The Pathways and Experiences of Illinois Computer Science Undergraduate Students Series

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Part 1 - Towards an "uplifting environment": Understanding supports and barriers for students in Illinois computer science college programs

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Part 1 – Towards an "Uplifting Environment": Understanding Supports and Barriers for Students in Illinois Computer Science College Programs

Introduction to The Series

The purpose of **The Pathways and Experiences of Illinois Computer Science Undergraduate Students Series**, as the name suggests, is to understand the pathways and experiences of computer science (CS) and tech[a] students in post-secondary programs throughout Illinois, paying particular attention to students from historically marginalized[b] groups including Black/African American and Hispanic/Latinx[c] students, women, first-generation students, and low-income students. The series will include several reports, each focusing on a different aspect of students' experiences or pathways into and through CS education. In the first report of this series, we focus on the specific supports that helped students succeed and barriers that may have impeded their success in their post-secondary CS education programs.

Background

While the CS community has focused on broadening participation in recent years to be more inclusive to all learners, post-secondary outcomes do not reflect this shift.[2-4] Many student groups, including female, Black/African American, and Hispanic/Latino students, are still underrepresented in many CS and tech programs at Illinois colleges and universities compared to their peers and relative representation in the undergraduate student body.[5,6] The underrepresentation and marginalization of these groups in post-secondary education prevents diverse talent from entering the CS and tech workforce. National data suggest that, while CS is becoming more diverse, there is much room for improvement.[7,8] Many highly ranked CS post-secondary programs in the U.S. (and Illinois) are concentrated at predominately White institutions.[5,9,10] Even those who attain a degree in CS may not have had positive experiences, and students from historically marginalized backgrounds are more likely to have to overcome more barriers to reach attainment.[11,12] Therefore, it is essential to understand the inner workings of these CS programs, especially the resources they offer students to be successful and the obstacles students face that may impede their success.

The supports and barriers discussed herein cover a range of topics including teaching practices, course structure, access, and interpersonal relationships. To provide an exhaustive research review here of each of these supports and barriers would take up many pages and not be at point-of-use for the reader. Instead, we provide context and relevant literature for each support and barrier in the results below, before launching into related findings within their respective sections.

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[a] Throughout IWERC's CS education research portfolio, we use the following definition of CS adopted from Illinois Legislative Assembly's 2021 definition: "Computer science means the study of computers and algorithms, including their principles, their hardware and software designs, their implementation, and their impact on society."[1] Many of our post-secondary institutions had programs they designated as not being strictly CS, and thus we use the term "tech" to encompass other computing-related programs.

[b] We interchangeably use "marginalized" and "minoritized" throughout the report.

[c] Throughout the report we use racial categories as used in the sources we reference. In our survey, our racial categories included "Hispanic/Latinx," which is why that is used the most frequently.

We hope that institutions find this report beneficial as they continue their work to understand student experiences and create a more welcoming and inclusive CS community where all students can thrive and succeed.

Methods

The data analyzed in this series was, in part, the result of a survey conducted in partnership with 35 2-year and 4-year colleges and universities in Illinois between October 2022 and May 2023. The survey consisted of questions to better understand students' experiences in CS and their pathways to careers in those fields. Institutions that partnered with IWERC in distributing our survey to their students each received an individualized report of their anonymized student responses. See the Supplemental Materials for the full survey and more information on recruitment of institutions and institution characteristics.

Survey participant demographics

A total of 940 students responded to our survey. See Table 1 below for demographic information on survey participants.

Table 1. Respondent demographics for full sample.

Gender		Race/ethnicity	
Women/Girls	31.8%	American Indian or Alaska Native (AIAN)	0.2%
Men/Boys	65.6%	Asian	20.7%
Non-binary	1.1%	Black or African American	9.5%
Other (self-described)	0.4%	Hispanic or Latinx	19.0%
Prefer not to disclose	1.1%	Middle Eastern and/or North African (MENA)	3.3%
		Multiracial	8.7%
		Native Hawaiian or Pacific Islander (NHPI)	0.1%
		White	37.0%
		Prefer not to disclose	1.4%
First-generation Status		**Low-income Status**	
Continuing-generation	48.9%	Non-low-income	41.9%
First-generation	45.6%	Low-income	39.5%
Unsure	1.4%	Unsure	3.8%
Prefer not to disclose	4.0%	Prefer not to disclose	14.8%
Year in School		**Program**	
1st year/freshman	26.9%	Computer Applications for Business	1.2%
2nd year/sophomore	31.2%	Computer Information Systems	10.5%
3rd year/junior	19.8%	Computer Networking	1.6%
4th year/senior	13.8%	Computer Science	57.4%
5th year +	5.6%	Cybersecurity	9.0%
Graduated	2.7%	Data Science	2.4%
Intent to Transfer from 2-year to 4-year Institution		Engineering or Robotics	6.7%
Intent to transfer	80.8%	Information Technology or Information Sciences	3.3%
No intent to transfer	9.7%	Not currently in CS/tech program but plan to be	6.7%
Unsure	9.4%	Other	1.1%
2-year Attendance		**4-year Institution Type**	
Did attend at any point	49.6%	Public	40.7%
Did not attend ever	50.4%	Private	59.3%
High School Location			
Graduated from an Illinois high school	76.1%		
Graduated from a high school outside Illinois	23.9%		

Our sample was quite representative of the CS undergraduate student body in Illinois in terms of gender and racial identity[5,6] (e.g., Asian and White students represent nearly 60% of our student respondents, and male students represent nearly 66% of our student respondents) and had sizable proportions of students identifying as low-income and/or first-generation students. Included in our sample was a small pool of high school students (N = 23) who were enrolled in CS courses at their local community college or a 4-year institution. For degree programs, we included eight CS or tech-related programs in our sample that were representative of the types of programs offered at each of our partnering institutions as well as an Other category and one for students not currently enrolled in a CS or tech program but planning to be. Throughout the series, we will use the term "CS" to encompass all these programs unless otherwise noted. See the Supplemental Materials for term definitions on each of the student demographic variables and programs.

Lastly, not all respondents answered every item. In this report, and future reports, we include the number of respondents who answered specific questions as we present the findings.

Survey items

Two survey items are analyzed in this report: one focusing on supports and the other on barriers (see Table 2). For both questions, students were presented with a list of possible supports or barriers for each of the respective questions and asked to check all that applied. We gathered the potential supports and barriers from CS and STEM persistence literature[13–15] and from conversations with experts in the CS education space. The vast majority of the supports and barriers included in the survey items are known factors of retention (or attrition) in extant research. The goal of this study was not necessarily to unveil novel factors, but to understand how known factors are represented in the experiences of CS and tech students in Illinois post-secondary programs and how to support our students. We also provided an *Other* option for students to write in supports or barriers that were not listed. Each of these questions was followed by separate open-ended items for students to provide more detail about the supports or barriers they had selected.

The supports and barriers explored in this report include institution-, program-, and individual-level factors that may aid or hinder success. These are based on known supports and barriers to STEM (and college) students and may not necessarily seem to be CS-specific; however, our participants were asked to think of their CS program when answering our survey. As such, we feel confident their answers reflect their feelings of their CS program and courses specifically.

Table 2. Item choices for the Supports and Barriers survey questions, respectively.

	Supports	Barriers
Item	What supports have helped you succeed in your CS or tech-related program? Check all that apply.	What were the largest barriers to your success as a student in a CS or tech-related program? Check all that apply.
Item Choices	• Campus supports (e.g., tutoring, writing support, mental health services) • Class supports (e.g., office hours, lab space, and computer lab usage) • Faculty or peer mentoring • I have family or friends within the computer science or a tech-related field to help me navigate • Joining student organizations or attending social functions within the department and/or university • Prior exposure/experience with CS or tech-related fields in high school or extracurricular activities • Study groups with my peers • Other	• Course content was not relevant to my life • Coursework was overwhelming or too fast-paced • Inadequate advising on course selection and academic problems • Lack of access to personal devices (laptop, software, etc.) or internet access • Lack of high school preparation for program • Lack of inclusive culture/climate in CS and tech-related fields • Lack of support (e.g., encouragement, respect) from family and friends • Negative interactions with the CS and tech-related communities • Not many of my peers looked like me • Poor teaching from professors and/or teaching assistants (TAs) • Other
Open-ended follow-up	Specify why the supports you chose helped you succeed in your CS or tech-related program.	Specify why the obstacles you chose impeded your success in your CS or tech-related program.

Analysis of survey items

We performed both quantitative and qualitative analyses of these survey items and their respective open-ended follow-up items. The quantitative analysis was descriptive in nature. A chi-square test of homogeneity (or a test of two proportions) was completed to determine whether group differences occurred for supports or barriers selected. Conservative Bonferroni corrections were used to adjust p-values for multiple comparisons throughout. For independent variables with more than two groups (such as race and year in school), a post-hoc test for pairwise comparisons (i.e., a z-test of two proportions) was completed to determine where the group differences occurred. All assumptions of the test were met, including meeting minimal sample-size requirements. Statistically significant group differences are noted throughout the report, and all descriptives and test statistics for group differences can be found in the Supplemental Materials. We did not include test statistics in the main text to avoid distracting from student experiences and ensure we center student voice.

For the qualitative analysis, we used inductive coding for the open-ended responses. The research team completed inter-coder reliability and maintained constant collaboration of ideas as more responses were coded, creating an iterative process through reflection. Because the Supports and Barriers items were check all that apply and their respective open-ended responses could apply to more than one code in our qualitative codebook, neither support or barrier categories nor qualitative codes are mutually exclusive and may not add up to 100%. For example, survey participants could select multiple supports in the check all that apply item; and within a selected support respondents could have written about many themes which may elicit several codes about that support. Percentages shown throughout the report indicate the proportion of students who selected that choice or who were within the qualitative code. Within each support or barrier subsection, the qualitative themes represent the different ways in which students experienced the supports and barriers. One important caveat when interpreting our qualitative results is that, for each support and barrier, we report what students chose to disclose in their open-ended responses. Some of the themes directly align with the wording and examples used in the survey items, indicating that they may have been more present in students' minds as they wrote their responses. Other themes emerged entirely inductively from the data and were described, in different proportions, by multiple students. However, we cannot guarantee that the absence of certain themes in other students' responses meant that they never experienced similar issues; it is possible that, for a variety of reasons, they simply did not mention them. This could be a limitation of our findings and our assumptions on differences described throughout the report. We did our best to present the information we collected from students to generate or support existing assumptions about supports and barriers experienced by CS undergraduate students. Committed to honoring students' voices, especially those of historically marginalized identities, we chose to include everything that emerged from the qualitative analysis, regardless of the percentage. This decision helps elevate the voices of identities that are underrepresented in our sample (see Table 1 above), amplifying areas of supports and barriers that, even though experienced only by a minority of respondents (or precisely because of that), deserve our attention. See the Supplemental Materials for more information about the total number of responses included in both the quantitative and the qualitative analyses and about how we conducted each analysis.

