Brown University

Undergraduate Honors Thesis

Downstream Effects of the Brown Computer Science Introductory Sequences

Author
Shawna Huang

Advisor
Dr. Kathi Fisler

Second Reader
Dr. Caroline Klivans

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Abstract

Though each of the Brown Computer Science introductory sequences are treated as equal prerequisites for intermediate and upper-level courses, the introductory sequence that a student takes shapes their identity and experience in the Brown CS program. This project examines how students decide which introductory sequence to take, as well as how their experience affects their preparation for and desire to take intermediate and upper-level courses. We also investigate students' perceptions of how well the introductory sequences prepare students for particular intermediate and upper-level courses, how students' community within computer science is shaped by their introductory sequence, and the relationship between introductory sequence, degree program choice, and areas of interest. Our results find that students who take cs15/cs16 tend to continue in visual computing, design, and software-engineering focused courses, while students who take cs17/cs18 and cs19 focus on systems and theory courses. For cs15/cs16 students, their desire to take these courses is shaped by both their prior interests in visual applications of computer science, as well as the introductory sequence experience. For cs17/cs18 and cs19, students have prior interest or experience in computer science, but tend to attribute their interest in systems and theory to their experience in the introductory sequence.

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Part 1

Introduction

As of Spring 2020, the Brown University Computer Science department offers four introductory sequences which lead into the Computer Science concentration.

cs15/cs16 is a two-course sequence which covers programming practice and system design in the first semester, followed by theoretical foundations in the second. The first course, cs15[1], teaches object-oriented design principles and graphical applications through building interactive games, including Tetris, Fruit Ninja, and DoodleJump. cs16[2] moves into more theoretical foundations of computer science, teaching fundamental algorithms and data structures [1]. It is the largest and most popular of the options, with over 350 students completing cs15 in Fall 2019 [18].

cs17/cs18[3] is also a two-course sequence, integrating programming practice with theoretical foundations. The first course, cs17, teaches programming principles and problem solving through functional programming, while also considering some basic theoretical techniques. In cs18, students learn algorithms and data structures, while also developing skills in imperative and object-oriented programming paradigms [1]. This sequence emphasizes pair programming, as every project is done in pairs. It also emphasizes a philosophy of "no magic," learning how programs work step by step with little to no support code. Approximately 200 students enrolled in this sequence in Fall 2019 [18].

cs19[4] is an accelerated sequence, condensing most of the introductory curriculum into one semester. Students must qualify for cs19 by passing a summer placement process. This process does not assume any prior computing background; however, many students with prior experience pursue cs19 to begin taking intermediate and upper-level courses in their second semester [1]. This is the smallest of the intro sequences, with around 60 students enrolled in Fall 2019 [18].

Finally, cs0111[5]/cs0112[6]/cs0113[7]is a three-course introductory sequence, which gives students more flexibility in integrating computer science into their academic program. The three-semester pace is slower than the other three options, but the sequence is designed to provide foundations in data structures, algorithms, and programming principles in a less intensive manner. This sequence was first offered beginning in Fall 2018, and it has not yet been taught in full (as cs0113 has not yet been offered) [1]. This sequence is similar in size to cs17; approximately 150 students enrolled in Spring 2020, which was the first time the course was offered without an enrollment cap [18].

The four options take different approaches, attract different students, and operate on different timelines; however, they are treated as equal prerequisites for all intermediate and upper-level courses. Furthermore, the introductory sequence a student chooses often becomes part of an identity that they carry with them through their computer science courses, affecting the courses they feel prepared to take, the community they build within the department, and the pathways and interest areas they pursue.

This thesis analyzes how a student's introductory sequence influences their trajectory through the Brown Computer Science program. We investigate the following questions:

[1]Introduction to Object-Oriented Programming and Computer Science
[2]Introduction to Algorithms and Data Structures
[3]both titled Computer Science: An Integrated Introduction
[4]Accelerated Introduction to Computer Science
[5]Computing Foundations: Data
[6]Computing Foundations: Program Organization
[7]not yet titled

- Why do students choose to study computer science, and what factors do they consider when choosing a specific introductory sequence?
- How does the introductory sequence affect the intermediate and upper-level courses students choose to take, as well as their preparation for these courses? Additionally, how does the introductory sequence affect the degree program and areas of interest that students choose to pursue?
- What are students' perceptions about how well each introductory sequence prepares students for further computer science courses? Do students perceive significant differences between each of the intro sequences?
- How does the introductory sequence experience affect students' feelings of community and fit within the department?

