summary.
[2] Anonymized link to statistics about degrees issued.

interfered with their coursework. We received 435 responses from students in the first year of the study and 2670 responses in the second across all six sites, and learned that the student experience and the impact of our intervention varied between campuses that were more restrictive and competitive, and those that were not.

Our results also let us explore conceptual replications of existing research in the field, much of which has been historically executed at primarily White institutions (PWIs), where results may not necessarily transfer to minority-serving institutions (MSIs). Of the six sites participating in the present alliance, five are designated as Hispanic-Serving Institutions (HSIs).

Our curricular intervention has had a positive impact on students' self-reported learning, including technical skills and SRC skills. Additionally, communal goal orientation was found to be important for *all* CS students, including for Hispanic/Latino students and students from underrepresented gender identities. We also found a significant positive change in the sense of belonging for Hispanic/Latino students at our most inclusive institutions, in terms of competitive enrollment, from Control to Treatment terms as well as within Treatment terms. This data indicates the value of integrating SRC assignments into computing courses when working towards broadening participation in computing.

2 Background

Our work is focused on improving the retention and experiences of historically underrepresented students in early post-secondary computing courses. We are working within an alliance of six post-secondary institutions that are all part of the Anonymous University System in Anonymous State in the USA. Given the population demographics in our state, our long-term focus with this work is specifically to **broaden participation of Hispanic/Latino students in computing**.

A wide array of literature addresses the complex issues that students face in STEM courses [19, 41, 52]. While external forces such as socio-economic realities surrounding families and communities or broader campus climate cannot be ignored [39, 40], our work focuses on academic factors of influence. Specifically, we focus on strengthening students' sense of belonging in computing, which we believe is necessary to broaden participation in computing. Further, echoing Nuñez [39], we move away from a universal approach to promoting a sense of belonging and instead examine the impact of our intervention on a specific group: Hispanic/Latino students.

A student's sense of belonging in an academic discipline has been described as their sense that they fit in and are valued as part of that community [25]. This sense can significantly influence a student's academic persistence and performance in the discipline [19, 20, 32]. Hispanic/Latino students have tended to report a lower sense of belonging than White students in college environments and in STEM fields like CS [28, 31, 38] and, at the institutions involved in this study, face higher attrition rates in CS programs (§3).

One factor that may affect a student's sense of belonging in computing is their perception that computing would enable them to meet communal goals [32], i.e., the sense that they can use computing for the betterment of society or their communities. Clear signaling in early courses that computing could further communal goals could positively impact students' sense of belonging in computing, particularly for those students with stronger communal goal endorsements.

Our work arises from a shared theme in the literature that both women and students of color are likely to strongly endorse communal goals [6, 9, 16, 19, 20, 27, 32], i.e., they tend to be drawn to goals that further the betterment of society. For example, there have been calls to "creatively find ways to better connect [underrepresented] STEM students to community-based learning opportunities or to find ways to emphasize how classroom content relates to prosocial communal outcomes" [19], leading Estrada et al. [20] to argue that "Among [historically under-represented] students there is growing evidence that communal goals are important to the retention and departure of students in science and engineering fields." In computing in particular, there have been calls to integrate justice and ethics into coursework to improve the experience of students of color [45, 50], and Lewis et al. [32] report, based on large-scale survey data, that students' senses of belonging in computing were negatively impacted when they perceived computing to offer *low* opportunity to meet communal goals. This effect was heightened when the student reported high levels of communal goal endorsement, which was significantly more likely for women and students of color. We note that not all prior literature has carefully attended to intersectionality [13, 42] or sometimes mixes findings, applying results from studies focused on women to students of color and vice-versa, implying that the same approach to broadening participation applies to different identity groups. We have found in our data that distinguishing along varied axes of identity is important.

We are also driven by certain tenets of culturally relevant and culturally responsive pedagogies, which are concerned primarily with the academic success and thriving of students of color. Culturally relevant pedagogy emphasizes the recognition of the varied cultures, perspectives, and experiences that students bring to the classroom [23, 30]. Ladson-Billings [30] recommends that culturally relevant classrooms "provide a way for students to maintain their cultural integrity while succeeding academically" by incorporating students' interests and existing strengths into lessons and assignments, and teaching "to and through" those strengths [24]. We integrate this emphasis on strengths in culturally relevant and responsive pedagogies with our focus on socially responsible computing by utilizing Yosso's community cultural wealth model as an assets-based framework grounded in and responsive to students' lived experiences [54].

One major way in which teachers can teach "to and through" students' strengths is by enabling them to make choices about their learning [48]. In an introductory programming classroom, this could take the form of students choosing a domain in which to exercise their developing programming abilities. For example, though not originally described as culturally relevant pedagogy, Bart et al. [5] empowered students in their data-centric introductory computing course to work with datasets of their own choosing, and students experienced improved outcomes in terms of learning and confidence. As another example, in an environment where students used found materials from their own homes to design and create computing artifacts, Johnson et al. [29] found that students formed strong connections between their designs, home lives, and computing.

Necessary to this exercising of student choice is that culturally relevant classrooms emphasize "active-participatory" communication styles, where students are in rapport with the teacher and with one another; as opposed to the traditional "passive-receptive" style of classroom communication where students are passive recipients of information unless they are called upon to answer questions with "factual, right-answer responses" [23]. In our continuing bid to invite students to bring their whole selves into the classroom, our work similarly includes numerous opportunities for students to discuss solutions with each other, often with no obvious "right" answer.

Also in accord with our emphasis on communal goal affordance, Ladson-Billings [30] emphasizes that culturally relevant classrooms should help students to "recognize, understand, and critique current social inequities", and Gay [24] and Tanase [48] describe culturally relevant classrooms as empowering students to focus on social justice and communal welfare.

Finally, our students do not experience our computing courses in a vacuum, and related work addresses the complex social, emotional, and historical contexts and injustices that impact marginalized students' experiences [19, 40, 41]. While our work is primarily focused on strengthening student sense of belonging through curricular interventions, we are also cognizant of the student experience holistically within an institution, for example through the lens of servingness [22]. This broader context seeks to acknowledge that students can face external pressures that can interfere with their academic performance. These obligations may include family duties, work responsibilities, and cultural expectations, which can vary significantly across different demographic groups.

There is evidence that students of color are often managing external obligations that can impact their learning and computing experience. Salguero et al. [43] sought to learn about the various sources of struggle that students might face in early CS courses, and found that Black, Hispanic/Latino, Native American, and Pacific Islander students were more likely than other students to report that personal obligations (like family obligations, work obligations, or illness) interfered with their learning. Duran and Núñez [18] reported that Hispanic/Latino students were more likely to experience basic needs insecurities. Similarly, plenty of evidence suggests that factors outside of the classroom can impact learning for the student body in general [34, 46, 47, 53]. Therefore, we also investigate at our institutions how and for whom personal obligations might affect learning.

In the following section, we describe the varied contexts of our six participating institutions and provide examples of our curricular interventions aimed at enhancing the sense of belonging of Hispanic/Latino students in our classrooms.

3 Institutional contexts

The Anonymous University System is a large and diverse university system in a large and diverse state in the USA. Access to CS courses in high school is highly inequitably distributed in the state, with lower-income counties and counties with larger populations of Hispanic/Latino, Black, Indigenous, and Pacific Islander students tending to have fewer schools that offer CS courses [1].

Similar variability is present among the six Anonymous University System campuses participating in this work, summarized in Table 1. Our CS departments serve varying percentages of Hispanic/Latino students, ranging from 11% to 63%. Across the six sites, 29% of our shared computing student population identified as Hispanic/Latino. Our varying contexts allow us to learn from one another and to see that the impacts of interventions to broaden participation in computing differ based on these contexts.

When considering what may influence a student to opt into and thrive in computing, we considered several factors that may influence the student experience: student's prior experience with computing, program attrition rates, and institutional selectivity. We ultimately narrowed our focus to campuses grouped in terms of their institutional selectivity, but we discuss a number of factors for the sake of context.