Student quotes included in the text were chosen because they were representative of the code theme and the demographics of the students responding. Some sections may have greater detail than others—this is because students provided more written comments (data) for some supports and barriers than others. We strove to integrate both quantitative and qualitative findings throughout the report for flow and clarity, and to note which findings we are speaking of when reporting.

Findings: Supports

A total of 927 undergraduate CS students responded to the check all that apply item of the survey that asked them to select the supports that helped them succeed. About 70% of these students (N = 643) responded to the Supports item of the survey that asked them *why* the supports they selected helped them succeed in their CS program. The most frequently selected supports were *prior exposure/experience to CS or tech in high school or extracurricular activities* (45.8%); *class supports such as office hours, lab space, and computer lab usage* (45.5%); *study groups with peers* (35.9%); and *family or friends in the CS field to help navigate* (35.8%; see Table 3). While the remaining four supports (*faculty or peer mentoring*, *campus supports*, *joining student organizations*, and *other* supports) each garnered selection from less than 30% of our respondents, our qualitative findings are helpful to understand the ways in which these supports contributed to student success and why they should not be overlooked. Awareness of what areas promote success among students can inform institutions to provide CS students with resources and opportunities that will contribute to more successful experiences.

Table 3. Percent of survey respondents who selected each support in the check all that apply item.

Supports	Percent of Respondents
Prior exposure/experience with CS or tech-related fields in high school or extracurricular activities	45.8%
Class supports (e.g., office hours, lab space, and computer lab usage)	45.5%
Study groups with my peers	35.9%
I have family or friends within the computer science or a tech-related field to help me navigate	35.8%
Faculty or peer mentoring	28.2%
Campus supports (e.g., tutoring, writing support, mental health services)	20.9%
Other	15.7%
Joining student organizations or attending social functions within the department and/or university	14.8%

The sections below begin with introduction of each support and relevant literature, summarize the findings from this study, and end with connections to other research. We will tease apart some of these themes and explore patterns across different demographic groups, as applicable.

1 | Prior experience with CS in high school or extracurricular activities (selected by 45.8% of students)

Prior research has shown that early or prior experience with CS learning opportunities (whether formal or informal) is beneficial to later success in the field. Early exposure aids in the initial spark of interest for the field and allows for more time to cultivate interest through elementary and secondary education.[16] Exposure before college also allows students to learn about the many avenues they can take to a career in CS and the versatility of options one has with CS education. Further, students who take CS before college are more likely to pursue it as a college major and consequently as a career.[17]

Our quantitative analysis found that students who took CS courses while in high school were statistically more likely (i.e., statistically significant difference) to select *prior experience* as a support (63.5%) compared to their peers who did not take CS courses in high school (18.2%). This indicates that many of our student respondents gained their prior exposure through more formal education settings as opposed to informal settings like extracurriculars, which was also apparent in our qualitative analysis of students' written responses. When discussing prior exposure to or experience with CS, slightly over half the responding students included information on where these experiences came from. Almost two-thirds of those responses specified that prior experience in CS came from previous formal class settings, while only about 9% said they gained experience from extracurriculars (although those informal experiences, of course, can be quite valuable for students). Outside of those options, 13% of students attributed their previous experience to personal interest in CS.

Students (mostly White students) described early exposure to technology, often "**at a very young age**," as a contributor to their interest in and familiarity with CS. This aligns with quantitative findings showing Asian (48.5%), Multiracial [d] (61.0%), and White (50.3%) students were statistically more likely to note *prior exposure* as a support compared to their Black/African American (27.7%) and MENA (19.4%) peers, and Multiracial (61.0%) students were statistically more likely to select this support compared to their Hispanic/Latinx (40.0%) peers. This points to how students from backgrounds and identities overrepresented in CS, such as White and Asian students[e,5,7,18], are more likely to start their CS programs in advantaged positions compared to students who may have not had the same opportunities growing up.

Over 80% of open-ended responses for this support included descriptions of how prior exposure in high school impacted the students' CS learning experiences in college. The vast majority of these responses included statements by students who valued previously acquiring a CS knowledge base and having some familiarity and "**comfort**" with the content, which led to increased confidence in themselves.

> **Having prior exposure to computer science in high school gave me a solid foundation to build upon in my college program. I found that this prior experience gave me a head start and made the material feel less intimidating. Additionally, I was able to draw on my high school experiences to help me navigate the more challenging aspects of my college program.** (woman, Asian, 2-year institution transferring to a 4-year public institution)

This finding aligns with existing research that prior experiences in CS have the potential to relieve the cognitive load of seeing

Our Mixed Methods Approach

All group differences noted in the quantitative findings are statistically significant. For example, in the section to the left, some groups based on students' racial identities were statistically more likely to select *prior experience* as a support compared to their peers in other racial groups. Throughout this report we remark on similar group differences as they arise in the findings. The Supplemental Materials includes output tables of all statistical analyses.

Quotes shared from the qualitative analysis are representative of the thematic analysis conducted of all student responses. When possible, the quotes shared are also representative of the student demographics and group differences observed in the quantitative data. For example, the bolded quote to the left highlights how *prior exposure* to CS helped this student in their college program with feeling less intimidated by material and knowing how to navigate the program. These were both outcomes of the thematic analysis of all student quotes. Further, this quote was from a student who had noted prior exposure to CS in high school and from a racial group who were more likely to select the support, tying in the quantitative group differences.

This weaving of both the quantitative and qualitative findings continues in each section of the report.

[d] See the Supplemental Materials for more information on our Multiracial student sample.

[e] In both national and Illinois-based data, Asian students are overrepresented in high school and post-secondary CS relative to their enrollment in those student bodies more generally. That said, this overrepresentation does not mean Asian students are less susceptible to feelings of exclusion, lack of belonging, or negative interactions that other historically marginalized racial groups may experience in CS. This will be explored further in the Barriers section of the report.

material for the first time in college, which can reduce anxiety and improve college course outcomes.[19–21]

About 30% of students who described this support reported that prior experience encouraged them to pursue CS by providing increased interest, motivation, confidence, and a sense of belonging in the CS community.

> **If it weren't for previous exposure, even outside of high school, I do feel as if I would have found a community or hobby/interest that suits me. I believe high school only encouraged me to pursue a career in tech. As a person of color, it was refreshing and invigorating to see a black woman teach a Python coding course. Being a person that grew up with technology in general also encouraged me.** (woman, Multiracial, 2-year institution transferring to a 4-year private institution)

While not apparent in the open-ended responses from students, male respondents were statistically more likely to select this support (50.1%) compared to their female peers (36.7%), which aligns with national and state data indicating boys having higher participation rates in CS prior to college.[7,18]

2 | Class supports (selected by 45.5% of students)

Prior research has shown that *class supports*, such as office hours and lab space, offer additional resources and individual attention to students to aid in their success for specific courses and are associated with better academic performance.[22,23] Supports like these may be more instrumental in courses like CS where complex problem-solving is done every class.[23,24]

When elaborating on *class supports*, students described the different types of academic support that positively influenced their learning experience, such as improving their understanding of topics and having spaces to ask questions, practice problem-solving, and work with other students. Students predominately described both office hours and professors or TAs as sources of positive academic support, emphasizing the helpfulness of receiving individual assistance.

> **My computer science professor has office hours multiple times during the week where he is abundantly available to answer any questions I might have, whether it'd be clarifying a concept that I don't get or helping me to debug one of my assignments. The support from my instructors is one of the most significant factors that have helped me succeed in CS so far, and allows me to push through the tough periods** (man, Asian, 2-year institution transferring to a 4-year public institution)

Students recognized labs as **"a necessity."** Described both as physical spaces and as class settings dedicated to getting more practice, labs were particularly helpful in providing access to equipment such as computers and software, as well as opportunities for practice and collaboration with available support from TAs or professors.

In some instances, students described how *class supports* led to an increase in interest, motivation, and/or confidence in CS. For example, this 4th-year student reflected on their experience at their 4-year university:

> **Being able to use class support has been a blessing here [at my university]. This has increased my passion for the CS concepts I was learning because class support allowed me to experiment with what I was learning and has opened up my vision of how hands-on work can really apply to the everyday applications of reality. […] Office hours, lab access, and computer lab use have made it possible for me to practice more and get assistance with my schoolwork.** (man, White, 2-year institution transferred to a 4-year private institution)

Students also emphasized the importance of collaborating and connecting with others in class, some of whom described their classes as **"a small community**" where students **"encouraged and helped one another."** For one student, a non-binary Hispanic/Latinx first-generation student in the first year of their program at a 4-year public institution, **"[h]aving class support allows for a chance to get to know those around you who are also interested in CS, and helps you not feel as alone in the process of understanding the material."**

Of note, students who only attended 4-year colleges or universities (either private or public) were statistically more likely to select class supports as being important to their success (53.0%) compared to their peers who attended a 2-year college at some point in their post-secondary academic career (38.0%).[f] This finding could possibly indicate that *class supports* like office hours and lab usage may be more prevalent at larger institutions or more critical to the success of 4-year students. However, as noted in the student quotes above, when utilized, *class supports* are important to many students from many different institution types. Moreover, when institutions create spaces encouraging students to receive help, students utilize these supports and, for some, achieve positive academic and personal outcomes.[25]

3 | Study groups with peers (selected by 35.9% of students)

Prior research has found that peer collaboration is especially important when working on complex problems, particularly in the brainstorming and modeling stages[26], indicating peer collaboration serves various functions. Moreover, student interactions with one another are among the highest predictors for persistence in the major beyond introductory CS coursework.[27] Engaging in *study groups with peers* not only helps with understanding class material, but it can lead to increased belonging in the CS field, as students may build a community when given the opportunity to collaborate with one another.

When talking about why being part of *study groups with peers* was a helpful support, 91% of students in this study described academic benefits, such as improved learning. These comments included mentions of peer support and collaboration, feeling more encouraged and/or motivated, and being exposed to multiple perspectives.