We hope that these results will provide a useful insight for the department as the number of students enrolling in these courses and concentrating in Computer Science continues to grow each year.

For our analysis, we focused on data collected from two sources:

1. survey responses collected from current students enrolled in introductory, intermediate, and upper-level courses; and
2. anonymized concentration declaration data collected from Brown's advising platform, Advising Sidekick (ASK).

This thesis is broken into seven parts:

1. **Survey:** an overview of the survey data, including demographics of survey respondents.
2. **Introductory courses:** why students choose to take any introductory computer science course, how they decide which introductory sequence to take, and how their experience affects their decision to take more computer science courses.
3. **Intermediate courses:** how well students believe their introductory sequence prepared them for their intermediate courses.
4. **Upper-level courses:** how well students believe their introductory sequence prepared them for upper-level courses, and student perceptions of which students are best prepared for certain courses.
5. **Community:** student responses to how the community within their introductory sequences has shaped their experience in the Brown CS program.
6. **Concentration declarations:** how students' introductory sequence choice affects their degree, pathways, and areas of interest.
7. **Discussion:** a summary of our analysis, limitations of this particular project, and suggestions for future work.

Part 2

Survey

2.1 Methodology

During Fall 2019, we developed a survey to collect student responses about their experiences in Brown Computer Science courses. Students were surveyed on the factors in their decision to study computer science, their prior exposure to computer science, and demographic data (gender, race, ethnicity, etc.). In addition to this, students were asked about their experience specific to their level (introductory, intermediate, or upper-level). All data was collected anonymously via Qualtrics. A complete list of all survey questions can be found in Appendix A.

Students concurrently enrolled in an introductory course and any other course (intermediate or upper-level) were instructed to answer with respect to their introductory course experience. Students concurrently enrolled in an intermediate and an upper-level course were given the option to answer with respect to either level.

The survey consists of a combination of multiple choice, Likert scale, and free-response style questions. The phrasing and structure of questions about students' background and prior exposure to computer science was largely inspired by the Computing Research Association's annual survey, as well as work by Lewis et al. [8].

We submitted the proposed survey for IRB review in early November 2019. In late November, IRB/HRPP determined that the project did not fall under Human Subjects Research, and thus that we did not need approval to proceed with our study.

All survey data was analyzed using Google Sheets and R.

2.2 Distribution

I chose to distribute the survey to students enrolled in introductory and intermediate courses, as well as a selection of upper-level courses, during the 2019 – 2020 academic year.

For data on introductory course students, I surveyed students enrolled in cs15, cs17, and cs19. I received no responses from cs0111 students, despite reaching out to course staff multiple times. Furthermore, the cs0111/cs0112/cs0113 sequence is less than two years old and has yet to be taught in full, so we have no data on the trajectory students take through Brown CS after completing this intro sequence. Given this, I chose to exclude cs0111 from my analysis.

For data on intermediate students, I surveyed students enrolled in cs0330[1] and cs0320[2]. I chose to focus on the systems-based intermediate courses, as these are the courses that tend to utilize programming skills taught in the introductory courses.

Finally, for data on upper-level students, I surveyed students enrolled in cs1230[3], cs1300[4], cs1320[5],

[1] Introduction to Computer Systems
[2] Introduction to Software Engineering
[3] Introduction to Computer Graphics
[4] User Interfaces and User Experience
[5] Creating Modern Web & Mobile Applications

Table 2.1: Number of survey responses for each course level.

Course level	N
Introductory	72
Intermediate	46
Upper-level	55

Table 2.2: Graduation years of all survey respondents.

Class year	N	Percentage
2019.5	2	1%
2020	19	11%
2021	33	19%
2021.5	2	1%
2022	52	30%
2023	65	38%

cs1570[6], cs1730[7], and cs1950y[8]. These courses were chosen because they have few or no prerequisites beyond completing an introductory sequence. In particular, we wanted to avoid courses that required cs0330 as a prerequisite, such as Software Security and Exploitation (cs1650) or Operating Systems (cs1670). I also chose these courses because, based on my own experiences as a student in the Brown CS program, I expected students might have strong opinions on whether these courses were better suited to students from particular intro sequences. These six upper-level courses were also the ones that I chose to ask students about in the survey.

I asked course professors and HTAs to distribute the survey to students enrolled in fall courses (with one exception; cs1570 course staff did not respond to emails) in early December 2019, and responses were collected until early January 2020. The survey was additionally distributed to students enrolled in spring courses (and to Fall 2019 cs1570 students) in late February 2020; responses were collected until early March. The survey was distributed via course-wide emails and posts on online discussion boards, such as Campuswire and Piazza.