Prior experience with computing. In Spring 2024, the percentage of students who reported having any high school experience with CS ranged from 21% (at NCE 4) to 65% (at CE 1). When considering the task of helping students opt-in to computing, we aim to influence students most newly exposed to computer science. We note that NCE 2 is somewhat unique as it draws from a large urban center that has been well served by efforts related to exposing high school students to AP Principals in Computing [21].

Student retention. As shown in Table 1 different sites have different retention rates. Anonymous University System institutional data categorizes students as belonging to "underrepresented minority" groups (URM) if they identify Hispanic/Latino, Black/African American, Native American, Hawaiian/Pacific Islander, or multiple races with at least one of those races list. Over 84% of "URM" students identify as Hispanic/Latino across all sites. Table 1 includes departmental attrition rates for URM students because that is the institutional data that is publicly available. We see that retention rates also correlate with admission with the largest potential impact for retention focused on certain sites. On average across the sites, URM students leave CS at a rate of 34.4% while non-URM students leave at a rate of 21.5%.

Institutional selectivity. In terms of enrollment policies, University acceptance rates range from 33% to 93%. Additionally, two out of the six CS departments have "competitive enrollment policies", i.e., students must declare a CS

Table 1. Our campuses vary in their student demographics, experience, and enrollment policies. All sites have between 1000-2000 CS majors in total. Campuses are identified anonymously as having a competitive enrollment policy (CE) or not (NCE). Campus identifiers will be added upon de-anonymization. Prior experience in CS was measured through survey questions (§5) and may suffer from selection bias. Other columns are based on institutional data.

Campus	CS in high school	% Hispanic/Latino Univ.-wide	% Hispanic/Latino CS majors	Univ. accept. rate	Leave CS % URM	Competitive CS enroll.?
NCE 1	21%	69%	63%	86%	42%	No
NCE 2	38%	75%	54%	91%	45%	No
NCE 3	43%	52%	27%	59%	30%	No
NCE 4	23%	37%	26%	93%	45%	No
CE 1	65%	53%	27%	44%	26%	Yes
CE 2	47%	23%	11%	33%	18%	Yes

major at the time of admission to the university, or must meet grade thresholds to become a CS major after admission as seats are limited [38]. These can reduce first-year students' sense of belonging in computing, and weaken their perception of their departments as being "welcoming" [38].

To reflect these broad contextual differences, we broadly group our sites into two categories, which we call *most inclusive* and *restricted*. While there are varying percentages of CS majors identifying as Hispanic/Latino between the sites (from 23-75% University-wide), we find that this categorization is most salient for considering opportunities and impact while working to encourage students to opt-in to computing. Broadly speaking, NCE 1, NCE 2, NCE 3, and NCE 4 have high acceptance rates and do not have a competitive CS enrollment policy, while CE 1 and CE 2 have lower acceptance rates and a competitive CS enrollment policy (students are admitted directly into the CS major or must meet pre-requisite requirements in order to take CS 1).

4 Curricular Interventions: Socially-Responsible Computing

Our alliance's goal is to increase the retention of Hispanic/Latino students in early computing courses. We do this by developing curricular materials that demonstrate to students their potential to use computing to help their communities and to think critically about the impacts of computing on communities and communities on computing. Borrowing from culturally relevant pedagogy [14, 30], we have developed curricular materials that strives to allow students to bring their own cultural assets into the computing classroom.

In particular, our curricular intervention focuses on integrating socially responsible computing (SRC) and, in doing so, situates computing firmly in the students' social surroundings. SRC goes beyond only teaching ethics in computing. It encourages students to actively consider the social and ethical implications of their work. It acknowledges the significant power computing systems have in society and aims to prepare students to exercise that power responsibly as they develop technical skills. By integrating societal considerations as they learn programming skills, we were encouraging students to bring their cultural norms, mores, and lived experiences into the learning process.

While particular cases of integrating SRC in the six sites varied, we share a set of core components that guide the SRC integration. First, we sought to integrate SRC considerations in the context of technological knowledge introduced in the class, rather than introducing separate modules for ethical and social considerations.

In one example of technical integration, students at NCE 4 were introduced to a project on deciding the priority for on-campus housing allocations. This was introduced when students were learning about conditional statements (if-then-else). They implemented their policies using conditional statements while reflecting on how their approach improved on the current state of affairs and critically noting the limitations of their approach.

Similarly, at NCE 3, students worked on an activity focused on fairly allocating pooled tip amounts in a restaurant when they were learning about conditional statements. This activity followed a POGIL-like structure with pre-assignment reading, critically analyzed variations of tip allocation algorithms that made use of conditional statements, and then designed their own algorithm.

Second, all of our assignments were designed to support students to reflect on the real-world impacts of computing decisions. For example at CE 2, an SRC assignment involved analysis of real-world datasets covering a breadth of domains, including domains and datasets chosen by the students. In the latter case, students worked with datasets about CS education enrollment in our state, learning about inequitable splits in enrollment along the lines of race, gender, and median household income. They worked on data about housing and food access, and still others worked with data provided by local non-profit organizations. Through these efforts, we sought to enable a rich environment to support students to bring their interests into the learning process. This course is described in detail in a prior publication [4].

Third, we created structures to foster reflection and discussion on the ethical dilemmas that students encountered when working on the SRC assignments. We supported this by providing students with reading materials relevant to the issue they were working on, and further encouraged them to venture out to broaden their understanding of the issue. In some cases, such as at NCE 4 and NCE 3, we leveraged a framework on feminist perspectives on power by introducing students to the potential of computing and social entities to have power over others (power-over) and the ability for developers and others to resist and realize a just future (power-to) [2]. We included discussions on ethical and social issues in various formats, ranging from online-only to a combination of online and in-person, as well as fully in-person sessions. For instance, at NCE 3, after completing the restaurant tip allocation assignment, students engaged in an asynchronous discussion to reflect on what they learned and justify that their group's algorithm is fair according to the power-to/power-over framework. Responses were divergent and suggested that students made connections to personal priorities, values, and experiences, consistent with culturally responsive pedagogy.

Assignments like the ones described above were incorporated into CS 0, CS 1, and CS 2 courses at our participating institutions. Levels of incorporation varied, ranging from the inclusion of a few new assignments to the creation of entirely new courses.

5 Study overview

We address the following research questions.

- **RQ1 What was the level of communal goal endorsement from our CS students?** Given our motivation for incorporating SRC into introductory coursework, we investigate whether students are interested in coursework that might appeal to communal goal orientations.
- **RQ2 How did sense of belonging in computing change with the inclusion of SRC coursework?** We explore this change quantitatively in two ways. First, we investigate the change in belonging between a "control" term (without SRC curricular additions) and "treatment" terms (with SRC curricular additions). Next, we investigate the change *within* treatment terms, measuring the difference between sense of belonging measured early vs. late in the term.

RQ3 How did SRC curricula affect students' self-reported learning of technical and "social technical" content? To answer this question, we look at survey responses at the conclusion of intervention terms.

RQ4 What other factors impacted students' experiences in early CS courses? Beyond academic factors, we would like to learn about other potential sources of difficulty in early CS courses. We asked students about the extent to which factors like in-class confusion, lack of confidence, and personal obligations interfered with their ability to learn or complete coursework.

To answer the questions above, data was collected through surveys administered in participating courses over the 2022–2023 and 2023–2024 academic years. Over the course of the two-year study, surveys were modified as we learned lessons, considered new hypotheses, or sought more feedback. In the second year of our study (2023–2024 academic year), surveys were administered twice in each term—once Early in the term and once Late in the term (more details in §7). Table 2 summarizes the time points at which specific items appeared in administered surveys.

Directly pertaining to our RQs, survey questions focused on students' **communal goal endorsement** (§6), their **sense of belonging in computing** (§7), their **perception of their attainment of CS and SRC learning outcomes** (§8), and **other sources of struggle that might have impacted their experience** (§9). We measured the strength of students' communal goal orientations using the question "How important to you are goals such as working with people, helping others, and serving the community?", used by Henderson et al. [27] in their study on goal congruity of STEM students. We measured students' sense of belonging in computing using questions from the scale validated by Moudgalya et al. [36]. To measure students' perceptions of their attainment of learning outcomes, we used questions defined by our research team (see Table 6). Finally, to learn about other sources of struggle for our students, we used questions from the survey published and validated by Salguero et al. [43].