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[f] Because of the way the survey was designed students were able to select more than one institution type if they had attended. Therefore, it is not possible to simply compare students at only 2-year institutions to students at only 4-year institutions. Instead, we compared students who at some point (previously or currently at time of survey) attended a 2-year institution to students who only ever attended a 4-year institution (and never attended a 2-year institution).

> **Studying with my classmates facilitated peer collaboration, giving everyone the chance to learn from one another, compare notes, and navigate difficult ideas or assignments. Being in a study group has given me the opportunity to be able to reinforce my understanding of the course material and allow me to get help when needed.** (man, White, 2-year institution transferred to a 4-year private institution)

Almost 20% of students' comments reflected the importance of promoting collaboration and connections within the CS learning community. In a variety of ways, students described working with others who can relate to their experiences as a factor that made study groups helpful and **"contributed to their sense of belonging and enjoyment in CS."**

> **Building a stronger bond with peers who are also trying to navigate the computer science space is very uplifting. Seeing my peers succeed motivates me to continue to work hard every single day.** (woman, Hispanic/Latinx, 2-year institution transferring to a 4-year public institution)

Though not evident in the written responses, students who only attended 4-year colleges or universities (either private or public) were statistically more likely to select *study groups with peers* as being important to their success (41.8%) compared to their peers who attended 2-year colleges (29.9%). As with the previous support, this may indicate that *study groups* are more prevalent (or more utilized) at 4-year institutions. One possible explanation is that students at 2-year institutions are more likely to attend part-time, care for dependents, and/or work a full- or part-time job.[28] While these additional factors were not part of the current study, they will be further explored in future research. With increased awareness of these issues, CS education researchers are exploring ways to improve inclusivity in study groups that could be beneficial for institutions. One such tool has yielded positive outcomes for students in study groups, including those with historically marginalized identities.[29]

4 | Family or friends in the CS field to help navigate (selected by 35.8% of students)

Extant research shows that the resources and access that a student attains from family or friends in the CS field typically result in the student's success within the field because they are able to understand the inner workings of the domain as well as have continued exposure.[30] Having family or friends to help navigate the intricacies of a growing field is a prime example of CS-related social capital.[31]

Students in our sample who described *having friends and/or family in the CS field* as a support reported benefiting from their expertise and guidance in the CS learning process. In addition to obtaining academic support, as stated in 86% of the students' comments, 22% of students highlighted receiving encouragement and motivation in their responses. As one continuing-generation student noted:

> **Friends and family members who work in the computer science field provided me with guidance and support. They were able to answer my questions, provide advice on coursework and career opportunities, and offer encouragement throughout my program.** (woman, Asian, 2-year institution transferring to a 4-year private institution)

Subtly, but still present and important to highlight, about 8% of comments included mentions of friends and family constituting a **"support network,"** helping students **"connect with others who share a similar interest in CS"** and feel like they are **"a part of a community,"** all of which are related to factors that contribute to sense of belonging.[32] Considering that lacking sense of belonging has been attributed to negative academic outcomes and disproportionately affects underrepresented identities in CS[33–35], we believe it is important to highlight areas of our supports findings that may suggest strategies to increase sense of belonging. The following quote by a first-generation, Hispanic/Latinx student showcases how making connections with others can positively impact historically marginalized students and potentially address existing barriers that lead to lack of belonging (more on this in the Barriers section).

> **Having connections with others with similar experiences really encourages me and helps make me feel like I'm not alone.** (man, Hispanic/Latinx, first-generation, 4-year public institution)

There were two additional findings apparent in the quantitative data that were not explicit in the written responses. First-generation students were statistically less likely to note this support (31.0%) compared to their peers who identified as continuing-generation students (41.2%). First-generation students, by definition, have had less exposure to post-secondary education from their parents, making them less likely to know how to navigate these spaces. Relatedly, Asian students were statistically more likely to select this support (45.9%) compared to their Hispanic/Latinx (26.3%) and Multiracial (25.6%) peers. This aligns with extant research that racially minoritized groups and first-generation students historically have less field-specific social capital in relation to general and STEM post-secondary education (though these groups have other valuable forms of social capital related to family support).[36,37] Institutions could fill this need for field-specific social capital (i.e., computing social capital) by helping students build such social networks with other students and peers, faculty, and industry representatives.

5 | Faculty or peer mentoring (selected by 28.2% of students)

Prior research indicates that mentoring plays a critical role in students' development academically and professionally.[38,39] Mentoring, whether between peers or between faculty and students, has been linked to increased self-efficacy, interest, identity, and belonging in CS, specifically.[33,40,41]

In this study, one quantitative difference between demographic groups was that student respondents who only attended 4-year colleges or universities (either private or public) were statistically more likely to select *faculty or peer mentoring* as a support (35.0%) compared to their peers who attended 2-year colleges (21.3%). As with the previous supports, we believe these differences may stem from the structural differences between institution types (e.g., size, contact with other students, contact with faculty).

In our sample of written responses, 45% of students differentiated between faculty or peers in this support, with almost 75% of those specifying that the supports described came from faculty and 25% referring to peers only. With less than half the students making this distinction, our data did not provide strong evidence about the importance of faculty versus peer mentoring. Nevertheless, our findings shed light on *how* mentoring was beneficial to students. Overall, the number one theme was receiving academic guidance and help from others with CS expertise (61% of open-ended responses), with some mentions of the importance of receiving individual assistance and professional advice. An increase in motivation and encouragement was highlighted in 14% of student responses, and the importance of making connections was particularly brought up when students described peer support in their comments. As one student put it when speaking of their 4-year private institution:

> **In my experience at a university, I have professors who are always willing to go the extra mile for their students. Mentoring relationships provided me with a supportive environment where I was able to seek guidance, receive constructive feedback, and learn from those who have experience. I received professional advice, access to tools for the IT industry, and assistance in navigating the difficulties of my CS program from faculty or peer mentors at [my university].** (man, White, 2-year institution transferred to a 4-year private institution)

There is a gap in the literature on research regarding structural and programmatic differences between 2-year and 4-year colleges and universities. Future cross-institution research efforts will help us better understand these issues.

6 | Campus supports (selected by 20.9% of students)

Different from *class supports*, *campus supports* are resources more general to a students' growth at their institution and typically are separate from individual courses. *Campus supports*, such as tutoring, writing support, and mental health services, provide students with different kinds of assistance and guidance. Existing literature notes these wrap-around services have positive impacts on students' overall wellbeing in college and may lead to better outcomes for students from historically marginalized backgrounds.[42,43]

In our qualitative analysis, 44% of students describing *campus supports* that were helpful for them mentioned CS tutors and mentors, although some students pointed out that **"as [they] progressed in course levels, less tutors were offered."** Ten percent of students mentioned other kinds of student support at their institutions, with half of those referring to mental health services that helped students **"manage stress"** related to common barriers experienced by CS students (more in the Barriers section below). While only a small percentage of our student sample made explicit mention of mental health issues, it is important to remember the long-standing stigma associated with it.[44] An area that has seen significant growth in higher education institutions, particularly as a result of the COVID-19 pandemic[45], mental health supports can help students navigate college life and lead to successful experiences in their CS programs.

> **My college had resources such as academic advisors, career services, and mental health services, which were valuable in helping me navigate college life and plan for my future. These campus supports were essential in helping me stay organized and manage my time effectively.** (woman, Asian, 2-year institution transferring to a 4-year private institution)

In addition to the academic benefits described in most responses, some students highlighted *campus supports* as a contributor to increased interest, motivation, and/or confidence in CS, as well as sense of belonging and preparedness for professional environments. No significant quantitative group differences were found among those who selected this support.

7 | Joining student organizations (selected by 14.8% of students)

Previous research has shown that *joining student organizations or attending social functions within the department or university* can provide students with opportunities to build their networks, explore career trajectories, build their sense of community at their institution, improve academic outcomes, and increase persistence in post-secondary education (for students from historically marginalized identities).[46,47]

In this study, our student respondents attest that student organizations have a positive impact on their academic journeys and help mitigate barriers related to academic requirements and lack of sense of belonging (more in the Barriers section below). Among those who addressed this support, 56% mentioned that joining student organizations or attending department social events **"provided additional opportunities for networking, learning, and support"** and made students **"feel welcomed"** and as if they were **"part of something."** Over a third of students' responses for this support indicated that this support had a positive impact on students' sense of community in CS, and on increasing students' interest, motivation, and/or confidence in CS.

> **Joining the Computer Science club at [my university] helped me to determine how to continue through the degree as well as helped me reaffirm that computer science is something that I would like to continue doing.** (man, White, 4-year public institution)

In addition, 25% of students who described this support specifically mentioned being part of clubs, like women's clubs and Association for Computing Machinery (ACM) clubs.

While not discussed much in the written responses, Asian students were statistically more likely to select this support (24.5%) compared to their White peers (9.9%), and students who only attended 4-year colleges or universities (either private or public) were statistically more likely to select this support (18.2%) compared to their peers who attended 2-year colleges (11.3%).

While this support was not a frequent selection by our respondent sample, it does not necessarily indicate that *joining student organizations or attending social functions within the department or university* is not an important support. It could be that it is an underutilized or inaccessible support, which will be further explored in the next stage of this research. Of those who did utilize this support, their use of the support and how it aided their success aligned with extant research in increasing their belonging and building their networks.[47] Joining student organizations, attending departmental social events, or belonging to CS-specific organizations are examples of ways that institutions can help fill gaps in students' social networks for those who may not have these kinds of supports (as previously noted in the *family and friends in the field to help navigate* support).

8 | Other supports (selected by 15.7% of students)

As part of the survey, we provided space for students to include supports not otherwise listed. From our qualitative analysis, we compiled the supports listed by students into the following categories:

- Online resources (68.3%)
- Students' personal interest and self-teaching (20.6%)
- Industry/professional experience (12.7%)
- Academic support and access to materials or equipment (11.9%)

Complementing the *Other* supports listed by students, 30% of students' open-ended responses provided details on why *Other* supports[g] were helpful. Predominantly, online resources—referencing mostly online videos or tutorials, forums, and other discussion and Q&A sites—were described as helpful for providing quick and easy access to information that complemented what was being learned in class, including some mentions of engagement with the online CS community.