2.3 Participants

A total of 231 (partial and complete) responses were collected; of these responses, 3 indicated they had not taken an introductory course at Brown, and were thus discarded. 156 students fully completed the survey. An additional 17 responses were partial, but complete enough to be included in parts of the data analysis (i.e. continued past the demographic questions), for a total of 173 responses. Table 2.1 shows the breakdown of these responses by course level.

As shown in Table 2.2, a majority of survey respondents are underclassmen in the class of 2022 (30%) or 2023 (38%). Most of these students are enrolled in introductory and intermediate courses, while most upperclassmen (class of 2019.5 through 2021.5) are enrolled in upper-level courses.

Table 2.3 shows that 39% of survey respondents identify as female. This closely matches the CS department's percentage of degrees awarded to female-identifying students, which is around 40% as of 2019 [3].

[6]Design and Analysis of Algorithms
[7]Design and Implementation of Programming Languages
[8]Logic for Systems

Table 2.3: Gender identities of all survey respondents.

Gender identity	N	Percentage
Male	86	50%
Female	68	39%
Did not respond	15	9%
Nonbinary/transgender	4	2%

Table 2.4: Race/ethnicity of all survey respondents (number of students = 173).

Race/ethnicity	N	Percentage
White	72	42%
East Asian	39	23%
Multiple/Mixed	26	15%
South Asian	15	9%
HUGs[1]	15	9%
Black or African American	6	4%
Southeast Asian	6	4%
Middle Eastern	5	3%
Hispanic or Latinx	2	1%
Did not respond	2	1%

[1] Fully or partially Black or African American, Hispanic or Latinx, American Indian or Alaska Native, or Native Hawaiian or Pacific Islander

From Table 2.4, a plurality of respondents are White (42%), though East Asian (23%) and students with two or more races/ethnicities (multiple/mixed, 15%) are also highly represented. Approximately 9% of respondents are historically underrepresented groups (HUGs), which Brown University defines as individuals who identify as Hispanic or Latinx, American Indian or Alaska Native, Black or African American, or Native Hawaiian or Other Pacific Islander [3]. Note that some HUGs students are included in the multiple/mixed category in Table 2.4. This percentage is similar to the department's percentage of degrees awarded to HUGs, which was around 8% in 2019 [3].

As seen in Table 2.5, a majority of survey respondents do not identify as first-generation college students (62%). However, a majority do identify as first-generation in computer science (58%), i.e. they are the first in their family to study computer science. Only 3% of survey respondents identify as first-generation college students. This is lower than the department's percentage of degrees awarded to first-generation students, which was around 7% in 2019 [3].

Table 2.6 gives a summary of survey respondents' prior exposure to computer science before college. Students indicated a variety of different prior experienced with computer science. The most common of these included AP Computer Science A (36%), at least a year of non-AP Computer Science courses (24%), self-taught (21%), and Scratch/block-style programming (20%). 24% of respondents have no prior experience in computer science before starting at Brown.

Table 2.5: Number of survey respondents who identify as first-generation college students, first-generation Computer Science students, and/or first-generation STEM students (number of students = 173).

	N	Percentage
At least one person in my immediate family attended college.	107	62%
I am the first person in my immediate family to study/work in Computer Science.	100	58%
At least one person in my immediate family studied/works in STEM, but not Computer Science.	68	39%
At least one person in my immediate family studied/works in Computer Science.	33	19%
I have a close relative or role model (not in my immediate family) who studied/works in Computer Science.	22	13%
I have a close relative or role model (not in my immediate family) who studied/works in STEM, but not Computer Science.	28	16%
I am the first in my immediate family to attend college.	5	3%

Table 2.6: Previous computer science experience of survey respondents (number of students = 173).

	N	Percentage
AP Computer Science A	63	36%
At least a year of non-AP Computer Science courses	42	24%
None	42	24%
Self-taught	38	22%
Scratch/block-style programming	34	20%
Participated in a summer program	26	15%
AP Computer Science Principles	19	11%
Regularly scheduled extracurricular program (e.g. after school program)	17	10%
Less than a year of non-AP Computer Science courses	16	9%
Non-regularly scheduled extracurricular program (e.g. one-time workshop)	8	5%
Other	4	2%

Part 3

Introductory Courses

We surveyed students enrolled in introductory courses in Fall 2019 about their experience in the introductory courses. We asked questions to learn why students chose to study computer science, what factors influenced their decision to choose a specific intro course, and how their experience in the intro course affected their desire to continue studying computer science. In analyzing this data, we wanted to better understand students' interests and goals in studying computer science before starting the intro sequence, and how their experience in the intro course they choose affects these interests and goals.