In addition to the questions above, the survey included questions to help us gain further context about the students' experiences. Additional questions asked about the student's campus, the course they were enrolled in, their race/ethnicity, gender, and prior experiences with computing (the latter using questions from Alvarado et al. [3]).

With regards to race/ethnicity, as a research project focused on broadening participation in computing for Hispanic/Latino students our survey included the choices: *Hispanic/Latino*, *Black, African American, American Indian, Alaskan Native, Pacific Islander*, *Another race/ethnicity not listed above*, and *Prefer not to state*. Our project sought to strengthen the participation and improve retention of Hispanic/Latino student who have been historically underrepresented in our institutions. Considering this, we code responses as being *Hispanic/Latino* or *not Hispanic/Latino*, where the *not* category includes all responses that did not select "Hispanic/Latino" in response to the question.

With regards to gender, our survey included the choices *Man*, *Woman*, *Nonbinary*, *Transgender*, *Agender*, and an open-ended option if the participant's gender was not listed. However, a very small percentage of responses (roughly 2% in each survey) selected anything other than *Man* or *Woman*. Despite efforts in broadening participation in computing, CS education has the second lowest involvement of women of all engineering and science programs in the US [37]. Our vision of a broader and inclusive computing education involves supporting non-male individuals to participate and feel that they belong in computing. To this end, we use *Man* as the control group and code responses as identifying as *men* or an *underrepresented gender* (URG), where the *URG* category includes all responses that did not select "Man" in response to the question.

Table 2. Summary of survey questions and time points at which they appeared.

Questions	Ref.	Appeared in
Campus & course	–	All surveys
Race and gender	–	All surveys
Prior computing experiences	Alvarado et al. [3]	Spring 2024 (early and late)
Communal goal endorsement	Henderson et al. [27]	Spring 2024 (late)
Sense of belonging	Moudgalya et al. [36]	All surveys
Attainment of learning objectives	Table 6	Spring 2024 (early and late)
Sources of student struggle	Salguero et al. [43]	Fall 2023 & Spring 2024 (late)

6 RQ1: Communal goal endorsement

As mentioned in §2, one motivation for our work is to appeal to the expected stronger communal goal orientation among students from marginalized communities. Students' sense of belonging is positively related with the alignment between their communal goal endorsements and their perception of their academic disciplines as allowing them to meet those goals [9, 17, 27, 32]. Therefore, we begin by exploring the strength of our students' communal goal endorsements.

6.1 Method

A question about communal goal endorsement appeared in the final survey we conducted (i.e., late in the Spring 2024 term). As a result, we cannot say how communal goal endorsement *changed* during our study. Nevertheless, for the purposes of understanding our student sample, we report their communal goal endorsements as measured toward the end of the Spring 2024 term.

Students answered the question "How important to you are goals such as working with people, helping others, and serving the community?" on a scale from 1 (*Extremely unimportant*) to 7 (*Extremely important*) [27].

Respondent demographics for the late-quarter survey in Spring 2024 can be seen in Table 3. A total of 341 participants completed this survey with an answer to the question about communal goal endorsement.

Table 3. Survey demographics in the Spring 2024 late-term survey, which included a question about communal goal endorsement (§6). Percentages in the **Total** column are based on **Race/Ethnicity** totals.

Race/Ethnicity	**Gender**		**Total**
(Check all that apply)	**Men**	**URG**	
Hispanic/Latino	101 (78%)	28 (22%)	129 (38%)
Black, African American, American Indian, or Alaskan Native	19 (82%)	4 (18%)	23 (7%)
Another race not listed here	113 (67%)	56 (33%)	169 (49%)
Prefer not to state	10 (50%)	10 (50%)	20 (6%)
Total	**243**	**98**	**341**

6.2 Results

Students in general reported a strong communal goal endorsement (mean ($\bar{x}$)=5.16, standard dev. (s)=1.44, median (M)=5 out of 7).

We did not observe a significant difference in communal goal endorsement between students who identified as Hispanic/Latino ($\bar{x} = 5.23, s = 1.31, M = 5$) and those who did not ($\bar{x} = 5.11, s = 1.52, M = 5$). Given the non-normal distribution of responses (Shapiro-Wilk test [44], $W = 0.91, p < 0.001$) and unequal variances between the two groups (Levene's test [11]; $W = 4.26, p = 0.04$), we used Welch's unequal variances t-test [51] to check for a difference in communal goal endorsements between the two groups. The test did not reveal a statistically significant difference ($t = 0.75, p = 0.45$). This is a deviation from previous findings [32].

We did observe that men were likely to report a significantly lower communal goal endorsement ($\bar{x} = 5.06, s = 1.42, M = 5$) than URG students ($\bar{x} = 5.42, s = 1.48, M = 5$). After confirming that responses from the two groups were homoscedastic (Levene's test; $W = 0.26, p = 0.61$), a Mann-Whitney U test [35] showed that the difference was statistically significant ($U = 9142.5, p = 0.01$). This is in keeping with previously reported results [9, 17, 27, 32].

A two-way analysis of variance did not suggest any significant interaction between the race and gender variables regarding their association with communal goal endorsement. We did, however, observe that non-male students who identified as Hispanic/Latino reported the highest median communal goal endorsements out of all groups at the intersection of race and gender.

Overall, our unexpected takeaway here is that targeting students' communal goal endorsements may not specifically impact Hispanic/Latino students in particular. However, it may have positive impacts in general, since the students overall appear to find communal goals to be important.

7 RQ2: Sense of belonging

We now turn to investigating how our students' sense of belonging changed with the introduction of SRC curricular elements.

7.1 Method

We measured sense of belonging using the 26-item scale validated by Moudgalya et al. [36]. The scale contains 4–6 items for each of the following constructs: *membership*, negative feelings of *acceptance*, positive feelings of *acceptance*, *affect*, *trust* in instructors or instructional materials, and *desire to fade*, i.e., to be inconspicuous. As suggested by Moudgalya et al., we first conducted an exploratory factor analysis (EFA) to validate the items belonging to each construct. Results of the EFA suggested that an item for *affect—In this computer science class, I feel calm—*was cross-loading on both the *affect* and *acceptance positive* factors. We decided to remove this item and conducted a Confirmatory Factor Analysis (CFA) with the remaining 25 items according to the factor structure reported in Moudgalya et al. The model indicators for the CFA were slightly lower than what was reported by Moudgalya et al: TLI = 0.850 (compared to 0.885); RMSEA = 0.098 (compared to 0.082). A new composite belonging score was computed using the factors scores resulting from the CFA—scores for the new belonging measurement ranged from -3.49 to 1.83 and is used throughout the rest of this paper.

For this research question, we administered surveys such that we can report on differences between *control and treatment terms* as well as changes *within treatment terms*, measured by surveys at multiple time points.

For our **control and treatment** analyses, Fall 2022 was treated as our Control term, i.e., no SRC-focused material was included in the studied courses. Spring 2023, Fall 2023, and Spring 2024 were our Treatment terms. All surveyed courses included some SRC-focused content.

For our **within treatment term** analyses, the Fall 2023 and Spring 2024 terms (i.e., the second year of our study) included multiple survey administrations per term: once early in the term, and once late in the term. This allowed us to measure the change in sense of belonging over the course of a single academic term that included SRC-focused curriculum.

7.2 Results

Results from both analyses—control vs. treatment terms, and within treatment terms—are presented below. As expected from our varied contexts (§3), results varied for different campuses.

7.2.1 Control vs. Treatment Terms. All courses in this analysis were first-year courses (either CS 0 or CS 1 at each campus). A given course was included only if it produced 20 or more responses in the Control Term and Treatment terms. (For those Treatment terms that included surveys at multiple time points, only the late-term surveys were considered, to facilitate comparison with the survey that was taken at a similar time point in the Control term.) NCE 3 was excluded from this analysis as a result of this filtering step—due to teaching assignments of the participating faculty, no course at that campus was given the survey in the Control term and at least one Treatment term. However, the resulting analysis still includes 277 students in the Control group and 418 students in the Treatment group, across the 5 remaining campuses.