> **YouTube is a great source, there are a lot of creators and communities that are willing to help on topics that you may not have understood in class. Stack Overflow is a great resource as well it can show you code that does work and you can compare it with yours to see where you may have ended up going wrong.** (man, Hispanic/Latinx, 2-year institution transferring to a 4-year public institution)

The utilization of online resources as a support to CS students in their college coursework is increasingly popular and many tools exist to help students test code, provide feedback, and offer opportunities for collaboration.[48]

Other supports described came from areas of self-reliance, such as personal interest or independent study, with students seeking additional resources to complement their learning—in some cases, to make up for the lack of supports in other areas. There were also some mentions of areas that could have fit other supports from the list of choices but that were not selected, like mentoring, collaboration, prior exposure/experience, or friends/family support. The support seen in opportunities to gain industry or relevant professional experience was particularly highlighted by students, who reported benefits both in terms of knowledge expansion as well as in increasing sense of belonging in CS.

> **Being around women working for Google, Twitter, Microsoft, etc as well as very bright undergrad students made me realize how perfect a CS career could be. Each woman had different interests, one ran a fashion blog, one was fascinated by data science, etc, and they all were able to integrate those pieces of their lives into their work and enjoy**

[g] Including supports described by 1) students who selected Other from the list of supports and addressed that selection in the open-ended space (not the same as, but complementing, the write-in section); and 2) from students who, without selecting Other, chose to use the open-ended space in similar ways. Codebooks can be found in the Supplemental Materials.

their jobs. It was just a very uplifting environment. (woman, White, institution type not specified)

Findings: Barriers

A total of 915 undergraduate CS students responded to the Barriers item of the survey that asked them to select the barriers that impeded their success. About 63% of these students (N = 576) responded to the Barriers open-ended item of the survey that asked them why the barriers they selected impeded their success in their CS program. The most frequently selected barriers were *coursework was too overwhelming or too fast-paced* (49.5%); *poor teaching from professors and/or teaching assistants (TAs)* (37.5%); and *lack of high school preparation for program* (35.0%). See Table 4 for the percentage of respondents who selected the remaining eight barriers.

Table 4. Percent of survey respondents who selected each barrier in the check all that apply item.

Barriers	Percent of Respondents
Coursework was overwhelming or too fast-paced	49.5%
Poor teaching from professors and/or teaching assistants (TAs)	37.5%
Lack of high school preparation for program	35.0%
Inadequate advising on course selection and academic problems	22.0%
Other	16.5%
Lack of inclusive culture/climate in CS and tech-related fields	15.7%
Not many of my peers looked like me	12.9%
Lack of support (e.g., encouragement, respect) from family and friends	10.1%
Negative interactions with the CS and tech-related communities	9.8%
Course content was not relevant to my life	8.6%
Lack of access to personal devices (laptop, software, etc.) or internet access	8.4%

Similar to Supports above, the sections below summarize the findings for each barrier. Awareness of what areas hinder success among students can inform institutions to provide CS students with resources and opportunities that will contribute to more successful and equitable experiences. As more students from historically underrepresented and marginalized identities populate post-secondary CS courses[5,6], barriers related to underrepresentation might start to surface. It is imperative to pay attention to those areas, even when quantitative findings on who is experiencing them remain low. In this section, we strive to bring an equitable approach to understanding the barriers experienced by CS students by describing the qualitative findings of all the options listed on the survey item.

1 | Coursework was overwhelming or too fast-paced (selected by 49.5% of students)

College-level CS *coursework being overwhelming and fast-paced* has the potential to exclude prospective students from succeeding in the course and continuing in the pathway. Students could be overwhelmed with the amount of content in a single lesson or across an entire course. The pace at which instructors deliver content and the time before moving on to new material can also affect student understanding and motivation. Previous research has linked heavy workload and fast pacing of CS instruction to a lower likelihood of first-year students entering the major or for students to drop the major entirely.[27,49] Moreover, CS courses, particularly introductory ones, are known "weed-out"[h] courses[50–52] and should give institutions pause on how they are structured and delivered to maximize student success. As many of the students in this study pointed out, CS is a difficult subject, thus the design of CS curricula and instruction should account for barriers that students will face in engaging with content learning and avoid creating—even if unintentionally—additional barriers. We acknowledge that this is a continuous struggle and that institutions might already be working towards addressing it. Thus, we hope our findings contribute to ongoing conversations and provide insights on (or further emphasize) how this barrier impacts students.

Among students who explained the reasons why *coursework was overwhelming or too fast-paced*, students most frequently described that the material was covered too quickly and felt rushed (45%). This involved covering a lot of material in a short amount of time, especially for those in quarter systems, and having short deadlines. Combining fast pace with **"an incredibly heavy workload"** and "**learning material being too difficult to understand**" (as reported by 25% and 15% of students, respectively), many students struggled in their CS classes.

Over half of the students who described this barrier also reported specific ways in which this barrier impacted their experience. Most commonly, they talked about their performance and their ability to understand the material and grasp concepts. Many students explained that concepts were not always fully covered or that the class moved on before they fully understood topics. As a result, they were struggling to keep up and often had to figure things out on their own, devoting a lot of time and work outside of class to avoid failing.

> **I feel like it has affected my success because for example, when I find it hard to understand a chapter I tend to give up and when the class moves on to the next, it's hard to keep up. Also, so much workload tends to make me rush and with that comes mistakes and slow performance.** (man, Black/African American, 2-year institution transferring to a 4-year public institution)

Other impacts described by participants spoke to the emotional stressors of feeling behind and struggling to keep up, with mentions of stress, burnout, and mental health. While some students added that feeling overwhelmed was to be expected in CS, others stated that, as a result of their negative experiences with coursework, they became disengaged, lost interest, or questioned if they were **"cut for this,"** clearly indicating that students' motivation and confidence were being impacted.

Course structure and context also seemed to matter in how this barrier was presented to students. In 10% of open-ended responses explaining selection of this barrier, students described aspects of the overall class context or format that presented barriers to their learning. These findings may be particularly helpful for those making decisions around curriculum development, course structure, as well as instruction and

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[h] Weed-out courses are introductory courses that typically have a high level of rigor and failing the course would prevent students from moving forward in the sequence or degree major. These courses also typically have high failure rates.

classroom management. For example, specific aspects of the structure within the class included mentions of lack of organization, poor distribution of time and assignments, and comparisons between individual and group work settings. The fast-paced nature of the classes also meant a lack of time for hands-on work, which was described by students as an important aspect of CS learning they felt was being sacrificed. Comments regarding online versus in-person classes revealed that both settings had pros and cons, often due to personal preferences and responsibilities that required more or less flexibility in students' schedules. However, as it relates to this particular barrier, online settings made classes harder for some students, as they could not rely on the support of peers or professors and felt more isolated. Students attending schools that used quarter systems voiced concerns that difficult class material was **"crammed"** into 10 weeks of curriculum. Students also noted class structures that were not setting students up for success, particularly classes with a high failure rate and what many perceived as **"weed-out classes."** Certainly, not all introductory CS courses at the institutions in our sample are viewed as "weed-out" courses, but student sentiments of overwhelming coursework and fast-paced nature are characteristics of such courses.

Students also offered their thoughts on how content was presented and its relevance, with themes that overlap with findings of other barriers listed, namely *poor teaching*, *content was not relevant*, and *lack of high school preparation*. (See below for more information on these barriers.) These overlapping themes are important to consider as we think of strategies to address barriers that students experience, and it shows that inequities among students may be reinforced as layers are added to the challenges they experience. A clear example can be seen as we compare how this barrier was perceived by a student with prior experience:

> **The coursework in my CS program right now has been fast paced, but my experience from high school has helped me greatly.** (man, Hispanic/Latinx, 4-year private institution)

And a student without prior experience:

> **Some coursework was moving really fast and all of my classmates seemed to know what they were doing because they had a lot of coursework in high school to prepare them. It was very discouraging to be last in the class and not know things that seemed to be common sense amongst my peers.** (man, Hispanic/Latinx, 2-year institution transferring to a 4-year public institution)

Courses or professors that expected students to have an existing CS foundation, even in introductory courses, made students who came without prior knowledge feel especially overwhelmed. With all said, our findings indicate that a combination of challenging elements presented by the course structure, content, and instruction can really hinder students' experiences—especially as they embark on their post-secondary CS learning journeys. Understanding the relationship between these barriers can help institutions think of ways to minimize the impacts of barriers that may be more inherently present in CS courses (e.g., CS is a difficult subject) by relieving other pressures associated with the requirements and delivery of such courses.

While institution type was not brought up in the comments from students, quantitatively, students who only attended 4-year colleges or universities (either private or public) were statistically more likely to select this barrier (55.3%) compared to their peers who attended a 2-year college (43.6%).[i]

2 | Poor teaching from professors and TAs (selected by 37.5% of students)

As indicated in the previous section, how well a course is taught impacts student experiences and success in the course. Moreover, prior research suggests that instructors are typically one of the main influences on student persistence.[53] Poor teaching habits or lack of teaching experience by college instructors inhibit learning and may gatekeep entrance to the field. However, student evaluations of instructors are often biased, overlooked, or dismissed as students just being difficult.[54–56] We would like to reemphasize a point made earlier in this report in that we hope this section in particular is read as intended, which is for institutions and instructors of CS students to understand how they may be contributing to barriers preventing student success. Learning from negative experiences and making changes to teaching practices can positively impact students. We also emphasize that there is no one definition of high-quality CS teaching and that our prompt was left open for students to define that for themselves. As such, it may be the case that CS programs are providing high-quality teaching (by scholarly definition) that is not perceived as such by students. Here, our goal is simply to report student perceptions of the teaching.

Our quantitative analysis revealed two differences between student demographic groups. First-year students were statistically less likely to select this barrier (28.2%) compared to their peers who were in their 3rd, 4th, or 5th (or more) years into the program (42.5%, 56.3%, and 60.4%, respectively), and 2nd year students were statistically less likely to select this barrier (31.3%) compared to their 4th and 5th year peers (56.3% and 60.4%, respectively). This could be due to students later in their years having more exposure to CS teaching to provide such evaluations or those who persisted having had better teaching early in their CS education. The second difference observed was that students who attended 4-year public institutions were statistically more likely to note this barrier (55.2%) than their peers who attended 4-year private institutions (36.7%). Private institutions typically have smaller class sizes, which could contribute to perceived teaching practices, though this difference was not discussed in students' open-ended responses and can be further studied in future research.