3.1 Data

A total of 72 students enrolled in introductory courses during the Fall 2019 semester responded to the survey. Figure 3.1 shows the proportions of survey respondents enrolled in each of cs15, cs17, and cs19, as well as the Fall 2019 enrollment numbers for each of the three courses.

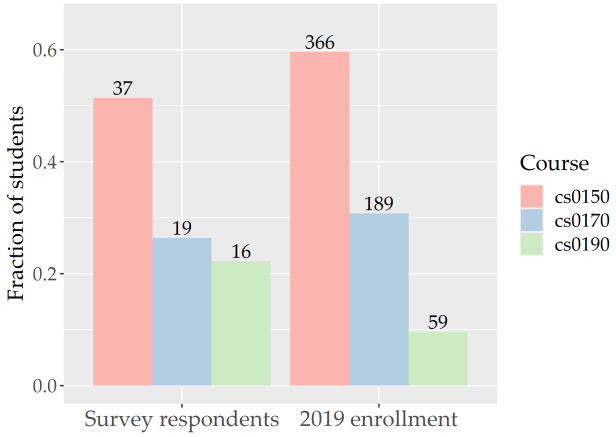


Figure 3.1: Proportions of survey respondents in each introductory sequence, compared to the Fall 2019 enrollment numbers for the same courses.

3.2 Methodology

Given the variety of question types in this survey, I used several different statistical tests to analyze my data. In general, due to the small sample sizes and the unknown shape of the distribution of the data, I opted for non-parametric statistical tests as opposed to their better-known parametric counterparts.

In order to measure whether certain groups of students gravitate towards specific introductory sequences, I used a Fisher's exact test to determine whether proportions of students enrolled in each of the intro sequences were different among students with different demographic backgrounds. The Fisher's exact test is similar to the Chi-square test, but it is generally more accurate for smaller sample sizes than the Chi-square test [13]. Thus, given my small sample size of $n = 72$, I chose a Fisher's exact test rather than a chi-squared test of independence. If a result is significant, post-hoc pairwise Fisher's exact tests

can provide more detail about the relationship between demographics and intro sequence [13]. However, because multiple comparisons are now being made, we must adjust the p-values to limit the number of false positive significant results we get. I chose to use the Benjamini-Hochberg (also known as false discovery rate, or FDR) method of p-value correction, which is less sensitive than other methods (such as the Bonferroni correction) [15].

Many survey questions asked students to rank a series of items on a 5-point Likert scale, such as "Strongly negative" to "Strongly positive." These scales were all converted into numbers ranging 1 to 5 to allow statistical tests to be conducted. In order to compare responses across CS15, CS17, and CS19 students, I used the Kruskal-Wallis H test. While the Mann-Whitney U test only allows for comparisons between two independent groups on an ordinal dependent variable (such as a Likert scale), the Kruskal-Wallis H test allows for comparisons between more than two groups [10]. It is similar to the one-way ANOVA test, but it does not assume normality in the data and is more appropriate for ordinal data [10].

We used ϵ^2 as a measure of effect size, which is commonly used for significant results from a Kruskal-Wallis H test [12]. In addition to this, we used a post-hoc Dunn test to compute pairwise group comparisons after a statistically significant Kruskal-Wallis H result [12]. These two measures allow us to measure the magnitude of the difference between intro sequences, as well as which of the intro sequences differs from the others.

Finally, one set of questions asked students about how many computer science courses they intended to take before starting the introductory sequence, as well at the time they were responding (i.e. near the end of the first semester introductory course). This was measured on a 4-point Likert scale, ranging from "just this semester-long course" to "concentrating or joint-concentrating in computer science." These responses were converted to numbers ranging from 1 to 4 for statistical analysis. Though this type of data might commonly be analyzed using a paired t-test, I chose to use the Wilcoxon signed-rank test to measure the difference in responses, as this test does not assume the differences are normally distributed [11,17]. I also chose this test over the sign test; while the the sign test is better suited for testing whether the number of differences in each direction is equal, the Wilcoxon signed-rank test allows us to analyze the size of the differences [17].

