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Taking the Next Course: Barriers and Facilitators Reported by Computer Science Majors

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Taking the Next Course: Facilitators and Barriers Reported by Computer Science Majors

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Abstract

This research paper studies barriers to students continuing in undergraduate computing programs. On the journey to a computing profession, every course has the potential to be an off-ramp away from students' goals. Every student who leaves a computing degree has a last class they took before not continuing, and a reason they didn't continue. Based on qualitative analysis of open-ended questions in surveys of students in eight undergraduate computer science and engineering (CSE) courses, we identify common barriers students anticipate, and learn what encourages them to persist onto the next CSE course. For example, even for students within the major, a commonly reported barrier was the perceived inability to enroll in their next computing course due to unclear enrollment systems and requirements. We disaggregate the data by three demographic categories—race/ethnicity, gender, and admissions-type—to understand potential disparate impacts of CSE majors at our large, research-intensive university. Solutions to the reported barriers faced by students may include student-focused interventions, policy and programmatic changes at the department level, and broader institutional or external support. **Keywords**: 5.b.vii. Computer science, 10.f. Retention, 3. Diversity

I. Introduction

Every student who decides to leave a computing degree has a last class they took before not continuing, and a reason they did not continue. In this work, we analyze survey data to understand student motivation in choosing whether to continue in their computing degree at our university. We study these responses through the lens of the social and institutional experiences of students. Notably, many of these factors are determined by policies set at the university level – like course registration systems and enrollment policies – and will require coordinated efforts across departments to change.

We analyzed 1428 survey responses of Computer Science and Engineering (CSE) majors from eight CSE courses at a large, research-intensive university located in the United States. Five questions about the student experience in the current course and their plans for the next course were embedded into larger surveys administered in each of the participating courses. In this paper, we focus on student responses to the following survey questions: "*What are barriers that might prevent you from taking the next course in this sequence?*" and "*What makes you feel good about your plans to take the next course in this sequence?*" Each of the participating courses serves as a prerequisite course for at least one subsequent course (for example: Intro to CS I is a prerequisite for Intro to CS II).

We address the following research question:

RQ: What barriers and facilitators do undergraduate students anticipate that may prevent or encourage them to continue in their CSE studies?

We use qualitative analysis techniques to answer this research question, using the dataset of open-ended survey responses and disaggregating based on demographic categories of the student respondents. Uncovering the primary concerns expressed by students about their progress, along with the factors that facilitate their success, we envision solutions that undergraduate programs and institutions can deploy and hypothesize on what effects those might have on student self-efficacy and success.

II. Related Work

A. Retention in Undergraduate STEM

Retention in computing majors is a challenge for meeting the demand for educated tech professionals and for broadening participation in the field [22], [18]. To address this challenge, Computer Science Education Research (CER) studies the factors that contribute to student decisions to persist in or leave a computing major. Seminal work on retention in the sciences found that students who did and did not leave their major were very similar students: there was little difference in grades or their feelings towards STEM; instead, it was primarily the competitive atmosphere that drove students (disproportionately women and students from groups historically minoritized in STEM disciplines) to leave [33]. Other barriers to retention in computing identified in prior work include varying levels of prior programming experience, student learning skills, and defensive (rather than collaborative) climate [34], [2], [16], [3], [13]. The relationship between student motivation and persistence is less clear: some work finds motivation and engagement are major factors associated with the success or retention of students (e.g. [16], [17], [8]), while others (e.g. [31]) do not.

B. Disparate Impacts

With persistent lack of diversity in the tech field, studies of undergraduate retention in computing must take into account the specific experiences of students from groups historically underrepresented in this discipline. Researchers observed gender differences in student behavior in undergraduate classes [1]; more sources of stress or factors interfering with their performance in courses among women, Black, Latinx, Native American and Pacific Islander, and transfer students [28]; racial/ethnic differences in enrollment patterns [35]; evidence that Black college students' academic self-efficacy may be influenced by their institutional context [11]; and differences in sense of belonging related to intersectional identities [6]. In this work, we use demographic information about students to disaggregate survey responses and analyze student experiences.

C. Proposed Solutions

Existing proposed solutions to broadening participation have sometimes focused on systemic and institutional changes, and sometimes on student support and coaching. The Exploring CS program [14] proposes curricular revision and efforts to improve access to K-12 CS education to increase the preparation of all students as they move to higher education. Nguyen and Lewis [26] find that some of the competitive major enrollment policies put in place in undergraduate departments overwhelmed with demand are negatively correlated with sense of belonging for students who do not have pre-college CS experience. Lehman et al. [19] observe that students' social contexts in computing are key to their persistence in computing majors. Indeed, other aspects of [their] larger research project have found that "socialization specifically in the computing context (e.g., with computing peers and the computing department-at-large) is particularly relevant to other desirable outcomes for computing students". Class design and pedagogy that may promote this social context include collaborative learning [27], pair programming [9], interest-based CS0 classes [15], and active learning strategies like peer instruction [29]. Student support services include near-peer mentoring (e.g. [23], [25]) and interventions to impact students' computing identify and perceptions of computer science [32]. In this work, we learn from students' self-reported barriers and facilitators for continuing in their computing studies to draw suggestions for institutional, department-level, and student-level approaches to support student persistence.