Among students' descriptions of why *poor teaching* was a barrier to their learning, over 70% attributed their comments to their professors, 5% mentioned their high school teachers, and 3% talked about TAs or tutors (the rest did not specify). Over half the comments described issues related to how material was taught in their classes. The most cited issues were receiving inadequate explanations of CS topics (e.g., topics not being explained enough, or materials presented without explanations or examples), and that class was not taught well (e.g., professors were not good at *teaching* CS or used outdated methods or concepts).

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[i] Only significant group difference findings are noted in the text of the report. Non-significant group differences and group descriptives are available in the Supplemental Materials for reference.

> **My instructor was not very good at explaining the material. They would merely read from long PowerPoint presentations and practically hand out the answers to our class 'activities.'** (woman, Hispanic/Latinx, high school student taking courses at a 2-year institution)

Students also shared their experiences with content taught in ways that lacked relevance and/or did not engage students (e.g., not enough hands-on instruction or real-life application). Poor organization in their courses and unclear expectations led to confusion, and some students also talked about instructors not making the best use of class time.

In addition to focusing on how content was taught, students also reported lack of support from their instructors (18%), instructors with poor attitudes (14%), too many expectations for students in introductory courses (11%), and lack of CS skills and preparation in their instructors (4%).

> **Professors were often aggressive and did not create environments where you could learn from mistakes. Many acted like they had no time for students and we had no right to be there. Very little communication.** (woman, White, 2-year institution transferred to a 4-year public institution)

About 38% of students who described this barrier delved into the impacts of the *poor teaching* they received, describing difficulties in understanding or learning CS content, a decrease in confidence and motivation, and having to rely on themselves to try and overcome barriers. The following student captured a variety of themes that emerged across many students' answers:

> **It can be disheartening when you have a great interest in a course, but the instructor is not able to effectively convey the material. This happens frequently and it is sad when that happens because when you invest your time and financial resources, but you only receive poor guidance. This can lead you to frustration and demotivation. To overcome this, I have found that doing additional research and finding additional resources can help to deepen my understanding of the material. By taking a proactive approach, I have been able to succeed academically.** (man, Black/African American, 4-year private institution)

Even when instruction felt like a barrier at first, some students **"managed to get through it by getting to know the teacher more and going to office hours,"** which signals to some instructors' efforts to help students overcome barriers (even when instructors might unintentionally create them).

Across STEM, poor teaching has negative consequences for the majority of students, whether it presents as negative learning outcomes or leaving the STEM major altogether.[57] The student examples above mirror other studies in how STEM students define poor quality teaching as being disorganized, unapproachable (both in instructor's demeanor as well as content complexity), and disengaged.[57]

This section's objective was to collect information on poor teaching as a barrier, but the issues that students described do not account for the positive impact that some instructors may have had on students' experiences (as evidenced in the *class supports* and *faculty and peer mentoring* sections above). Our findings here show the importance of the delivery of instruction in CS learning. While this is true for any subject area, it may be especially relevant when learning the complex topics and processes involved in CS. As one student put it,

> **Instruction plays a huge factor into how well students comprehend material. Without proper teaching, I had a greater struggle understanding course material than when I received good instruction.** (man, Multiracial, 4-year private institution)

3 | Lack of high school preparation (selected by 35.0% of students)

Extant research notes that prior experience in CS has been shown to impact student performance and persistence to varying degrees.[19,21] However, a lack of access to CS education negatively impacts student success and hurts the field more broadly.[21] Many students do not have access to CS education before college.[7] This limits their opportunities for post-secondary CS education because they may not know how to navigate course offerings or have a foundational understanding of CS concepts that could make introductory CS courses a lower bar to overcome.

Given that 40% of our survey respondents reported not taking CS while in high school, it was no surprise that students who did not take CS in high school were statistically more likely to select this barrier (46.3%) compared to their peers who did (26.8%). This was reflected in students' narratives regarding lack of high school preparation. These students said they were **"new to the field,"** learning CS **"from scratch,"** and had no prior experience coming into CS in college. The lack of background knowledge in CS was emphasized, sometimes with comments like **"I didn't take CS in high school/before college,"** although not always specifying whether students had the opportunity to take CS in high school and simply did not take it, or if it was not an option altogether.[j] One student said, "**I did not know my high school offered computer science classes so I sometimes feel behind than others who have taken classes in high school"** (woman, Hispanic/Latinx, low-income, 4-year public institution). In some occasions, like this student who felt behind, students described that due to having no previous CS experience, they had a hard time and needed to adjust to the pace and content of their courses.

In 35% of the responses explaining this barrier, students described having exposure to CS during high school, but receiving inadequate preparation (i.e., what kind or how many CS classes were offered, and the quality and relevance of the content taught). While most students talked about course content in terms of CS skills (e.g., that it did not go in depth, was too vague, taught them things that were not helpful in college or in a different programming language), some students also described poor preparation for **"what's to come"** and lack of adequate guidance in terms of field expectations and knowledge about the industry. A few students referred specifically to their high school teachers as the reason they were unprepared, stating that they caused insecurities, that they did not foster confidence, or that they were learning CS while teaching it **("my [high school] teacher knew nothing about CS")**. This theme also

[j] Reasons why students did not take CS in high school will be further explored in subsequent reports of this series.

came up in the *poor teaching* barrier, where some students used the space to describe barriers they experienced with their CS teachers in high school.

In addition to gathering information on where the lack of preparation originated from, 22% of the student responses captured that being unprepared made students feel insecure about their CS skills and abilities and that they were behind. In the majority of those comments, students compared themselves to other students in their classes who seemed to be more prepared. Below is one such example:

> **Deciding to major in computer science my first semester of college posed a challenge as most people I have spoken to in the community have been taking classes/pursuing computer science since early high-school. This has caused me to feel unconfident and self conscious in my ability.** (woman, Hispanic/Latinx, 2-year institution transferring to a 4-year public institution)

As we know, access to CS coursework in high school is still inequitable.[7,18] Students from low-income neighborhoods and schools are less likely to have access to such coursework.[7] In Illinois, low-income students are not equitably represented in general or rigorous high school CS coursework.[18] This was exemplified by another quantitative finding that revealed that low-income students were statistically more likely to select *lack of high school preparation* as a barrier to their success (40.8%) compared to their non-low-income peers (29.4%). As the above student quotes explained, lack of high school preparation hindered success in many ways and the inequitable access for some groups further exacerbates standing inequities in the field. Introductory courses can address students' different levels of experience to better mitigate the challenges students face when coming into post-secondary CS education as beginners.

4 | Inadequate advising on course selection and academic problems (selected by 22.0% of students)

Similar to instructors, counselors and academic advisors could unintentionally be a source of gatekeeping and participate in the exclusion of learners.[58,59] Inadequate advising (both in terms of quality of advising and presence of advising) can create issues in proper course selection (relative to prior knowledge), sequencing of courses, completing necessary requirements, and time-to-degree.

In this study, one quantitative finding not evident in students' written responses was that students who attended 4-year public institutions were statistically more likely to select this barrier (32.1%) compared to their peers at 4-year private institutions (19.9%), indicating that there may be some structural factors at play (e.g., size, advisor-to-student ratio, access to an advisor). Once again, we see institution type (and possibly embedded structures) play significant roles in the support or hinderance of student success.

When students elaborated on why *inadequate advising on course selection and academic problems* impeded their success, most described experiences with their advisors. There were also some instances when students described receiving poor advising from a professor, tutor, or advisors in high school, as well as the lack of CS guidance growing up. With that in mind, there were various ways in which students received inadequate advice on course selection or enrollment, an issue described in 69% of the comments on this barrier. In terms of overall course enrollment (CS and other courses), students stated that poor advice resulted in a heavy load and impacted their performance in CS courses. When students described inadequate enrollment advice within CS programs, they mentioned issues that affected course sequence, preparation for upper-level courses, appropriate timeline to stay on track with academic goals, and meeting program requirements while also allowing for students' CS skills to progress gradually. Some students specifically described receiving inadequate advising around classes' difficulty, whether they were put in a class that did not fit their needs or level, or simply stated that the introductory courses they took were more advanced than an introduction to CS. A few students brought up course selection and enrollment advice during high school, reporting that their high school advisors did not advise on course-taking appropriately, both in terms of CS courses to take in high school or in looking forward to college and helping choose the right path. Students' responses also highlighted the implications of receiving inadequate advice and how its consequences could truly impede success, as in the case of the following 4th year student:

> **Bad advising has extended my university stay by two semesters. Finding credit hours to keep Full Time status and Financial Aid is now a challenge. Additionally, this has developed some semesters with an intense workload too.** (man, White, 2-year institution transferred to a 4-year private institution)

Relatedly, students further along in their academic career were statistically more likely to select this barrier (27.4% of 3rd year students, 31.7% of 4th year students, and 35.8% of 5th year or more students) compared to their peers in their first year (11.0%). While being in college longer increases one's chances of experiencing advising issues, issues in course selection and advising could impact students' time-to-degree and, in turn, cause them to incur more expenses, as noted by the student above.

In addition to course selection, 43% of student responses about this barrier included issues of poor academic guidance or support from advisors. This includes mentions of advisors not being helpful or available, with examples of CS programs and departments with not enough advisors, negative interactions with advisors (**"they belittled my ideas"**), and poor guidance regarding overall academic goals towards graduation or career goals.

> **When I was getting help from my advisor for my first semester of college, I feel like she didn't help me pick the best courses even though I made it clear that I was interested in computer science, so I feel like that was a setback.** (woman, Hispanic/Latinx, 2-year institution)

All the different ways students described receiving *inadequate advising* signal areas in which advising could improve. With advising resources being a form of support utilized by many students (see *faculty and peer mentoring* support above), it is crucial that advising addresses students' needs and helps them overcome challenges, not impose new ones. Given the changing nature of CS programs and student needs, advisors (both in high school and college settings) need to be prepared to better serve students and ensure a pathway to success.