Changes (or lack thereof) in sense of belonging for each of the remaining campuses are depicted in Figure 1.[3] Increases in median sense of belonging are visually apparent for the NCE 1, NCE 2, and NCE 4 campuses (see the paired box-and-whisker plots on the left of Figure 1). Recall that these are the campuses with *higher acceptance rates* and *no competitive CS enrollment policy*, and, with the exception of NCE 4, *a larger percentage of CS majors who are Hispanic/Latino* (Table 1). Students at these campuses appeared to experience an increase in their sense of belonging with the introduction of SRC coursework in the Treatment terms.

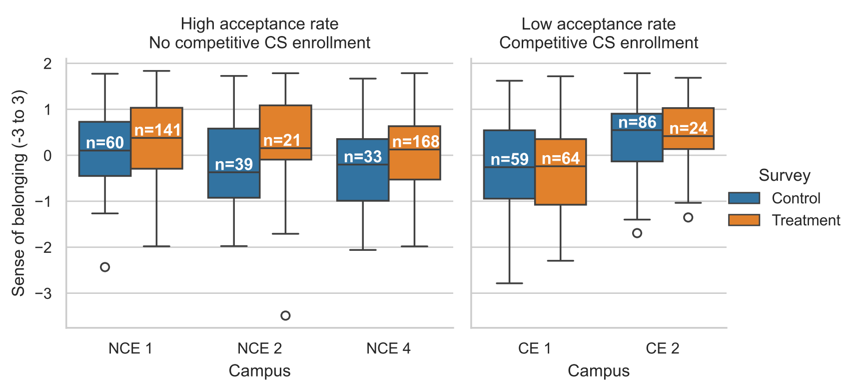

Fig. 1. Changes in sense of belonging from control to treatment terms varied by campus. Numbers printed within each box indicate the number of responses to that survey from that campus.

[3]Figure will include campus identifiers upon de-anonymisation.

Table 4. Results from a series of Mann-Whitney U tests for differences in sense of belonging between Control and Treatment terms (§7.2.1). Reported p-values reflect adjustments using a Bonferroni correction.

Competitive CS Enrollment?	Students	U	p	N (Control, Treatment)
No	All	17921	0.0117	132, 330
	Hispanic/Latino	4417	0.0162	74, 156
Yes	All	7395	0.1679	145, 88
	Hispanic/Latino	582	0.9048	49, 20

We used hypothesis testing to confirm this visual inspection statistically (Table 4). We used four non-parametric Mann-Whitney U [35] tests for differences in sense of belonging between Control and Treatment terms: one test for the campuses *without* competitive enrollment policies, one test for the campuses *with* competitive enrollment policies, and an additional test each looking only at students identifying as Hispanic/Latino in each group. A Bonferroni correction [7] was applied to account for the four comparisons, and significance of the adjusted p-values was decided at $\alpha = 0.05$.

For the campuses with *higher acceptance rates* and *no competitive CS enrollment policy* (NCE 1, NCE 2, and NCE 4), we observed a **statistically significant increase in students' sense of belonging** between the Control and Treatment terms, with a median increase from -0.13 in the Control term to 0.22 in the Treatment terms. This increase was slightly more pronounced for Hispanic/Latino students at these campuses (median increase from -0.13 in the Control term to 0.29 in the Treatment terms).

For the campuses with *lower acceptance rates* and *competitive CS enrollment policies* (CE 1 and CE 2), the test revealed no significant difference in students' sense of belonging between Control and Treatment terms. There was also no significant difference when we considered only the students identifying as Hispanic/Latino.

7.2.2 Within Treatment Terms. We omitted course sections that included fewer than 20 responses in both Early and Late term survey responses. Following this, we were left with responses from multiple course types, i.e., introductory CS (CS 0 or CS 1), and slightly more advanced second-year courses (CS 2). Therefore, this section presents results for each course type separately. Again, we grouped campuses by whether or not they have a competitive CS enrollment policy.

Since our surveys were anonymous, responses were not attributed to specific individuals. As a result, although some students took both the Early and Late surveys, we are unable to treat the Early and Late survey responses as paired samples, since we cannot say which response belongs to which students. We therefore use the unpaired Mann-Whitney U test to check for differences in reported sense of belonging Early in the term versus Late in the term.

For CS 0 and CS 1 courses, results largely mirrored what we saw in the Control/Treatment analysis presented in §7.2.1. We ran three Mann-Whitney U tests to test for differences in sense of belonging between Early and Late surveys for the following groups:

- All students at the campuses *without* competitive CS enrollment policies.
- Hispanic/Latino students at the campuses *without* competitive CS enrollment policies.
- All students at the campuses *with* competitive CS enrollment policies.

We did not conduct a hypothesis test for students identifying as Hispanic/Latino at CE 2 (the only campus with competitive CS enrollment in this analysis), since only 8 such students took the Early survey, and 7 took the Late survey.

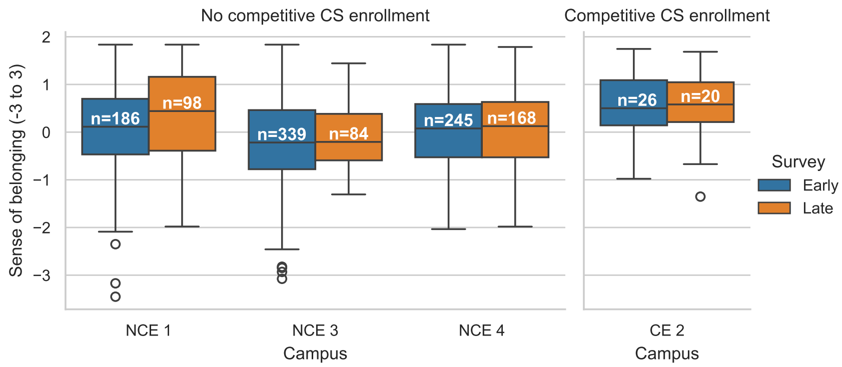

Fig. 2. Sense of belonging in CS 0 or CS 1 courses, in Early-term surveys (taken around week 3) and Late-term surveys (taken around 2 weeks before the end of the term).

NCE 2 and CE 1 are not present in this analysis because no CS 0 or CS 1 section at those campuses produced 20 or more responses in both the Early and Late survey, thus precluding comparisons. Bonferroni corrections were applied to account for the three comparisons, and adjusted p-value significance was decided at $\alpha = 0.05$.

Table 5. Results from a series of Mann-Whitney U tests for differences in sense of belonging between Early and Late surveys in CS 0 and CS 1 courses (§7.2.2). Reported p-values reflect adjustments using a Bonferroni correction.

Competitive CS Enrollment?	Students	*U*	*p*	N (Early, Late)
No	All	122399.5	0.0415	805, 370
	Hispanic/Latino	21826.5	0.0346	342, 149
Yes	All	247	1.000	26, 21
	Hispanic/Latino	*Not enough data*		7, 8

Hypothesis testing results are summarized in Table 5 and distributions of belonging scores for each campus can be seen in Figure 2. For the campuses *without a competitive CS enrollment policy* (NCE 1, NCE 3, NCE 4), hypothesis testing revealed a **statistically significant increase in sense of belonging** between Early and Late term surveys, for all students as well as for Hispanic/Latino students in particular. Inspecting the distributions in Figure 2 suggests that NCE 1 saw much of this increase. For the campus *with* a competitive enrollment policy (CE 2), there was no significant change in sense of belonging.

For CS 2 courses, we did not see a change in sense of belonging between Early and Late surveys for any group of campuses. NCE 1 is omitted from this analysis because its CS 2 course produced fewer than 20 responses in each survey, and NCE 4 is omitted because no CS 2 course took the survey at all at that campus.

8 RQ3: Impact on student perceptions of their learning

We consider the impact of our intervention on students' self-perceived academic skills in terms of traditionally valued technical content as well as social-technical skills related to communication with community members and contextualizing computing in a larger social context.