III. Methods

A. Institutional Context

At our large, public, research-intensive university, there are approximately 2000 undergraduate CSE majors. Many students in other majors also take CSE courses. Enrollments in undergraduate CSE courses are roughly 10,000 unique students each academic year. To meet student interest in CSE courses, many core courses are offered in multiple sections every term. Nonetheless, enrollment pressures persist, with many popular classes seeing long waitlists at various stages of the enrollment process. Most undergraduate CSE majors are expected to take eight foundational courses within their first two years. These eight CSE courses, which range from programming to systems and discrete math, were the focus of this project. Section sizes for these courses range from 48 to 395 students per section. Since these classes are foundational for many related disciplines, enrollments in these courses is mixed between CSE majors and nonmajors. This project focuses on the experiences and sentiments of CSE majors.

B. Data Collection

Surveys were administered in eight CSE courses: two sections of Intro to CS I, Intro to CS II, Accelerated Intro to CS, Basic Data Structures, Discrete Math I, Discrete Math II, Computer Organization and Systems Programming, and Advanced Data Structures. Survey questions as well as a template including all questions were provided to each participating course and administered by the instructors of the course, according to the research protocol (reviewed by our IRB). Instructors were asked to administer the survey *at least twice* during the term, but some offered the surveys to students three or more times (integrated with course assessments). Surveys were administered through a mix of Google Forms and learning management system (LMS) platforms like Canvas.

After the term, a university analyst added demographic attributes (race/ethnicity, gender, and admit type) based on university records and then assigned a participant ID to each student so that the responses were stored in a de-identified format. As part of this process, 116 survey responses were removed due to mis-typed or incomplete student ids in the responses. Of the total enrollment of 3429 across the eight sections, there were 2753 unique student-course respondents, an overall response rate of 85%. Some students were enrolled in multiple classes, so we separate responses for each of the different courses in which each student enrolled. Restricting to CSE majors, there are 660 CSE majors who responded at least once in at least one their courses, of a total enrollment of 732 CSE majors among these courses, a 90% response rate.

We use demographic categories based on the available institutional metrics and categories. Race/ethnicity is reported as "Asian/Asian-American" (A), "Black or African-American" (B), "Hispanic, Chicano, Latino or Spanish" (H), "White/Caucasian" (W), "Not Given or Decline to State" (D). The number of American Indian/Alaska Native respondents was too low to report without risk of re-identification. Gender is reported as Female (F), Male (M), and X; where F includes trans female, M includes trans male, and X includes individuals who identify as non-binary or other gender identity. The admit type categories are NFRS (New High School Admit) and TRAN (Community College or University Transfer).

C. Qualitative Coding

We focus on two open-ended questions in the survey:

- *What makes you feel good about your plans to take the next course in this sequence?* [Facilitators]
- *What are barriers that might prevent you from taking the next course in this sequence?* [Barriers]

Two researchers on the team coded survey responses to these questions by CSE majors in the eight participating CSE classes. A cyclical and multi-stage process was used to derive codes from the survey responses. Once the codebook was established for these codes, axial coding was used to categorize the codes of facilitators and barriers expressed by CSE majors in these classes. One of our motivations in this analysis is to make principled suggestions about which program improvements we might pursue to improve the student experience to enable persisting through undergraduate computing studies. To that end, our axial coding for facilitators was designed to be descriptive, finding commonalities in student experience that contributed to their confidence, whereas the axial coding for barriers was designed around potential categories of *solutions* to the barriers students faced. So, for example, since we would address a barrier about *grades* with some kind of *Academic Support*, that solution category is used for that code. These categorization decisions are informed by institutional context, and are an important component of our results and analysis.

IV. Results and Discussion: Facilitators and Barriers

The full codebook is provided in the supplemental materials.[1] There are 18 codes related to facilitators and 22 codes related to barriers. Tables I and II summarize the codebook, organized by the nine categories yielded by axial coding. The two codes *no-barriers* and *no-answer* are worth distinguishing: *no-barriers* indicates a positive assertion by the student that they do not expect any barriers to them continuing, where *no-answer* indicates a blank response or a response like “I don’t know”. Some codes appear both in the Facilitators and the Barriers data, with different interpretation: for example, *prep* coded a response to the barriers question when a student said they didn’t feel adequately prepared to succeed in their next class, and it coded a response to the confidence question when the student reflect on the extent to which the preparation that they do have equips them for success.

A. Most frequent categories for facilitators and barriers

When coding responses of CSE majors in the eight participating classes to the question: *What makes you feel good about your plans to take the next course in this sequence?*, the most frequently seen category was Knowledge, which includes the codes *prep* and *cs-skills*. Students feel confident continuing in a course sequence when they feel they have adequate content knowledge and skills and can build on this foundation in the future. Other frequently seen categories of responses (not including the No-answer responses) were Self-efficacy, Capacity, Validation, and Motivation. We noticed that some students explicitly did not feel good about continuing in their CSE course sequences, with a total of 32 students’ responses coded in the Lack-confidence categories.