5 | Lack of inclusive culture or climate in CS (selected by 15.7% of students)

The next two barriers share some similarities regarding lack of inclusion and underrepresentation in the field. National and state data suggest secondary and post-secondary CS education are often overenrolled by White and Asian students and are cis-male-dominated.[5,6,18,60,61] This may make it more difficult for someone who does not identify as a cisgender male to feel a sense of inclusion and belonging, which has also been shown to negatively impact persistence.[62] This lack of diversity and inclusion in CS, and STEM more broadly, has often gone hand in hand with hostile environments filled with misogynistic or bigoted behaviors and microaggressions towards students.[63,64]

From our quantitative data, we found that this barrier differed on gender and racial identities. Women were statistically more likely to select this barrier (20.8%) compared to their male peers (13.3%), and Asian (21.6%), Black/African American (23.2%), and Hispanic/Latinx (19.8%) students were statistically more likely to select it compared to their White peers (8.8%). These findings indicate that this barrier is more likely to be perceived by students with historically marginalized identities, which exemplifies why addressing barriers that may have been selected seemingly infrequently by the aggregated sample is necessary in this discussion. Such barriers were selected two times as frequently, in some cases, by historically marginalized students less represented in our sample.

The findings of why *lack of an inclusive culture or climate* was a barrier to students predominantly include themes of underrepresentation and community and belonging in CS college classes and in the field. The majority of students (58%) who described this barrier spoke about race or gender underrepresentation and the stereotypes that come with it. Half of them identified as part of a minoritized group and described underrepresentation as the reason for their own lack of inclusion in CS. Students also reported reactions to this barrier, such as feeling the need to prove stereotypes wrong (i.e., stereotype threat[65]; for example, that women are not good enough for CS), being intimidated by the lack of inclusion or representation of their identities and questioning their ability to succeed in CS, or having feelings of not belonging or not being supported. As one female student said,

> **It can be a bit intimidating at times being a woman pursuing a degree in tech. In a way, it's motivating to be a female software engineer since there is such a lack of them. But at the same time, it can be discouraging. There seems to be a superiority complex that is commonly found in a lot of people in computer science. A holier than thou type complex where if you don't know how to do something, you are looked down upon as stupid rather than having a community that is open minded and helpful.** (woman, White, 2-year institution transferring to a 4-year public institution)

The other major category in student responses describing this barrier (44%) was the lack of community and belonging. This sometimes reflected the students' individual challenges engaging with peers, or a general lack of a sense of belonging by feeling excluded or unwanted. In the latter, students did not always offer details about why they felt excluded, thus limiting our ability to attribute a cause. What we can say, however, is that this lack of inclusion created barriers to students at both academic and emotional levels, impacting opportunities for success. As one student put it, **"It's hard to focus on work while feeling unwanted,"** (gender self-identified as "uncertain," White, 4-year public institution). These findings align with extant literature in that being from a marginalized racial or gender group in STEM often left students feeling isolated, overlooked, and unable to relate to their peers.[66]

In addition to the issues described above, 11% of students who described this barrier talked about a lack of inclusive culture in CS due to the competitive nature of the field. These students referred to unspoken expectations of what and how much students are supposed to know, or being looked down upon for not knowing something, for example.

> **While the university that I attended has a lot of diversity, it does not feel like they leverage that to create a good community among its students. There's also stereotypes among the CS field where it is dominated by straight cis men. That in itself does not feel diverse.** (man, Hispanic/Latinx, 4-year public institution)

The *lack of inclusive culture or climate*, including competitive peers and difficulty building community, have been noted in STEM persistence literature before.[66] Moreover, women and students of color were more likely to note being negatively affected by STEM's climate and lack of belonging compared to their White and male peers.[66]

Another theme brought up was the lack of inclusion of industry exposure in CS programs (8%). Students described lacking connections with the field and having no opportunities at their schools to connect with businesses. They also noted the importance of having exposure to CS/tech related fields during their college experience to understand the real-life applications of CS content (more hands-on work). A third-year student shared:

> **I feel that there could always be more inclusive opportunities, and I feel my school, like many, needs to find out how to connect with businesses to work on real world projects with college students, benefiting both parties.** (man, White, 4-year private institution)

While this last theme differs from other areas of exclusion (e.g., not feeling worthy or not belonging in the field), it exemplifies the perceived barriers of students with marginalized versus non-marginalized identities. Mentions of lack of opportunities for industry exposure were less prevalent in the comments students made explaining this barrier. However, students made comments of this nature across different barriers, which indicates the value that students see in getting real-life experience as part of their CS learning[67] and the different areas of their experiences that may be impacted without it.

6 | Not many of my peers looked like me (selected by 12.9% of students)

Related to the previous barrier, inclusion can also take the form of feeling underrepresented physically in courses and the field more broadly. Because CS is overrepresented by White, Asian, and male students, students not identifying as one or more of those identities may feel out of place.[5,6,61,66]

Our quantitative data from the survey revealed several significant differences in who selected the *not many of my peers looked like me* barrier. Women (22.8%), Black/African American (19.5%), Hispanic/Latinx (22.7%), first-generation (17.7%), and low-income students (16.6%) were all statistically more likely to select this barrier compared to their peers.[k] Similar to the previous barrier, despite lower selection of the aggregated sample, students with marginalized identities experienced this barrier more.

These differences were also evident in the students' comments. When students explained why *not many of my peers looked like me* was a barrier to their success, 56% (mostly female students, but not exclusively) talked about the underrepresentation of women in their CS classes, departments, or the field as a whole. Similarly, 33% of students' responses included mentions of race underrepresentation, particularly of Black/African American and Hispanic/Latinx identities. Only a few students described issues unrelated to race or gender underrepresentation; in these cases, this barrier was presented by students from non-traditional pathways (e.g., older students, from a military background, etc.) who struggled to connect with peers due to having different interests and priorities.

Some students from historically marginalized identities were aware of persistent inequities in the field before starting their programs and expressed being nervous about entering a space where they would be a minority: **"the few amount of women of color in STEM related fields made me reluctant to take the course"** (woman, Asian, 2-year institution). Expectations of barriers unique to historically marginalized groups became reality to them, most of whom went on to explain how it impacted their CS learning experience. Due to the underrepresentation of their own identities, students carried the weight of being **"the minority"** and felt a lack of connection with peers. As a result, these students reported feeling **"uncomfortable," "stressed," "different," "alone,"** feeling like **"the odd one,"** and **"unable to relate to peers"**—all feelings that impacted their sense of belonging in the class, but also more generally in CS.

> **Out of any challenge I've ever experienced in learning computer science I'd have to say that being one of the only women in all my classes for computer science has been the hardest. In any college computer science class I've taken, I'm always either the only woman or one of two women and that is just difficult mentally because it makes me feel like I don't fit in. It also makes me feel like I have to do above average just to prove myself since the field is very male dominated.** (woman, Multiracial, 2-year institution)

For some students, the mere fact of feeling like a minority triggered stereotype threats and assumptions based on underrepresentation, thinking, for example, that others may **"look down on [them]"** or **"think less of [them]."** These comments were predominantly made by women who expressed feeling like they had to work harder to fight gender stereotypes and **"prove [their male peers] wrong."** Oftentimes, these assumptions were also based on negative interactions with other peers from dominant groups (mostly White male students) or even professors. Whether students experienced negative interactions due to their

[k] Compared to their male (8.3%), White (6.8%), continuing-generation (8.2%), and non-low-income (8.2%) peers, respectively. See the Supplemental Materials for statistical testing and result tables.

identities or not, our data show that the type of pressure felt by minoritized students in CS classes was a unique challenge they had to face. Without peers or professors who could relate to their experiences and offer appropriate support, these students felt a lack of community and the need to make a space for themselves. As a result, CS was perceived by many minoritized students as a **"solitary major"** where they constantly felt inferior to their peers, questioned their abilities to learn or do CS, and experienced a decrease in confidence and self-esteem.

> **I am an inexperienced woman in CS which is a recipe for disaster. I constantly feel like I have to prove to the male students in my class that I belong there. In addition, the concepts taught are overwhelming and taught poorly, so I feel like I have no chance of catching up to my peers.** (woman, Asian, 2-year institution transferring to a 4-year public institution)

Intersectionality plays a big role in students' journeys, as each layer of marginalization that forms a student's identity adds unique challenges. The intersection of gender and race came up a number of times, particularly around the **"the few amount of women of color"** in CS classes or the field as a whole. For women of color, this added to their challenging experiences in ways that other (White) women may not experience.

> **In the past, I have experienced hesitation when asking peers in my CS courses for help due to feeling like I was the odd one out. My previous CS courses had lots of people of the opposite gender and race as mine. I have also seen how they interacted with people when asked for help, and it made me uncomfortable and even doubt my abilities. It is really up to you to find a group or community of people that you fit into when it comes to CS.** (woman, Multiracial, 2-year institution)

Similarly, students who identified as LGBTQ+ were uniquely impacted by the exclusionary climate that they experienced.

> **Being a trans woman, I often feel like when discussing with peers that I'm looked down upon, or that I'm perceived as less qualified than other students in the same class. I don't see many women in my classes, and I especially don't see openly queer people in my classes.** (woman, White, 4-year public institution)

The issues brought up in these findings are shared with other barriers commonly experienced by all students (like *overwhelming coursework* or *poor teaching*), adding layers of challenges that compound each other. Our findings show that these barriers not only exist but that when students face a combination of barriers, the impact may be greater. Combining issues of underrepresentation and other barriers like lack of prior exposure, first-generation status, and more can be—as the student in the quote above put it—**"a recipe for disaster."**

Unfortunately, much of our findings in this section are not new to STEM or CS, specifically. They have been reoccurring, prevalent themes in research for decades.[15,68]

7 | Lack of support from family and friends (selected by 10.1% of students)

As previously noted in the Supports section of this report, having the support of friends and family can provide students with social capital to navigate not only the post-secondary space but also the CS field more broadly. The opposite of this could be detrimental to students. Previous research has shown that if a student does not have the respect or encouragement from their family or friends to pursue CS as a major or career, they are less likely to persist.[30,69]

Similar to previous barriers, while this barrier garnered lower selection by the aggregated sample, this barrier was noted more frequently by students with marginalized identities. First-generation students were statistically more likely to select *lack of support from family and friends* (14.0%) than their continuing-generation peers (6.4%), which is highlighted in the qualitative findings. Among those who described lack of support from family and friends, almost two thirds described not being able to receive family support due to lack of CS knowledge (**"family doesn't get it"** or **"they aren't technologically inclined"**) or unfamiliarity with how to navigate post-secondary systems (including balancing life/studies). This was particularly true for first-generation students, exemplified by the following student:

> **Not many members from my family understand my program, so it is intimidating as a first-generation Latino to enter CS programs.** (man, Hispanic/Latinx, first-generation, 4-year private institution)

About another third of students who described this barrier also shared that their families did not support the idea of them pursuing CS, or simply encouraged them to choose another field they thought provided better future opportunities (e.g., medicine or the law) or to pursue a degree in a specific field **"like the rest of the family."** As another first-generation student noted, **"some of my family is disappointed that I decided to go into tech as they want me to stay in healthcare"** (woman, Multiracial, 2-year institution transferred to a 4-year public institution).