8.1 Method

In the Late surveys in the second year of our study (i.e., Fall 2023 and Spring 2024), students were asked to rate the degree to which their SRC and non-SRC assignments and projects supported their (a) technical computing knowledge, (b) ability to use CS to solve real-world problems, (c) ability to engage with and design a CS solution for a real community, and (d) individual agency and interests. The survey questions and a response means can be seen in Table 6. Responses ranged from -2 (*Not at all*) to 2 (*A lot*) for all questions.

Table 6. Student perceptions of their learning and agency for treatment terms Fall 2023 and Spring 2024.

	CS 0 or CS 1 (n=304)			CS 2 (n=267)		
To what degree do your assignments or projects help you do the following?	**Non-SRC**	**SRC**	**Diff.**	**Non-SRC**	**SRC**	**Diff.**
Develop technical vocabulary (e.g., knowing words like "conditional statements" or "loop")	1.24	1.54	$t = 506$ $p < 0.0118$	1.23	1.26	$t = 393$ $p = 1.000$
Develop programming skills (e.g., writing and reading code)	1.27	1.54	$t = 395$ $p = 0.0375$	1.19	1.37	$t = 368.5$ $p = 0.2669$
Understand how CS can help solve concerns in society	0.87	1.43	$t = 215.5$ $p < 0.0001$	0.62	1.22	$t = 173.5$ $p < 0.0001$
Use real-world data to solve CS problems	0.80	1.34	$t = 579.0$ $p = 0.0001$	0.41	1.13	$t = 141$ $p < 0.0001$
Communicate with people (outside of your class) in a real community about their concerns and explain how CS can help solve them	0.37	0.68	$t = 1069.5$ $p = 1.000$	0.12	0.54	$t = 189.5$ $p = 0.0127$
Design a CS solution for a real community	0.46	0.88	$t = 602$ $p = 0.0142$	0.17	0.78	$t = 148.5$ $p < 0.0001$
Use CS to solve problems you find interesting	0.94	1.14	$t = 677$ $p = 1.000$	0.71	0.86	$t = 334$ $p = 0.1609$
Give you choice in what to focus on or how to approach the assignments	0.86	1.08	$t = 607$ $p = 0.3626$	0.67	0.93	$t = 410$ $p = 1.000$

Diff. columns report p-values and test statistics for paired t-tests for differences between SRC and Non-SRC assignments. All p-values reflect adjustments with a Bonferroni correction, and cells highlighted in gray indicate that a significant difference was observed.

For each question in Table 6, we ran a hypothesis test to check for differences in student perceptions of the support offered by each type of assignment—similar to the analysis in §7, we did this separately for first-year courses (CS 0 and CS 1 courses) and CS 2 courses. A Bonferroni correction was applied within each course's family of tests to control the familywise error rate, and significance of the adjusted p-values was decided at $\alpha = 0.05$. We employed the Wilcoxon Signed Rank test [12], a non-parametric paired t-test, since the samples were not normally distributed and SRC and non-SRC responses came from the same individuals.

8.2 Results

Results are summarized in Table 6.

In both groups of courses, students felt that SRC assignments, to a greater degree than non-SRC assignments, helped them understand how they could use CS to address societal concerns, work with real communities to design computational solutions, and design a CS solution for a real community. In the earlier courses (CS 0 and CS 1), students also felt that SRC assignments better supported their learning of technical CS content, and in later courses (CS 2), students felt that SRC assignments better prepared them to communicate with people outside of their classes about concerns and how CS might address them.

For the most part, results were similar when looking at the perceptions of only those students who identified as Hispanic/Latino, i.e., **they felt that SRC assignments better supported their learning and agency than non-SRC assignments**. In the earlier courses, Hispanic/Latino students ($n = 132$) felt that SRC coursework helped them develop technical vocabulary ($t = 506, p_{adj.} = 0.0118$) and programming skills ($t = 395, p_{adj.} = 0.0376$), and to understand how CS can help address concerns in society ($t = 215.5, p_{adj.} < 0.0001$), use real-world data to solve CS problems ($t = 579, p_{adj.} = 0.0003$), and design CS solutions for real communities ($t = 602, p_{adj.} = 0.0142$). In the CS 2 course, Hispanic/Latino students ($n = 97$) felt that SRC coursework helped them understand how to use CS to solve concerns in society ($t = 173.5, p_{adj.} < 0.0001$), use real-world data to solve CS problems ($t = 141, p_{adj.} < 0.0001$), communicate with communities about CS solutions ($t = 189.5, p_{adj.} = 0.0127$), and design CS solutions for real communities ($t = 148.5, p_{adj.} < 0.0001$). Similar to overall results, in neither course did students identifying as Hispanic/Latino express the increased freedom of choice that was felt by the overall student sample with SRC assignments.

While these results are based on student responses about their perception of their learning, prior evaluations of courses developed as part of this work have shown that external measurements of learning outcomes (grades; success in follow-on courses) were also not sacrificed when incorporating socially responsible computing into early computing courses, and indeed showed some improvements [4].

9 RQ4: Other sources of student struggle

We sought to learn about sources of struggle for our students in early CS courses. This section presents a partial replication of findings from Salguero et al. [43], who found that Black, Hispanic/Latino, Native American, and Pacific Islander students were more likely than other students to report that *personal obligations* interfered with their learning in early CS courses.

9.1 Method

In the second year of our study, we used sub-scales corresponding to the factors *lack of confidence*, *in-class confusion*, and *personal obligations* from the survey published by Salguero et al. [43] to learn about other potential sources of struggle faced by our students. Questions were phrased as *To what degree did each of the following interfere with your ability to learn or complete the work for this course?*, and each factor included 3–4 items. Responses for each item ranged from 1 (*Not at all*) to 5 (*Significantly*). The questions were included in the Late surveys in Fall 2023 and Spring 2024. They were not included in the Early surveys since they asked the students to reflect on how the past academic term had gone. We used hypothesis tests to check for differences in levels of interference with learning reported by Hispanic/Latino students and other students.

9.2 Results

Overall results are summarized in Figure 3. We conducted three Mann-Whitney U tests to test for differences in reported levels of interference from *lack of confidence*, *in-class confusion*, and *personal obligations* for students who identified as

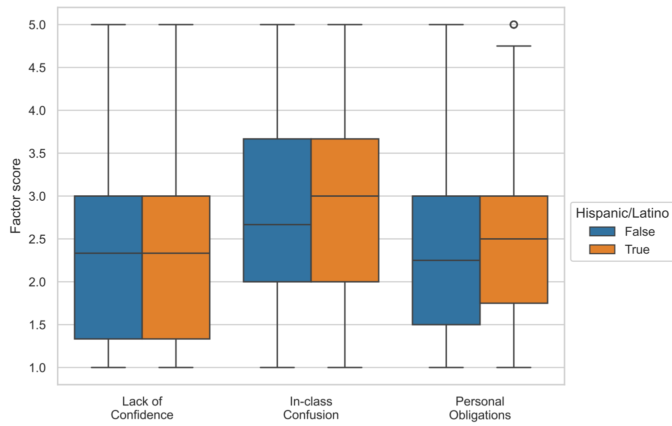

Fig. 3. Responses to questions about sources of struggle in CS courses. Responses for each factor—*Lack of confidence*, *In-class confusion*, and *Personal obligations*—were obtained by averaging the items associated with that factor. $n = 729$, 37% Hispanic/Latino.

Hispanic/Latino and those who did not. A Bonferroni correction was applied to account for the three comparisons. A weakly significant Mann-Whitney U test suggested that reported levels of interference from *Personal obligations* were higher for our Hispanic/Latino students than other students ($U = 70798.5, p_{adj.} = 0.05$). Hispanic/Latino students did *not* report different levels of interference from in-class confusion or a lack of confidence than other students.

As described by Salguero et al. [43], the composite factor *Personal obligations* includes the items *requirements for other classes*; *illness*; *family obligations*; *work obligations*; and *social/personal obligations*. In addition to averaging the items into a single factor like Salguero et al. [43], we unpacked the factor further to learn *which* personal obligations appeared to affect our students most.

For each of the five items within the *Personal obligations* factor, we conducted a hypothesis test to check for differences between students who identified as Hispanic/Latino and those who did not. Bonferroni corrections were applied to account for the five comparisons. We found that Hispanic/Latino students reported significantly higher levels of *family obligations* (Mann-Whitney U-test; $U = 71083.5, p_{adj.} = 0.0192$) and *work obligations* (Welch's unequal variances t-test; $t = 3.4885, p_{adj.} = 0.0026$).