When coding responses of CSE majors in the eight participating classes to the question *What are barriers that might prevent you from taking the next course in this sequence?*, the top three most frequent categories were No-answer, Academic support, and No barriers. No-answer and No barriers are the categories that include blank responses as well as those that confidently state that the student predicts not facing *any* barriers at all. The Academic support category includes the following codes: *grades*, *cs-skills*, *difficulty*, *learning-skills*, *prep*, *falling-behind*, and *TAs*. The most frequent categories primarily describe barriers that ought to be addressed by academic or institutional support. We analyze each of these barriers categories and potential solutions next.

[1] https://github.com/CSedResearch22/ASEE.git

Category	# Students	Codes	Example Response
Knowledge	362	prep, cs-skills	"*strong foundation*" [prep], "*I am understanding Java, to an extent where I can solve problems with the concepts that we have already learned.*" [cs-skills]
No-answer	243	no-answer, idk	"*Nothing has really gone wrong yet I guess?*" [idk]
Self-efficacy	162	confidence, ease	"*If I put in the effort, I understand what I am doing.*" [confidence], "*I'm pretty familiar with the course material and can usually knock out PAs without any help.*" [ease]
Capacity	141	learning-skills, prof, TAs friends, workload	"*What makes me feel good is my good study habits.*" [learning-skills], "*The great teachers who have helped me through my classes*" [prof], "*There are helpful tutors available at multiple times throughout the day.*" [TAs]
Validation	130	grades	"*I have performed well in previous classes.*" [grades]
Other	128	other, other-institutional	"*That I'm getting close to graduation*" [other], "*That it is part of my major.*" [other-institutional]
Motivation	125	excitement	"*I like to code*" [excitement]
Lack-confidence	32	not-good	"*I'm terrified*" [not-good]
Modality	8	modality, external	"*That I am able to be on campus and focus on my studies*" [modality], "*The pressure of what would happen if I failed*" [external]

TABLE I

FACILITATORS - CATEGORIES AND ORIGINAL CODES. # STUDENTS IS THE NUMBER OF SURVEY RESPONDENTS AT LEAST ONE OF WHOSE RESPONSES WAS CODED WITH AT LEAST ONE CODE FROM THAT CATEGORY. CODES IN EACH CATEGORY ARE LISTED IN DECREASING FREQUENCY, ACCOMPANIED BY AN EXAMPLE STUDENT RESPONSE CODED BY THE TOP THREE MOST FREQUENT CODES IN EACH CATEGORY. CATEGORIES GROUP CODES EXPRESSING SIMILAR SENTIMENT.

Category	# Students	Codes	Example Response
No-answer	289	no-answer, idk	"*Not sure as of now*" [idk]
Academic support	258	grades, cs-skills, difficulty, learning-skills, prep, falling-behind, TAs	"*Failing this course*" [grades], "*I am still not too good with algorithms which will be a core part of [the next course].*" [cs-skills], "*This class has some challenges [sic] assignment and it moves fast, I barely have time to go over what I did wrong before.*" [difficulty]
No barriers	202	no-barriers	"*There are none, I am privileged*" [no-barriers]
Enrollment	199	class-size, scheduling-conflict, modality	"*If there are not enough seats in the class.*" [class-size], "*Course overlaps or conflicts with another course*" [scheduling-conflict], "*If the next courses are not offered remotely or asynchronously I fear that I may have trouble adapting to an in-person format*" [modality]
Department norms	104	workload, prof, other-institutional	"*The homework may cost me too much time.*" [workload], "*Teachers are a little unclear when introducing new concepts.*" [prof], "*Since I am a new transfer student, I am afraid I can't adapt to [this school's] academic system.*" [other-institutional]
External resources	59	external, health	"*Money for books might be an issue.*" [external], "*Scheduling conflicts with my sport*" [external], "*Anxiety*" [health], "*COVID restrictions/spreading*" [health]
Other	35	other	"*meteor strike.*", "*Feeling like I don't fit in, this is just the first intro course and there are not very many girls.*", "*Being lazy*"
Motivation	24	confidence, excitement	"*Worried if I'm capable*" [confidence], "*If I don't enjoy CS and transfer out*" [excitement]
Social	7	friends	"*I don't have a study group*"

TABLE II

BARRIERS - CATEGORIES AND ORIGINAL CODES. # STUDENTS IS THE NUMBER OF SURVEY RESPONDENTS AT LEAST ONE OF WHOSE RESPONSES WAS CODED WITH AT LEAST ONE CODE FROM THAT CATEGORY. CODES IN EACH CATEGORY ARE LISTED IN DECREASING FREQUENCY, ACCOMPANIED BY AN EXAMPLE STUDENT RESPONSE CODED BY THE TOP THREE MOST FREQUENT CODES IN EACH CATEGORY. CATEGORIES GROUP CODES THAT DESCRIBE BARRIERS THAT MAY BE ADDRESSED BY A POTENTIAL SOLUTION STRATEGY.

B. Barriers Category: Academic Support

Many students mentioned academic concerns when responding to the Barriers question. Some made specific comments about learning skills and computing knowledge, for example "*I have very poor reading comprehension and it's causing me issues on tests and programming assignments*" or "*I took a lot of the* *other courses at community college, so I have credit for many and will not be taking an orthodox path. I don't know how difficult this will be for me*". Several responses mention personal challenges with time management as barriers, such as "*I have a bad habit of procrastinating, which I hope doesn't influence my progress in this class*". One can imagine a mentoring intervention supporting the development of meta-academic skills to help mitigate these barriers.