As noted in the Supports section above for *family and friends in the field to help navigate*, those who had relationships with people within higher education or the CS field helped them in many ways. For students who do not have existing relationships, or in the case of this barrier, lack support from those close to them in their decision to pursue CS, institutions can step in to help students build other kinds of supports. Supports noted previously that helped students build communities of support included *joining student organizations and attending departmental functions*, *faculty or peer mentoring*, and joining *study groups* with their classmates.

8 | Negative interactions with the CS community (selected by 9.8% of students)

Negative interactions with the CS community reveal aspects of the environment that may not be welcoming to some groups of students or describe the competitive nature of the field. Students from historically marginalized backgrounds in STEM (e.g., women, Black/African American and Hispanic/Latino, low-income, and first-generation students) are more likely to face negative interactions within STEM, whether that's with other students, instructors, or the field more broadly.[66,70]

In the qualitative data, the competitive culture of the CS field and stereotypes around how **"CS people"** behave and interact with others were common topics in most students' descriptions of this barrier.

> **The CS field is very competitive and didn't make me feel too welcome.** (man, Hispanic/Latinx, first-generation, 4-year public institution)

Interactions with others in CS spaces and the pressure students felt to fulfill expectations of **"being a CS person"** impacted students' motivation to pursue CS or made them feel unwelcomed and as if they did not belong. This barrier also surfaced topics of underrepresentation and lack of sense of belonging that have been described in addition to, or in combination with, other barriers to success (e.g., *not many of my peers look like me* and *lack of inclusive culture*). From the qualitative data, negative interactions related to issues of underrepresentation in the field were mostly reported by students from historically marginalized identities. In these interactions, oppressive behaviors and stereotypes were being reinforced by male peers and professors, causing feelings of inferiority, insecurity, and/or exclusion. Female students from various racial identities reported being affected by this barrier, sometimes making direct comparisons to how they were treated compared to their male peers:

> **I also have had a couple negative experiences individually with a CS student where I felt that they treated me in a very condescending way and doubted my knowledge and abilities. It also felt slightly sexist to me because I am a woman and I've seen how that CS student has treated their male peers in comparison to me. That was kind of discouraging for me because it made me doubt myself. At the end of the day though I know I can overcome no matter what.** (woman, Multiracial, first-generation, 2-year institution transferring to a 4-year public institution)

Or as one student put it plainly:

> **The CS community is almost all men and they don't really seem to want to talk to me.** (woman, White, first-generation, 4-year private institution)

The intersection of race and gender seemed to exacerbate this issue, which was evident in comments made by some women of color who described their own experiences:

> **I also feel scared that my professors (who are mostly white men) will think of me as just a stupid black girl who isn't trying. One of my professors looked at my code and told me word for word "What the hell is that?". Things like that would shake the confidence I had in myself.** (woman, Black/African American, 4-year private institution)

But also acknowledged by students who identified as part of both a minoritized and a privileged group:

> **There isn't enough Latino representation in tech and the subject matter and subject culture don't encourage that to change. It feels like a toxic boys club that excludes people based on race, culture, and sex.** (man, Hispanic/Latinx, first-generation, 4-year public institution)

While first-generation status was not directly brought up in students' written responses, the experiences detailed above came mostly from first-generation students. In fact, our quantitative data revealed that first-generation students were statistically more likely to select *negative interactions with the CS community* (12.8%) compared to their peers who were not first-generation college students (6.4%). This aligns with extant research that first-generation students are more likely to have feelings of imposter syndrome due to negative interactions in their STEM classroom, and were thus at a higher risk for poor academic outcomes and likelihood of dropping out.[71,72]

Once again, even though this barrier was not often selected by the aggregated sample, it was noted twice as frequently by students with marginalized identities.

9 | Course content was not relevant to my life (selected by 8.6% of students)

Prior research has shown that relevancy of course material when learning new topics has been found to be among the most critical factors for motivating students.[73] Personal and professional relevancy not only keep students engaged but provide examples of how complex concepts apply to real-world problems.[74] If relevancy is not apparent in course content, students can be left uninterested, demotivated, and questioning their place in the field.[75]

While this barrier was selected by a smaller proportion of our sample, existing literature shows relevancy of content is important for student learning (e.g., culturally relevant pedagogy in CS[76]). Our data add student voice to that body of literature and provide specific information on what students perceive to be (ir)relevant curriculum.

When describing why content was not relevant, half of the students commented on academic aspects related to their program, including required courses that did not seem helpful or relevant to their specific programs. For example, irrelevant advanced CS courses for certain CS majors: **"As a CyberSecurity major there were a lot of really difficult classes that weren't relevant to me"** (man, White, 2-year institution transferred to a 4-year public institution). Students also discussed limited availability of course options and enrollment limitations, having to take courses that did not fulfill graduation requirements, or having to spend time on non-CS courses to fulfill general requirements.

> **I think I have spent way too much time on subjects that don't make any sense to me or my career. I am taking Humanities 101 to fulfill the Humanities requirement, and it's extremely frustrating to spend so much time on something I will never revisit in the future.** (woman, Hispanic/Latinx, 2-year institution)

Students also made comments about the topics taught in class being outdated and the lack of teaching of modern tools and technology, or about not finding class material engaging due to the way it was taught.

One third of the comments on this barrier focused on personal relevance. Students described that for personal reasons (passion, career goals, etc.), they did not feel CS courses, or specific CS topics they had to learn, were relevant to them. Some students said they enjoyed some topics or courses more than others, which sometimes impacted the student's overall interest, motivation, and learning. As the following quote exemplifies, this issue amplified other barriers experienced by students:

> **In some specific courses, the perfect storm of lack of background knowledge, overwhelming course work, poor teaching, lack of passion/motivation due to irrelevance, and lack of support really pulls me down.** (man, Asian, 2-year institution transferring to a 4-year private institution)

Industry relevance came up again in our qualitative findings for this barrier. Students described ways in which they thought CS courses were not preparing them for the industry workforce. Some students said that what they were learning did not align with skills required by the industry, or that they did not have industry exposure and these courses were not enough to help them see how skills will apply in real-life situations:

> **Some classes are never needed in the future work environment and made me feel demotivated to learn it.** (man, White, 2-year institution)

While not evident in students' written responses, the quantitative data revealed some significant differences in the selection of this barrier among students' demographic groups. One difference was that students who attended a 4-year public institution were statistically more likely to note this barrier (12.7%) compared to their peers at 4-year private institutions (5.7%). While we cannot know for certain why this difference is apparent, it could possibly be similar to the rationale for the same difference observed in the *poor teaching* barrier—private institutions typically have smaller class sizes which could contribute to perceived teaching practices. Similarly, future research into these differences between 4-year public and private institutions is warranted.

10 | Lack of access to personal devices or internet access (selected by 8.4% of students)

About 9% of households in the U.S. do not have access to the internet and about 4% do not have access to a personal computing device such as a laptop, tablet, or smartphone.[77] National studies show that those without internet access mostly attribute it to affordability or infrastructure, with rural communities less likely to have the infrastructure needed.[78] For CS students, personal devices and internet access are needed to complete even basic assignments, not to mention that more and more course materials are only being stored online in learning management systems. So, while access to affordable broadband internet and personal devices is critical to everyone in a digital society, it is a necessity to those pursuing CS education.

While this barrier was the least selected by our respondents, it is still a barrier of which institutions should be aware. Moreover, according to our quantitative data, low-income students were statistically more likely to select a *lack of access to personal devices (laptop, software, etc.) or internet access* (12.2%) than their non-low-income peers (4.4%), which aligns with national research that low-income families are less likely to have internet access.[79]

Students' written descriptions of how they were impacted by this barrier focused on three areas: devices, internet, and programs or software. Students said not having access to a laptop or machine was a major barrier and those without had to rely on school resources. However, this reliance limited the time they were able to spend working on their CS coursework and their access was dictated by what resources were available at their schools and when they were accessible (number of computers available, hours of operations in labs/libraries, etc.). In a few instances, students described that it was not just about having a computer, but the type of computer that was needed. Some students said their personal computer did not have the capacity to handle required programming, thus impacting their ability to get work done and practice outside of class. Software and programming were described in this barrier not only in terms of the capacity required to run specific programs, but also referring to cost and accessibility.

> **I faced some financial difficulties this particular semester and so I did not have access to a laptop, and I had to pay my tuition entirely out of pocket with no help from any family. This made it a bit difficult to spend as much time as I wanted on my CS course, as I didn't have a laptop or computer always accessible.** (woman, Asian, 2-year institution)

The lack of access to internet (or just **"high speed internet"**) was described by students as a barrier that prevented their success in similar ways as noted above.

11 | Other barriers (selected by 16.5% of students)

Just like in the Supports survey item, students had the option to select *Other* and to write-in other barriers that were not listed. Our quantitative findings show that 16.5% of students selected this choice, 70% of whom wrote in information on what other barriers they experienced:

- Personal barriers (58.5%)
- Course-related barriers (41.5%)
- Underrepresentation and exclusion (11.9%)
- Lack of support and resources (7.5%)

Students' open-ended responses captured additional information about the ways in which *Other* barriers[l] impeded their success (see Table 20 in the Supplemental Materials). The largest theme (personal barriers) described situations specific to students' lives that presented barriers to their learning, including references to school-life balance, personal health (mental health, in most cases), feelings and emotions, and financial issues. Despite not being presented as named options in the survey, these barriers were sometimes common across students' experiences and could point to systemic barriers that, again, may disproportionately impact students from marginalized identities. Most students who described these barriers said it was challenging to balance CS studies and responsibilities outside of school (e.g., work, families), or described emotional challenges from feelings like self-doubt, low confidence, or burnout. There were also students describing personal health issues (including mental health), poor study habits, and financial burden.

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[l] These findings combine barriers described by students who selected Other from the list and by students who, without selecting Other, chose to use the open-ended space to describe barriers outside of the options provided in the survey.