We did not observe this effect when the analysis was limited to the more restrictive campuses with competitive enrollment policies—for all factors, there were no differences in levels of reported interference from Hispanic/Latino students and other students.

10 Final remarks

In this section, we discuss the implications of our findings and threats to the validity of our results. We close by considering some lessons learned and directions for future work.

10.1 Discussion of results

In general, we saw positive results at the campuses *without* competitive CS enrollment policies. All of these campuses are designated as Hispanic-Serving Institutions, have relatively high attrition rates for "URM"-designated students (including Hispanic/Latino students), and two of them (NCE 1 and NCE 2) have high percentages of CS majors who identify as Hispanic/Latino. All of this suggests that our curricular interventions are having positive impacts. The following sections discuss implications or explanations for each of our research questions' results.

10.1.1 RQ1. Communal goal endorsements. Communal goal endorsements were relatively high for all our students, and URG students reporting significantly higher communal goal endorsements than men. Prior research has reported that students of color (including Hispanic/Latino students) and women tend to report higher communal goal endorsements than White students and men (e.g., [10, 16, 32]). When considering factors that impact historically marginalized students' sense of belonging in computing, women and students of color are sometimes considered together with shared characteristics as a minoritized group. These types of simplifications can be problematic, glossing over important specific challenges faced by subgroups with intersectional identities [42]. Our findings further the argument that a one-size-fits-all approach to promoting a sense of belonging among all groups who have been historically marginalized in computing is an over-simplified solution.

Additionally, illustrating the importance of considering intersectional identities, we observed that non-male Hispanic/Latino students reported the highest median communal goal endorsement compared to other groups at the intersection of race and gender. Given the broad appeal to all students, we propose that attending to this orientation is likely to be a fruitful strategy for strengthening students' senses that they belong in computing.

10.1.2 RQ2. Sense of belonging. We saw improvements in students' sense of belonging in computing when our institutions embraced an intervention to include intentionally-designed socially responsible computing assignments in early computing courses (§7). In particular, these improvements were present and statistically significant for students in the CS programs with inclusive selection criteria and large Hispanic/Latino populations. This increase in sense of belonging at our most inclusive institutions was also statistically significant for Hispanic/Latino students in particular.

We were at first surprised by the relative stability of student sense of belonging at the two institutions with competitive enrollment policies (CE 1 and CE 2). However, consider that students at those two institutions have been through significant filtering criteria like AP courses and scores[4] and university GPA requirements, it would make sense that they have a relatively stable sense of self in the computing discipline. Nguyen and Lewis [38] found that first-year students in CS departments with competitive enrollment policies tend to report a lower sense of belonging in computing. We observed both this and the opposite (see Figure 1)—at one institution with competitive CS enrollment (CE 1), we observed an average *lower* sense of belonging than other institutions, while at the other institution with competitive CS enrollment (CE 2), we observed a *higher* sense of belonging than other institutions. However, for students at both institutions, sense of belonging appeared to be relatively stable.

This interaction between institutional contexts and the malleability of sense of belonging in a discipline ought be studied further. Would results from prior research on recruitment and retention of Hispanic/Latino students or underrepresented students look different if such studies were replicated at institutions with different demographics and enrollment policies? Future work may want to run such replication studies to confirm prior findings or add context to these findings. Results from these studies will better guide us in developing appropriate interventions to ensure Hispanic/Latino and underrepresented students' success.

Overall, we view it as a success that students at our least restrictive institutions (in most cases, with large Hispanic/Latino populations) appeared to have experienced positive outcomes from our curricular interventions.

[4]Which mirror, in many cases, filters based on household incomes and race.

Our findings also replicated prior results that show that students who identify as men tend to have a higher sense of belonging in computing than those who do not. When considering the Late surveys in Fall 2023 and Spring 2024, a Mann-Whitney U test indicated that sense of belonging was significantly higher for men than it was for students not identifying as men ($U = 62478.5, p = 0.021$). Similarly, we observed that a higher sense of belonging correlates with the intention to enroll in a follow-on computing course. When considering both Fall 2023 and Spring 2024 data, Kruskal-Wallis H tests showed that there was a statistically significant difference in sense of belonging by level of interest in taking future CS courses ($H = 97.23, p < 0.0001$) and, for those who were so declared, intention to remain in the CS major or minor ($H = 129.10, p < 0.0001$). Interest in future CS coursework was, as expected, higher as belonging scores increased.

10.1.3 RQ3. Student perceptions of their learning. We found that in general, students felt that SRC assignments helped them develop skills to use computing to address societal concerns, work with real communities, and exercise more choice in how they approached coursework (§8). Students' views on benefits to their learning of technical content were mixed—they reported higher perceived benefits in earlier courses (CS 0 and CS 1), but no difference CS 2. It is likely that CS 2 students' self-assessed command of "technical vocabulary" and "programming skills" were sufficiently advanced already.

10.1.4 RQ4. Other sources of student struggle. Finally, we observed that students identifying as Hispanic/Latino were more likely than other students to report that work and family obligations interfered with their learning in early CS courses (§7). This effect was primarily observed at the less restrictive campuses with high acceptance rates and no competitive enrollment policies. This result underscores the need for future work to examine the role that pedagogical choices (beyond curriculum) play in the student experience and particularly its impact on broadening participation and improving retention and student success. Examples of such choices include flexible due dates, dropped lowest scores, and other measures that allow students the flexibility needed to achieve a course's learning objectives while managing work or family obligations.

It is worth noting that our restrictive campuses also serve students who transfer to our institutions in their third years after completing introductory coursework at a community college. This transfer student population tends to have a higher percentage of Hispanic/Latino students, many of whom have not had prior computing experiences in secondary school. It is possible that the interventions described in this paper would have the same positive impacts reported here for their early computing courses at a four year institution; however, our current focus has been in CS courses in the first two years of a four year degree.

10.2 Threats to validity

In this section we acknowledge limitations and threats to validity, and describe mitigations where appropriate.

10.2.1 Instrument validity. For the most part, our surveys used scales that have been validated and used in previous computing education research studies with students similar to ours (post-secondary first-year students at public universities). The one exception to this is the scale used to measure students' self-perceptions of their experiences (Table 6). Therefore, we have reason to believe that our study has generally high instrument validity.

We reported on measurements of students' communal goal endorsements using a single question from Henderson et al. [27] (see §6). Given that the question was added to an already-large survey, and that participants were being surveyed at multiple time points, we were wary of inducing survey fatigue. Henderson et al. reported similar concerns, so following their example we opted to use a single communal-coded question. We acknowledge that this measure would be made stronger with an accompanying agentic-coded question—this has now been added for future iterations of the survey.

10.2.2 Internal validity. We used statistical tests to study various aspects of students' experiences, perceptions, and priorities. Each such test carries with it some risk of Type I error, i.e., the risk of a false positive conclusion. We have mitigated this risk by using Bonferroni corrections throughout to control the error rate when conducting families of statistical tests. As a result, we do not believe this to be a significant threat to the validity of our results.

It is possible that the changes we have observed were a result of factors beyond our curricular interventions. Students' perceptions of computing and themselves are naturally influenced by forces within and without the classroom. Our experimental design (control and treatment groups and, in the case of RQ2, surveys at multiple time points) helps to mitigate this threat.

In RQ1, we saw that communal goal endorsements trended relatively high for our student sample. The measurement took place at the end of the Spring 2024 term, which included SRC-focused curricular content. It is possible that communal goal endorsements were not originally high for our students on average, but rather *increased* as a result of our intervention. We cannot say for sure since we did not think to measure communal goal endorsements in earlier surveys.

10.2.3 External validity. Our work was conducted at six campuses in Anonymous State that varied in a number of dimensions (Table 1). As such, our study constitutes a conceptual replication of results that were observed at multiple participating campuses, as well as results that have been observed and reported from other institutions. Of key importance are the results that were *not* observed at all campuses, allowing us to gird our results with important contextual information that was pertinent to specific research questions.