One challenge with interpreting student responses coded with academic concerns, is that (at our institution) most students typically do very well in the introductory courses participating in surveys so some of their responses mentioning *grades*-coded barriers may have been hypothetical. Responses have a range of sentiment when referring to grades: "*I don't see any barriers besides the event that I fail this course, which I think is very unlikely [final grade: B+]*", "*Not doing well in this course [final grade: A+]*", "*Not understanding concepts and failing the class [final grade: A+]*". While the majority of students who expressed "*Failing this course*" as a barrier passed the class, some did not.

C. Barriers Category: Enrollment

A common theme in student responses was concerns around waitlists and registration slots. For example, "*Mainly enrollment issues, since CSE courses are usually fairly impacted*", or more strongly "*[University's registration system] waitlist situation is absolutely awful please get more spots for [Advanced Data Structures]*". This result is striking in part because the CSE department has made the commitment that CSE majors will have priority enrollment in required classes and that student advisors proactively work to make sure that class sizes do not impede these students' progress in their degrees.

Despite this, enrollment is not simple. In first-pass enrollment, students select a small number of courses; a second-pass (several weeks later) is their opportunity to fill out their schedule. Within these phases students are assigned an *enrollment time* where the system unlocks for them to enroll in courses. This is assigned based on a number of factors, including seniority in terms of credits.[2] In order to have control over enrollment within our department to prioritize major enrollment, our staff works with the affordance available to in the system: setting class sizes *artificially low* so that nearly all students go onto the waitlist. This way, they can (manually, at a scale of hundreds of students for each class!) move majors from the waitlist to the course before opening enrollment to all students in the second pass.

This means a few things for our students. First, we only guarantee seats to majors in first-pass enrollment. In second-pass enrollment, nonmajors have access to the course, and this has to happen to accommodate nonmajors whose programs nonetheless require taking CSE courses. Second, it's likely that our majors are spending a long time officially on the waitlist from the point of view of the registration system. While our advising staff is consistent on this messaging, clearly many students perceive that the scarcity may affect them. This messaging has reached some students, who left comments like, "*As long as spots are reserved for CSE majors I don't think there will be much issue*", but many students continue to experience the uncertainty, stress, and anxiety that come with being placed on the waitlist even though that is part of the normal, labor-intensive process the student advisors go through to give majors priority. As one student put it, "*If I don't get off the waitlist... When does it let the waitlisted CS majors in???*".

One student cited a specific enrollment rule: "*I can't take [Software Engineering] yet since I don't have junior standing*". Indeed, a number of advanced CSE courses required junior or senior standing. Following the analysis of the survey responses in this project, and after consultation with the instructors of the many courses that listed this restriction, we realized that the restriction was a historical artifact—originally intended to be helpful by communicating normative paths through the program—that was instead serving

[2]Interestingly, in the course of this research, we learned that all credits, including e.g. AP credits, count towards this, so students with more AP credit are able to enroll in courses earlier than others. This is certainly a potential source of inequity given the availability of these opportunities and something we want to understand better. The full policy is at https://students.ucsd.edu/academics/enroll/undergraduate-enrollment/enroll-in-classes.html

as a barrier. We dropped all these references to "standing" from all CSE course descriptions and the course catalog, using course-based prerequisites to communicate course dependency chains instead. We are grateful to this student for prompting this change by responding candidly to the survey.

D. (Non) Barriers

Despite prior work [4], [30], [20] suggesting that sense of belonging can be a primary determinant of persistence in computing, we only observed one case where it was mentioned as a barrier in CSE major students' survey responses. A female student wrote: "*Feeling like I don't fit in, this is just the first intro course and there are not very many girls*". It could be that the survey format is not conducive to sharing these aspects of their experience, or that students did not interpret the question as one related to non-course-specific factors.

V. Results and Discussion: Disaggregated Analysis

Prior work indicates that persistence and retention rates are not uniform across various aspects of student identities. To determine whether certain barriers are reported disproportionately by students with different identities, we analyze the survey responses disaggregated by race/ethnicity, gender, and admit status. In particular, we ask whether there are differences in which students experience *no* barriers or *some* barriers. We sorted respondents in each course into three categories: 1) those who specifically stated they encountered no barriers (the code *no-barriers*), 2) those who reported any barrier, and 3) those who left a blank or "I don't know" response. For each demographic category (race/ethnicity, gender, and admit type), we then conduct pairwise two-sample Z-tests for proportions with a post-hoc Bonferroni correction to identify whether any demographic groups are unusually likely (or unlikely) to have that response.[3] Any category with fewer than five students is omitted from this analysis.

Table III reports the proportion of students with each identity that mentioned at least one barrier, left the barriers question blank, or explicitly (and confidently) affirmed they have no barriers. Most students (471 of 660) reported *some* barrier at some point during the quarter. While these data indicate many differences across groups, pairwise two-sample Z-tests for proportions give no statistically significant results after Bonferroni corrections for the p-value cutoffs.