> **Biggest obstacles for me have to be that I am 25 years old I live out on my own and I'm fighting for survival everyday trying to work and make money and at the same time finish up school and get this degree so I can better my life it's been a challenge but I refuse to give up because I know what this degree can do for my life and current situation.** (man, Middle Eastern and/or North African, 2-year institution transferring to a 4-year public institution)

Another area commonly described in students' open-ended responses brought up course-related barriers, with topics that align with barriers described by students who selected survey options related to coursework, course structure, or instruction. While barriers pertaining to online learning and class availability were predominant, these findings also surfaced barriers experienced by students without prior exposure to CS, international students, and students who described language barriers in their learning.

Less frequent but still common topics across survey responses, students' comments also reflected a general lack of help or supports in their program, as well as issues of underrepresentation in the CS community and a lack of sense of belonging. In a more positive light, some students provided descriptions of being able to overcome the barriers they experienced. These comments included mentions of students relying on themselves, making use of existing supports at their institutions or online, maintaining a positive attitude and determination, and, as conveyed in the following quote, being an advocate for oneself and for other marginalized groups.

> **When I was first exposed to computer science I was in a room with around twenty-two men and three women (including myself). I recall feeling very excluded and constantly getting spoken over when I pitched ideas. I did not have the best support system in the space that I was in and I often felt like I didn't belong. I now avidly advocate and make space for myself and fellow Latinas in stem. It is important for us to continue to be our best authentic selves even in spaces where we feel excluded.** (woman, Hispanic/Latinx, 2-year institution transferring to a 4-year public institution)

Findings from barriers not already captured by the survey highlight support structures that are essential to ensuring students' success: health care (physical and mental), financial support, academic support, and flexibility needed to balance what students face outside the classroom.

Conclusion

This study explored the supports and barriers undergraduate students faced in their CS programs. Some supports and barriers were individualistic (specific to the student), and others were focused on the institution. By centering student voice and honoring all shared experiences from both our quantitative and qualitative findings, we hope to provide a wide range of issues and improve our understanding of how students view their CS learning opportunities. We hope these findings inform post-secondary institutions on how to provide their students with a more inclusive learning environment and continue to promote success for all students.

Supports

Our study found several resources that helped students succeed in their CS programs: *prior experience* in CS, *class supports* provided by the instructor, and family, friends, and peers in the field to support them. It should be no surprise that *prior experience* was seen as a top resource for students. This reinforces the importance of early exposure to CS-related content because not only does it help students who pursue CS as a major, but it also opens the door sooner to ignite interest in students of all backgrounds. That said, male, Asian, White, and Multiracial students were all statistically more likely to note they had this support compared to their peers. Possible solutions to bridge such gaps could be introducing a summer preparatory course for those with no or limited previous CS coursework experience and ensuring that introductory post-secondary CS courses are indeed introductory. Many students in our sample noted that their introductory courses were not truly introductions into the field and assumed some prior knowledge. Additional supports such as added office hours, supplemental instruction, and tutoring may prove beneficial for those for whom high school CS coursework was inaccessible.

CS-related social capital was another major theme in our analysis of the supports. Students relied on family, friends, and peers in their class to help with studying, networking, and more. Social capital is also pivotal in continued interest in the field and overall persistence. We see familial and friendly relationships as another avenue to introduce students into CS that may be part of broadening participation at younger years. However, according to our quantitative findings, Hispanic/Latinx, Multiracial, and first-generation students were statistically less likely to note *family or friends in the field* compared to their peers, and students who attended 2-year institutions were statistically less likely to note supports such as *class supports*, *study groups*, *faculty or peer mentoring*, and *joining student organizations* compared to their peers who attended only 4-year institutions. For students without connections or relationships in the CS field, it would be prudent to work with students to extend their networks so they too can reap the benefits of CS-related social capital. Institutions can help students extend their networks by connecting them to industry internships or apprenticeships, holding first-year seminars with alumni and other CS majors on campus, introducing students to existing (or creating) CS clubs and organizations at the institution or in their community, and establishing mentoring programs with faculty, more senior CS majors, or industry partners.

Barriers

Common barriers included *overwhelming coursework*, *poor teaching*, *lack of high school preparation for their CS program*, and issues related to lack of diversity and inclusion in the community. These findings should signal to post-secondary programs that there is a lot of work to be done on many fronts. Efforts related to broadening participation in high school CS will positively impact students' interest and participation in post-secondary CS education, and hopefully prepare them better for the content they study in college. While we realize the responsibility here falls on high schools, it is important for college programs to acknowledge the disparities impacting students entering their programs. The other issues are ones that need to be addressed as a community and on an individual basis with post-secondary institutions. Institutions need to place an emphasis on instructor preparation and effective teaching methods. Students frequently noted that their instructors were more than capable of teaching the content of their CS course, but their methods were not always conducive to effective learning. For instance, students described several bad habits (e.g., reading off slides, moving on too quickly, not unpacking complex topics or explaining their code) that hindered their learning. From our quantitative data, students attending 4-year public institutions were statistically more likely to note issues with *poor teaching* than their peers at 4-year private institutions, and students who only attended 4-year institutions were statistically more likely to note *coursework being overwhelming or too fast-paced* compared to their peers who attended a 2-year institution. Providing adequate teaching preparation can improve teaching quality and offer insights for necessary levels of difficulty in content, while not being overwhelming. This teaching preparation could also delve into topics frequently discussed at the K-12 level for CS teacher preparation such as collaboration with peers and culturally-responsive teaching.[80,81] Both these practices can promote cohesion of the community within the program, foster inclusivity of all learners, and provide instructors with skills to adapt their teaching for a diverse student body.

Barriers such as *not many of my peers look like me*, *lack of inclusive culture or climate*, and *negative interactions with the CS community* had many commonalities related to equity and inclusion. Female, Black/African American, Hispanic/Latinx, low-income, and first-generation students were all statistically more likely to note these barriers compared to their peers with more privileged identities. The overlap in topics brought up by students, as well as the high co-occurrence of these selected barriers, clearly indicates that groups that have been historically excluded continue to face unique challenges that, unless adequately addressed, will continue to perpetuate inequities in CS. Without the right supports and strategies to alleviate barriers related to sense of belonging, it is not surprising that increases in enrollment of historically marginalized students in CS are slow.[5] Our findings also reveal possible reasons why retention and graduation rates for these students continue to be low.

It is important to note that our sample of student respondents may have survivorship bias, as the findings represent students who *persisted* in their program at the time of completing the survey. Our sample did not include students who were once pursuing CS and then switched to another program or dropped out entirely. These students likely experienced more barriers (or experienced the barriers more intensely) that led to their leaving. As such, our findings may understate the severity of some of the barriers discussed. Learning from the experiences of students who left their program could provide insights not found in the current study and should be a future direction of research.

Cross-cutting themes

Two themes arose across several supports *and* barriers: high school preparation and structural differences between institutions. High school preparation appeared as both a support (when it was present) and barrier (when it was lacking) in the quantitative data and was repeatedly remarked upon within students' written responses. In short, if a student was exposed to CS prior to college either in a formal (e.g., course) or informal education setting (e.g., clubs), then it was an advantage to those students in their CS undergraduate programs. These students were more comfortable with the material and spoke of greater confidence in their skills. Moreover, male, Asian, White, and Multiracial students were all statistically more likely to note they had prior exposure to CS in high school, with some of these students increasing their advantages (i.e., privilege) in the CS classroom. However, if a student was not exposed to CS in high school, it served as a disadvantage in their post-secondary education. These students felt behind their peers and felt like they were constantly playing catch-up. This dichotomy further emphasizes the need for more high school preparation or exposure to CS before college. Moreover, low-income students were statistically more likely to note they lacked preparation for their program in high school, which places additional barriers on students already marginalized in the field.

Institution type (whether private vs. public or 2-year vs. 4-year) repeatedly came up as a difference for both supports and barriers in the quantitative data. Students who enrolled in a 2-year community college were statistically less likely to select *class supports*, *study groups with peers*, *faculty or peer mentoring*, and *joining student organizations* as supports and statistically less likely to select *coursework was overwhelming or too fast paced* as a barrier, compared to their peers who only attended 4-year colleges or universities. Students did not discuss these supports or barriers in their written responses as it pertained to their institution type. However, we posit that these supports may be less present or available to students at community colleges given the that students at 2-year institutions are more likely to be attending part-time, care for dependents, and/or work a full- or part-time job. On the other hand, community college students noting the *coursework was overwhelming or too fast paced* barrier less could indicate that introductory courses at these institutions are more accessible and take into account varying levels of experience better than introductory courses at 4-year institutions. The other institutional difference was students who attended 4-year public institutions were statistically more likely to select *poor teaching*, *inadequate advising*, and *course content not being relevant to their lives* as barriers compared to their peers at 4-year private institutions. In this case, we speculate that the differing priorities of the instructional staff (possibly due to research focus vs. teaching focus) and size of the institution (higher student-to-advisor or student-to-instructor ratios) may be at play. Because students' written responses did not shed any light on these differences, this should be explored further in future work. Despite general differences noted between institution types, these differences could also depend on individual institutions as well. Future work can focus on the underlying mechanisms for these institutions and why some may be better or worse prepared to support students.

Some of the challenges that students described might not be directly—or intentionally—imposed by institutions, but they reflect structural barriers that often reinforce educational inequities. It is imperative to increase awareness of the ways in which this country's history of exclusion and oppression prevail in today's education system; in this context, in the forms of student supports and barriers to success. Better equipped to identify and address systemic issues, CS programs and educators can account for existing barriers in students' experiences and try to alleviate them by providing adequate supports. For some institutions, this could mean creating new areas of support to foster equitable learning. For other institutions, it might simply mean revamping existing resources and programs to ensure the changing needs of our increasingly diverse student bodies are addressed. We hope this report supports the work institutions are already doing to ensure equitable access, retention, and learning opportunities in their CS programs.

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The Illinois Workforce & Education Research Collaborative, a Discovery Partners Institute research unit of the University of Illinois System, conducts rigorous, relevant, and timely cradle-to-career research. IWERC collaborates with community partners to co-construct solutions to pressing issues and ensure informed decision-making leads to statewide equity advancement. IWERC is an applied research initiative of Discovery Partners Institute, which also advances tech talent development and business building in Chicago. With state investment, an innovation district in development, and a high-powered network of university partners regionally and internationally as a part of the University of Illinois System, DPI has the resources to attract, develop, retain, and leverage the most ambitious talent in Chicago to address global challenges in our environment, agriculture, industry, life sciences, and shared digital future.

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