10.2.4 Ecological validity. Our study protocol required informed consent from students before they could provide survey responses. As a result, students were made aware of the high-level goals of our work and the fact that they were learning from an "experimental" curriculum. This could have affected their responses to survey questions related to the SRC assignments in particular.

Another potential threat to ecological validity is that in January 2024, faculty at all six campuses (as well as all other campuses in the Anonymous University System) withheld labor and went on organized strike. This involved cancelling classes and not doing other class-related tasks like grading or responding to email and class forums. Though the strike lasted one day, students and faculty were aware of the planned action from the beginning of the term. We are unsure how this would affect results, except to say that it was certainly a departure from the "normal" learning environment.

10.3 Future work

Addressing the diverse needs of students calls for structural changes within educational institutions. We plan to extend this work to more deeply understand our individual sites' student needs. Specifically, we aim to develop a more robust model of student profiles to understand the types of journeys experienced by our students in their early computing courses. For example, we saw that Hispanic/Latino students were more likely to report that work or family obligations interfered with their learning (§9). We will focus on how students' obligations interact with faculties' perspectives and pedagogical choices to create more or less inclusive environments. We will build on existing scholarly work on inclusive climates that suggests that policies like equitable grading using flexible deadlines [49], using more low-stakes assessments as opposed to fewer high-stakes ones, and allowing re-submissions to demonstrate mastery [8, 15] lead to more equitable course outcomes for students. We intend to lean into these strategies and, as we have done in this paper, understand the impacts for students in varying institutional contexts. One immediate question is how the effect of our curricular intervention would be mediated by pedagogical policies related to deadlines, grading, and classroom practices.

Our work also included a faculty learning community that ran monthly for the duration of our two-year study. Participants (that is, faculty whose courses are represented in this research) learned about assets-based pedagogical frameworks and culturally relevant pedagogy, and had access to like-minded faculty who were trying to make similar improvements to their computing courses. We aim to study the extent to which participation in this learning community translated into impacts on sense of belonging, learning, and agency.

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References

[1] 2021. The Anonymous State Computer Science Access Report. (2021).

[2] Amy Allen. 2005. Feminist perspectives on power. https://plato.stanford.edu/entries/feminist-power/.

[3] Christine Alvarado, Gustavo Umbelino, and Mia Minnes. 2018. The persistent effect of pre-college computing experience on college CS course grades. *ACM Inroads* 9, 2 (April 2018), 58–64. https://doi.org/10.1145/3210551

[4] Anonymous Authors. 2024. An Anonymous Curricular Initiative Paper. In *Proceedings of a Conference*. Association for Computing Machinery, New York, NY, USA.

[5] Austin Cory Bart, Ryan Whitcomb, Dennis Kafura, Clifford A. Shaffer, and Eli Tilevich. 2017. Computing with CORGIS: Diverse, Real-world Datasets for Introductory Computing. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*. ACM, Seattle Washington USA, 57–62. https://doi.org/10.1145/3017680.3017708

[6] Aimee L. Belanger, Mansi P. Joshi, Melissa A. Fuesting, Erica S. Weisgram, Heather M. Claypool, and Amanda B. Diekman. 2020. Putting Belonging in Context: Communal Affordances Signal Belonging in STEM. *Personality and Social Psychology Bulletin* 46, 8 (2020), 1186–1204. https://doi.org/10.1177/0146167219897181 arXiv:https://doi.org/10.1177/0146167219897181 PMID: 31928327.

[7] Yoav Benjamini and Yosef Hochberg. 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal statistical society: series B (Methodological)* 57, 1 (1995), 289–300.

[8] BENJAMIN S. BLOOM. 1984. The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring. *Educational Researcher* 13, 6 (1984), 4–16. https://doi.org/10.3102/0013189X013006004 arXiv:https://doi.org/10.3102/0013189X013006004

[9] Bo Brinkman and Amanda Diekman. 2016. Applying the Communal Goal Congruity Perspective to Enhance Diversity and Inclusion in Undergraduate Computing Degrees. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education (SIGCSE '16)*. ACM. https://doi.org/10.1145/2839509.2844562

[10] Bo Brinkman and Amanda Diekman. 2016. Applying the communal goal congruity perspective to enhance diversity and inclusion in undergraduate computing degrees. In *Proceedings of the 47th ACM technical symposium on computing science education*. 102–107.

[11] Morton B. Brown and Alan B. Forsythe. 1974. Robust Tests for the Equality of Variances. *J. Amer. Statist. Assoc.* 69, 346 (June 1974), 364–367. https://doi.org/10.1080/01621459.1974.10482955

[12] WJ Conover. 1999. *Practical nonparametric statistics*. John Wiley & Sons, Inc.

[13] KW Crenshaw. 1989. Demarginalizing the intersection of race and sex: A black feminist critique of antidiscrimination doctrine (pp. 139–168). In *University of Chicago legal forum*.

[14] Kalisha Davis, Shana V. White, Dinah Becton-Consuegra, and Allison Scott. 2021. *Culturally Responsive-Sustaining Computer Science Education: A Framework*. Technical Report. Kapor Center. https://www.kaporcenter.org/equitablecs/

[15] Adrienne Decker, Stephen H. Edwards, Brian M. McSkimming, Bob Edmison, Audrey Rorrer, and Manuel A. Pérez Quiñones. 2024. Transforming Grading Practices in the Computing Education Community. In *Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1* (Portland, OR, USA) *(SIGCSE 2024)*. Association for Computing Machinery, New York, NY, USA, 276–282. https://doi.org/10.1145/3626252.3630953

[16] A. B. Diekman, E. K. Clark, A. M. Johnston, E. R. Brown, and M. Steinberg. 2011. Malleability in communal goals and beliefs influences attraction to stem careers: Evidence for a goal congruity perspective. *Journal of Personality and Social Psychology, 101(5), 902–918. https://doi.org/10.1037/a0025199* (2011).

[17] Amanda B. Diekman, Mia Steinberg, Elizabeth R. Brown, Aimee L. Belanger, and Emily K. Clark. 2016. A Goal Congruity Model of Role Entry, Engagement, and Exit: Understanding Communal Goal Processes in STEM Gender Gaps. *Personality and Social Psychology Review* 21, 2 (April 2016), 142–175. https://doi.org/10.1177/1088868316642141

[18] Antonio Duran and Anne-Marie Núñez. 2021. Food and Housing Insecurity for Latinx/a/o College Students: Advancing an Intersectional Research Agenda. *Journal of Hispanic higher education* 20, 2 (2021), 134–148.

[19] Mica Estrada, Myra Burnett, Andrew G. Campbell, Patricia B. Campbell, Wilfred F. Denetclaw, Carlos G. Gutiérrez, Sylvia Hurtado, Gilbert H. John, John Matsui, Richard McGee, Camellia Moses Okpodu, T. Joan Robinson, Michael F. Summers, Maggie Werner-Washburne, and MariaElena Zavala. 2017. Improving Underrepresented Minority Student Persistence in STEM. In *CBE—Life Sciences Education*.

[20] M. Estrada, A. Eroy-Reveles, and J. Matsui. 2018. The Influence of Affirming Kindness and Community on Broadening Participation in STEM Career Pathways. In *Social Issues and Policy Review*.

[21] J. Flapan and J Margolis. 2019. *Plugging Into Power: What Communities Can Do to Democratize Computer Science Education: "Mobilizing Communities for Leadership in the High Tech Sector in the Los Angeles Region: Transforming Schools and Neighborhoods Through Digital Inclusion."*. Technical Report. UCLA Center for Transformation of School Conference.

[22] Gina A. Garcia, Anne-Marie Núñez, and Vanessa A. Sansone. 2019. Toward a Multidimensional Conceptual Framework for Understanding "Servingness" in Hispanic-Serving Institutions: A Synthesis of the Research. *Review of Educational Research* 89, 5 (2019), 745–784. https://doi.org/10.3102/0034654319864591 arXiv:https://doi.org/10.3102/0034654319864591

[23] Geneva Gay. 2002. Preparing for Culturally Responsive Teaching. *Journal of Teacher Education* 53, 2 (March 2002), 106–116. https://doi.org/10.1177/0022487102053002003

[24] Geneva Gay. 2018. *Culturally responsive teaching: Theory, research, and practice*. teachers college press.