A finer-grained analysis of possible differences across demographic groups is in Figures 1, 2, and 3. Each of these grouped bar charts compares the percentage of students with each identity whose survey responses were coded in particular categories. In the following subsections, we highlight several places where responses differ by group and may motivate potential interventions.

A. Academic Support and Race/Ethnicity

Figure 1 shows that Black or African-American and Hispanic, Chicano, Latino or Spanish CSE majors were more likely to respond to the survey expressing barriers that would be addressed by Academic Support (especially those barriers coded *grades*). Notably (as mentioned earlier), many of the students expressing concerns around grades completed the course with very high grades, for example: "*Me failing this class or really not enjoying this class.*" [Black or African-American, final grade: A+], "*If my final grade is really bad, that might make me want to change.*" [Black or African-American, final grade: A]

[3] A two-sample Z-test for proportions is appropriate when the population proportion is unknown – in our case, the proportion of students one would expect to express some barrier, for example (and so there is not enough information to use the chi-squared distribution).

	Some barrier mentioned	Blank response or "*I don't know*"	Responded "*no barriers*"	**N**
Race/Ethnicity				
A	67%	18.7%	14.3%	427
B	80%	10%	10%	10
H	80.3%	7%	12.7%	71
W	78.4%	10.8%	10.8%	111
D	71%	17.7%	11.1%	45
Gender				
M	70.3%	7.0%	12.5%	488
F	70.8%	13%	16.2%	154
X	82.6%	8.7%	8.7%	23
Admit Type				
NFRS	72.5%	15.3%	12.2%	510
TRAN	66.9%	15.5%	17.6%	142

TABLE III
WHO HAS BARRIERS? PROPORTION OF EACH DEMOGRAPHIC GROUP THAT MENTIONED SOME BARRIER, RESPONDED WITH A BLANK RESPONSE, OR EXPLICITLY STATED THEY ENCOUNTERED NO BARRIERS. (SEE SECTION III-B FOR DEFINITIONS OF THE ABBREVIATIONS USED IN DEMOGRAPHIC CATEGORIES)

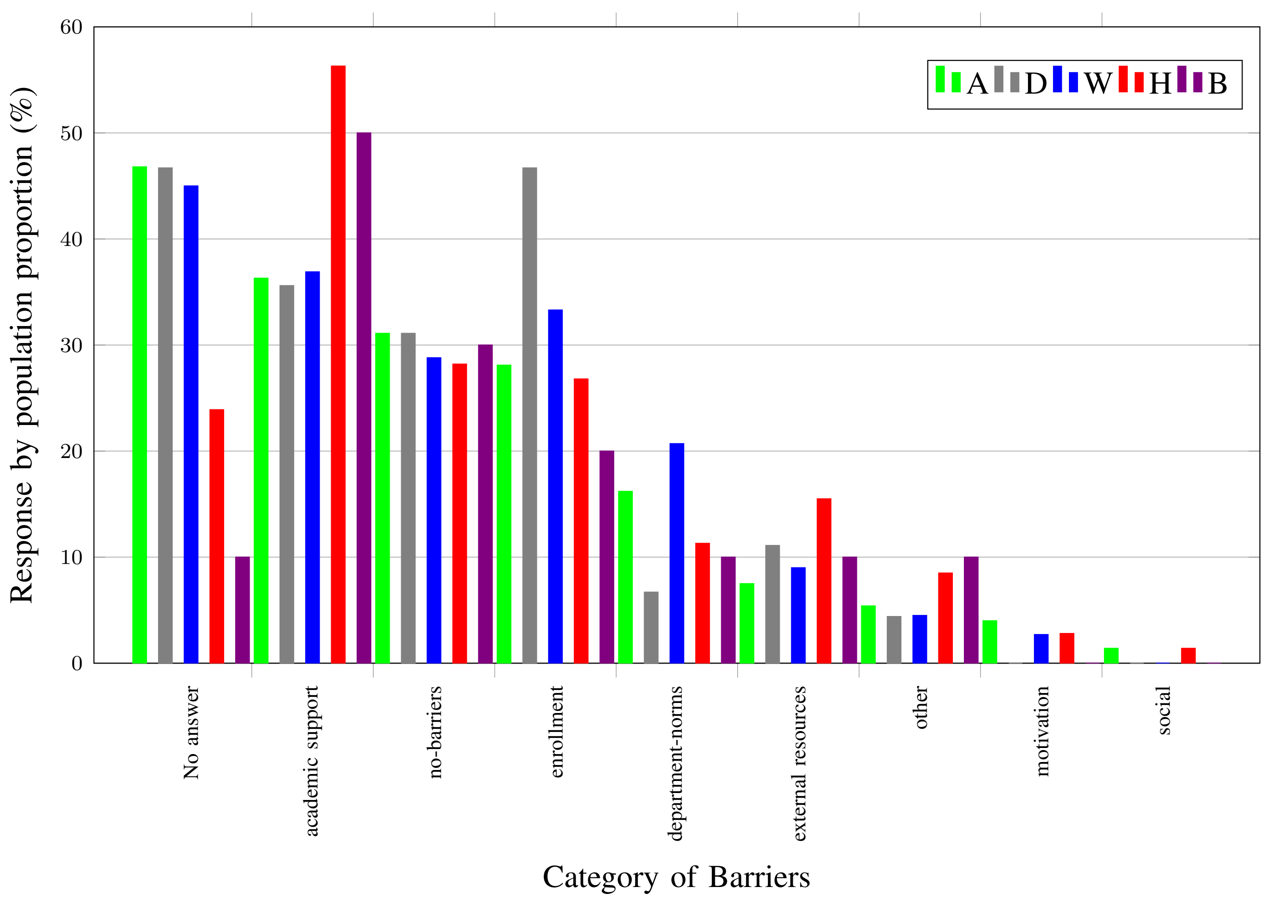

Fig. 1. Barriers disaggregated by Race and Ethnicity: Proportion of students in each race/ethnicity group whose responses are coded with codes in each category of barriers. For each category, the bars representing "Asian/Asian-American" (A), "Black or African-American" (B), "Hispanic, Chicano, Latino or Spanish" (H), "White/Caucasian" (W), "Not Given or Decline to State" (D) students are ordered from left to right.

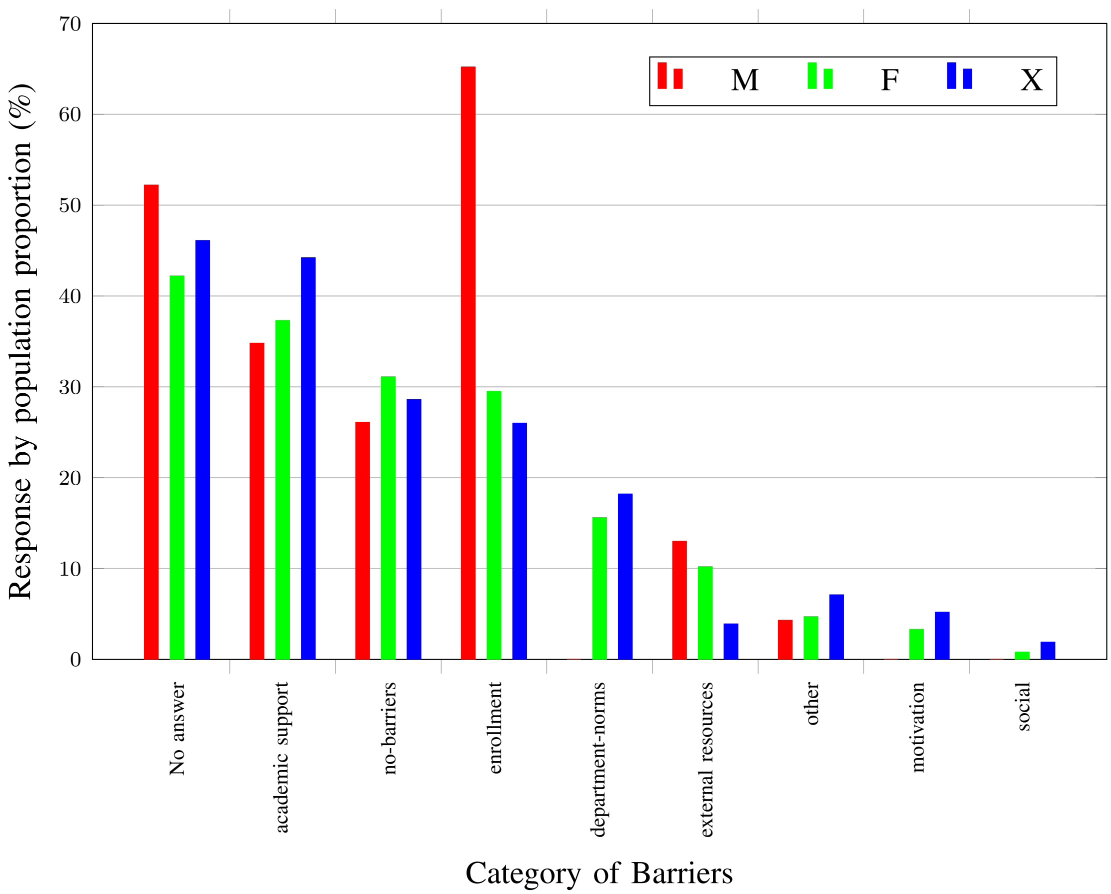

Fig. 2. Barriers disaggregated by gender: Proportion of students in each gender group whose responses are coded with codes in each category of barriers. For each category, the bars representing students identifying as Male (M), Female (F), and non-binary or other are ordered from left to right. Note: female includes trans female and male includes trans male.

B. Enrollment Concerns and Admit Type

Students who entered as direct admits from high school (rather than transferring from another university or college) gave responses to the barriers question that were coded as enrollment concerns relatively more than transfer students. We hypothesize that this may be because these students are enrolling in more introductory courses, which tend to be in higher demand among non-majors and hence use artificially low enrollment caps to manage enrollment. Introductory courses are more likely to have enrollments over 500; fewer courses of this size exist after the introductory sequence is completed. Another hypothesis is that transfer students tend to take courses “off-sequence” and may see less enrollment pressure as a result.