[25] Carol Goodenow. 1993. The psychological sense of school membership among adolescents: Scale development and educational correlates. *Psychology in the Schools* 30, 1 (1993), 79–90. https://doi.org/10.1002/1520-6807(199301)30:1<79::AID-PITS2310300113>3.0.CO;2-X arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/1520-6807%28199301%2930%3A1%3C79%3A%3AAID-PITS2310300113%3E3.0.CO%3B2-X

[26] Mark Guzdial. 2016. *Learner-Centered Design of Computing Education: Research on Computing for Everyone*. Springer International Publishing. https://doi.org/10.1007/978-3-031-02216-6

[27] Heather L. Henderson, Brittany Bloodhart, Amanda S. Adams, Rebecca T. Barnes, Melissa Burt, Sandra Clinton, Elaine Godfrey, Ilana Pollack, Emily V. Fischer, and Paul R. Hernandez. 2022. Seeking congruity for communal and agentic goals: a longitudinal examination of U.S. college women's persistence in STEM. *Social Psychology of Education* 25, 2–3 (May 2022), 649–674. https://doi.org/10.1007/s11218-021-09679-y

[28] S. Hurtado and D. F. Carter. 1997. Effects of college transition and perceptions of the campus racial climate on Latino college students' sense of belonging. In *Sociology of education*.

[29] Michael J Johnson, Francisco Enrique Vicente Castro, Betsy DiSalvo, and Kayla DesPortes. 2023. Chronicles of Exploration: Examining the Materiality of Computational Artifacts. In *Proceedings of the 2023 ACM Conference on International Computing Education Research - Volume 1* (Chicago, IL, USA) *(ICER '23)*. Association for Computing Machinery, New York, NY, USA, 29–47. https://doi.org/10.1145/3568813.3600132

[30] Gloria Ladson-Billings. 1995. Toward a theory of culturally relevant pedagogy. *American educational research journal* 32, 3 (1995), 465–491.

[31] T. Lamont Strayhorn. 2008. Sentido de pertenencia: A hierarchical analysis predicting sense of belonging among Latino college students. In *Journal of Hispanic Higher Education*. 301–320.

[32] Colleen Lewis, Paul Bruno, Jonathan Raygoza, and Julia Wang. 2019. Alignment of Goals and Perceptions of Computing Predicts Students' Sense of Belonging in Computing. In *Proceedings of the 2019 ACM Conference on International Computing Education Research*. ACM, Toronto ON Canada, 11–19. https://doi.org/10.1145/3291279.3339426

[33] Colleen M. Lewis. 2017. *Good (and Bad) Reasons to Teach All Students Computer Science*. Springer International Publishing, 15–34. https://doi.org/10.1007/978-3-319-54226-3_2

[34] Janet Lowe and Vernon Gayle. 2007. Exploring the work/life/study balance: the experience of higher education students in a Scottish further education college. *Journal of further and Higher Education* 31, 3 (2007), 225–238.

[35] Henry B Mann and Donald R Whitney. 1947. On a test of whether one of two random variables is stochastically larger than the other. *The annals of mathematical statistics* (1947), 50–60.

[36] Sukanya Kannan Moudgalya, Chris Mayfield, Aman Yadav, Helen H. Hu, and Clif Kussmaul. 2021. *Measuring Students' Sense of Belonging in Introductory CS Courses*. Association for Computing Machinery, New York, NY, USA, 445–451. https://doi.org/10.1145/3408877.3432425

[37] National Science Foundation. 2023. Demographic Attributes of S&E Degree Recipients: S&E Degrees by Sex. https://ncses.nsf.gov/pubs/nsb20223/demographic-attributes-of-s-e-degree-recipients#s-e-degrees-by-sex Accessed: 2024-09-19.

[38] An Nguyen and Colleen M. Lewis. 2020. Competitive Enrollment Policies in Computing Departments Negatively Predict First-Year Students' Sense of Belonging, Self-Efficacy, and Perception of Department. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education*. ACM, Portland OR USA, 685–691. https://doi.org/10.1145/3328778.3366805

[39] Anne-Marie Nuñez. 2009. A critical paradox? Predictors of latino students' sense of belonging in college. *Journal of diversity in higher education* 2, 1 (2009), 46.

[40] J. Peckham, L. L. Harlow, D. A. Stuart, B. Silver, H. Mederer, and P. D. Stephenson. 2007. Broadening participation in computing: issues and challenges.. In *ACM SIGCSE Bulletin*. 9 – 13.

[41] Katherine Rainey, Melissa Dancy, Roslyn Mickelson, Elizabeth Stearns, and Stephanie Moller. 2018. Race and gender differences in how sense of belonging influences decisions to major in STEM.. In *International Journal of STEM Education*.

[42] Yolanda A Rankin, Sheena Erete, Jakita O Thomas, and Nichole Pinkard. 2024. The Choice is Yours: Intersectional Studies versus Studies of Intersectional Populations in Computing Education Research. In *Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1*. 1098–1104.

[43] Adrian Salguero, William G. Griswold, Christine Alvarado, and Leo Porter. 2021. Understanding Sources of Student Struggle in Early Computer Science Courses. In *Proceedings of the 17th ACM Conference on International Computing Education Research* (Virtual Event, USA) *(ICER 2021)*. Association for Computing Machinery, New York, NY, USA, 319–333. https://doi.org/10.1145/3446871.3469755

[44] S. S. Shapiro and M. B. Wilk. 1965. An Analysis of Variance Test for Normality (Complete Samples). *Biometrika* 52, 3/4 (Dec. 1965), 591. https://doi.org/10.2307/2333709

[45] E. Soep, C. Lee, S. Wart, and T. Parikh. 2021. Code for What.. In *Popular Culture and the Civic Imagination: Case Studies of Creative Social Change*. (pp. 89–99). https://doi.org/10.18574/nyu/9781479891252-008

[46] Justin M. Sprung and Anna Rogers. 2021. Work-life balance as a predictor of college student anxiety and depression. *Journal of American college health* 69, 7 (2021), 775–782.

[47] Leslie S. Stratton, Dennis M. O'Toole, and James N. Wetzel. 2008. A multinomial logit model of college stopout and dropout behavior. *Economics of education review* 27, 3 (2008), 319–331.

[48] Madalina Tanase. 2020. Is good teaching culturally responsive? *Journal of Pedagogical Research* 4, 3 (Sept. 2020), 187–202. https://doi.org/10.33902/jpr.2020063333

[49] Frank Vahid, Ashley Pang, and Kelly Downey. 2023. Towards Grading for Equity in a Large CS1 Class: An Experience with Flexible Deadlines and Resubmissions. In *Proceedings of the 2023 Conference on Innovation and Technology in Computer Science Education V. 2* (Turku, Finland) *(ITiCSE 2023)*. Association for Computing Machinery, New York, NY, USA, 646. https://doi.org/10.1145/3587103.3594200

[50] S. Vakil. 2018. Ethics, identity, and political vision: Toward a justice-centered approach to equity in computer science education. In *Harvard Educational Review*. 26–52.

[51] B. L. WELCH. 1947. The generalization of 'student's' problem when several different population varlances are involved. *Biometrika* 34, 1–2 (1947), 28–35. https://doi.org/10.1093/biomet/34.1-2.28

[52] Kyle M. Whitcomb and Chandralekha Singh. 2021. Underrepresented minority students receive lower grades and have higher rates of attrition across STEM disciplines: A sign of inequity?. In *International Journal of Science Education*. 1054–1089.

[53] Melissa R. Witkow, Virginia Huynh, and Andrew J. Fuligni. 2015. Understanding Differences in College Persistence: A Longitudinal Examination of Financial Circumstances, Family Obligations, and Discrimination in an Ethnically Diverse Sample. *Applied developmental science* 19, 1 (2015), 4–18.

[54] Tara J. Yosso. 2005. Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education* 8, 1 (2005), 69–91. https://doi.org/10.1080/1361332052000341006 arXiv:https://doi.org/10.1080/1361332052000341006

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