C. External Resources and Social and Gender

Women (F gender) were less likely to respond to the barriers question with comments related to health, wellbeing, financial concerns, and external obligations (categorized as External Resources). On the other hand, women were relatively much more likely (though not in absolute numbers) to mention social issues, like lack of community or friends, as barriers. Nearly all the comments in this category come from women (n = 3); “*I don’t have a study group*”, “*Imposter syndrome and not opening my collaborative circle.*” “*PA [Programming Assignment] stuff is my barrier, so I hope to give more info or work as a team.*”

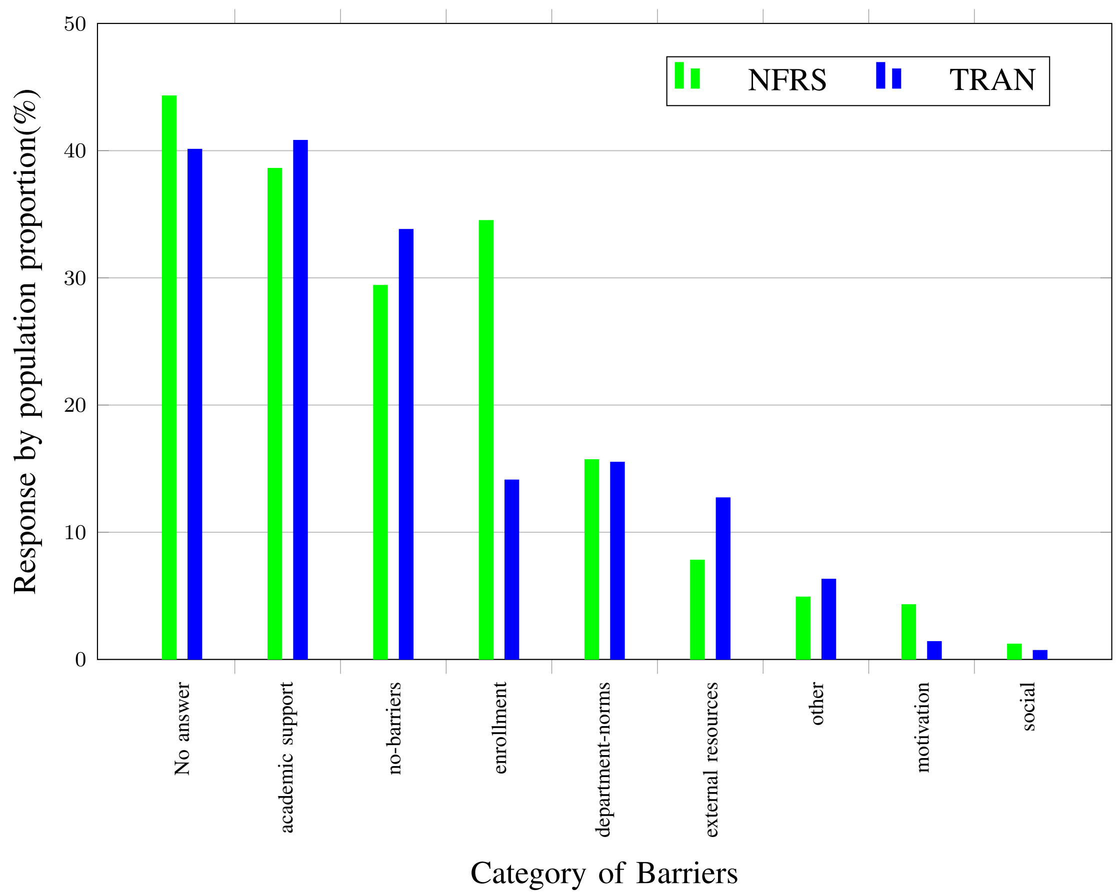

Fig. 3. Barriers disaggregated by admit type: Proportion of students in each admit type whose responses are coded with codes in each category of barriers. For each category, the bars representing students admitted directly from high school (NFRS) are on the left and those representing community college or university transfer students are on the right.

D. Multivariate logistic regression

To analyze whether the apparent differences in Figures 1, 2, 3 reflect statistically significant disparate impacts of barriers across the demographic identities, we use a multivariate logistic regression. Demographic categories are treated as independent variables with the code category as the dependent variable. By convention, we show comparisons to the most frequent independent categorical variables of Race/Ethnicity (Asian), Gender (Male), Admit Type (New High School Admit). In Table V-D, we report the statistically significant results[4]. We find a significant effect for three code categories: External resources, Enrollment, and Academic support. External resource barriers (things like "*money for books might be an issue*", "*Scheduling conflicts with my sport*" or "*COVID restrictions/spreading*") were significantly less likely to be experienced by women and more likely to be experienced by Hispanic, Chicano, Latino or Spanish students and transfer students (with coefficients -1.04, 0.92, and 0.61 respectively). In terms of enrollment issues, these barriers are reported significantly more often by non-binary/third gender students and less often by transfer students (with coefficients 1.35 and -1.18). This is somewhat surprising as transfer students often face time-to-degree challenges, however, they also typically have more senior standing. Finally, Hispanic, Chicano, Latino or Spanish students are significantly more likely to report barriers around Academic support (those having to do with *grades*, *preparation*, and *learning skills*), with a coefficient of 0.82.

[4]All model results are included in the supplementary materials. We do not perform subset selection, where only a subset of variables are retained in the final model, to avoid introducing bias.

Dependent Variable	Identity	Intercept	Coef	$P > \|z\|$	LLR p-value
External Resources	Gender - F	-2.514	-1.042	0.019	0.026
External Resources	Adm - TRAN	-2.514	0.61	0.049	0.026
External Resources	Race/Eth - H	-2.514	0.92	0.016	0.026
Enrollment	Gender - X	-0.689	1.35	0.030	<0.01
Enrollment	Adm - TRAN	-0.689	-1.18	<0.001	<0.01
Academic Support	Race/Eth - H	-0.653	0.818	0.002	0.062
No Answer	Race/Eth - H	-0.126	-2.13	0.045	0.001
No Answer	Race/Eth - B	-0.126	-1.081	<0.001	0.001

TABLE IV

MULTIVARIATE LOGISTIC REGRESSION. BY CONVENTION, WE SHOW COMPARISONS AGAINST THE MOST FREQUENT INDEPENDENT CATEGORICAL VARIABLES OF RACE/ETHNICITY (A), GENDER (M), ADMIT TYPE (NFRS). FOR SPACE, WE REPORT ONLY THOSE RESULTS THAT ARE SIGNIFICANT WITH $p < 0.05$. SEE SECTION III-B FOR DEFINITIONS OF ABBREVIATIONS.

We also note two groups of students are less likely to provide No-answer: Black or African-American and Hispanic, Chicano, Latino or Spanish students are less likely to provide no answer about barriers they may be encountering (coefficients -1.08 and -2.13). This likely indicates those students encounter more barriers, although it might also indicate a greater willingness to answer our surveys.

VI. LIMITATIONS AND FUTURE DIRECTIONS

Disaggregation of data by aspects of identity is an important piece of this work. We recognize that there are other aspects of identity that might be significant in identifying and understanding persistence through the major but that were not reflected in data easily accessible by institutional research reporting decisions at our university. For instance, whether students are international or domestic students and the ways in which this intersects with race and ethnicity is an area of further study. Other intersectional analyses may well be relevant and helpful in this work. One challenge is finding statistical signal as the number of demographic categories grows. For example, our race/ethnicity data contained more fine-grained distinctions for Asian/Asian-American students; it is conceivable that the experiences of some subgroups of these categories are significantly different than the aggregated conclusions. In particular, anecdotally, it appeared that some of the most frequent barriers reported by Vietnamese students seemed different than those aggregated over all Asian/Asian-American respondents. Similarly, examining intersectional effects across multiple identities leads to statistical challenges as the number of students in these finer-grained categories becomes small. Nonetheless, experiences related to intersectional identities are important to explore in future work.

Beyond statistics, we noticed some limitations with the question design in the survey. Students seemed to be more willing to share barriers than facilitators, and many responses were framed as hypothetical. This, coupled with our observation that only one student explicitly mentioned aspects of her identities suggests that work on the student experience should pull on multiple sources of forms of data, including (potentially) focus groups and interviews to supplement larger scale surveys.

VII. DISCUSSION

In this study, we seek to understand what helps undergraduate students persist in their CSE studies along with what barriers can drive them to leave.

The largest barrier students expressed was around academic support. Many universities have tested efforts to level the playing field of prior preparation, along with efforts to improve tutoring and peer support [5], [7], [10], [12]. Our institution has engaged in similar efforts, with extensive tutoring, summer transitional programs, and mentoring, but this work suggests that institutions may need to make a greater effort to connect students to these existing resources. Our results also reflect that some students believe they are under-prepared with learning skills more generally and may be unaware of opportunities like office hours or believe that such opportunities are not intended for them. Often these gaps in knowledge and expectations are referred to as a "hidden curriculum," that researchers have sought for decades to make visible and known [21], [24]. Our work indicates that these efforts must continue – and with data like ours may be able to target these efforts in a more focused way: for example, in our institution, it may be particularly impactful to connect Hispanic, Chicano, Latino or Spanish students with such resources since they were significantly more likely to report academic support barriers.

Given the strong and growing interest in computing majors, a second critical issue surrounds enrollment. Departments and universities need to ensure that there are enough spots for students, but they also need to make sure that students feel safe and secure in their ability to enroll. If students feel there is a risk they will not be able to complete required courses in their own major, they may feel discouraged and not continue on. Particularly at large public universities this kind of messaging can be difficult to do well, but it forms a significant mental barrier to continuing in the major. We also encourage reflection around policies like prioritizing by standing that may embed existing inequities (e.g., access to AP courses in high school).

VIII. Conclusions

Institutional policies related to enrollment have significant impacts on student persistence in computing majors at our institution. Analyzing student responses to a large-scale survey administered in eight foundational undergraduate computing classes, we found that the most common barriers expressed by students were related to institutional factors such as academic support, enrollment, and department norms. An institution looking to improve retention and persistence in their computing majors can look at the specific solutions proposed to address these barriers, in particular focussing on the disaggregation of the results by demographic category that highlight specific student experiences.

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