3.3 Results

In this section, I will summarize the significant results found in the data collected from introductory course students. See Section 3.5 for a thorough breakdown of the statistics.

3.3.1 Demographics and Intro Sequence Choice

How do students' backgrounds affect which intro sequences they decide to take? Using self-reported demographic data, I compared the proportion of different demographic groups enrolled in each of the introductory sequences to the proportions of all 72 survey respondents.

Gender. Table 3.1 gives the breakdown of survey respondents by their gender identity. A Fisher's exact test found that the relationship between students' gender identity and their choice of introductory sequence is not independent. In particular, post-hoc pairwise comparisons found that differences in female vs. male students are significant when comparing CS15 vs. CS19 proportions, and nearly significant when comparing CS17 vs. CS19. The difference is also significant between female and other students (nonbinary/transgender, or did not respond) when comparing CS15 and CS19 proportions. This implies that female-identifying students enroll in CS15 and CS17 more frequently than CS19, and male-identifying and other students tend to enroll in CS19.

This is likely closely correlated with prior experience (see Prior Experience discussion below). A majority of CS19 students have prior experience in computer science before college, and male students are more likely to have prior experience than female students.

Table 3.1: Introductory course enrollment by gender identity.

	cs15	cs17	cs19
Female	23	9	1
Male	12	9	12
Other[1]	2	1	3

[1] Nonbinary/transgender, or did not respond

Table 3.2: Introductory course enrollment by race/ethnicity.

	cs15	cs17	cs19
White	11	4	8
Asian[1]	17	9	6
HUGs[2]	5	4	0
Middle Eastern	1	2	0
Other	3	0	2

[1] East Asian, South Asian, or Southeast Asian
[2] Fully or partially Black or African American, Hispanic or Latinx, American Indian or Alaska Native, or Native Hawaiian or Pacific Islander

Ethnicity. Table 3.2 gives the number of students enrolled in each introductory course by race/ethnicity. "Asian" refers to students who identify as fully East Asian, South Asian, or Southeast Asian. "HUGs" refers to students who identify as either fully or partially Black or African American, Hispanic or Latinx, American Indian or Alaska Native, or Native Hawaiian or Pacific Islander. "Other" refers to students who selected two or more races/ethnicities, none of which were HUGs. A Fisher's exact test found that students' choice of intro sequence is independent of their race/ethnicity.

First-Generation Status. As shown in Table 3.3, only 3 students currently enrolled in intro courses identify as first-generation college students, though many more students identify as first-generation in Computer Science, first-generation in STEM fields, and/or having close relatives or role models (not in their immediate family) in Computer Science or STEM. However, a Fisher's exact test found no relationship between students' first-generation status and their choice of introductory sequence.

Prior Experience. While students indicated a wide range of different prior experiences with computer science, we chose to focus only on students who had taken AP Computer Science A, AP Computer Science

Table 3.3: Introductory course enrollment by first-generation identity.

	cs15	cs17	cs19
First-generation college	2	1	0
Continuing-generation college	23	10	11
First-generation CS	22	12	11
Continuing-generation CS	6	4	0
Continuing-generation STEM (not CS)	15	3	7
Relative in CS	4	4	4
Relative in STEM (not CS)	11	2	2

Table 3.4: Introductory course enrollment by prior experience.

	cs15	cs17	cs19
AP Computer Science A	9	7	12
AP Computer Science Principles	8	1	2
None	7	6	0

Principles, or no experience. AP Computer Science A is a Java-based course in programming foundations and object-oriented programming, while AP Computer Science Principles is a broader approach to concepts in computer science, including some programming [7]. We believed that these would be most standardized forms of prior experience across all students; other forms of prior experience (such as after-school activities, summer programs, and self-taught) are too variable in their range of instruction to draw useful conclusions. Table 3.4 gives the breakdown of student enrollment in the three introductory courses by prior experience, including only AP Computer Science A, AP Computer Science Principles, and no experience.

A Fisher's exact test found that students' prior experience in computer science is not independent of their choice of introductory sequence. Post-hoc pairwise comparisons found nearly significant differences between students with AP CS A experience vs. no experience. Students with AP CS A experience enroll in cs19 slightly more frequently than cs15 and cs17.

This is not a particularly surprising result — students with prior computing experience are more likely to pursue an accelerated intro course and its associated summer placement process, as they want to avoid repeating material and move into upper-level courses quickly. This also aligns with our previous discussion of Gender above. In 2018, 38,195 female students took AP computer science exams, of a total of 135,992 students [6]. This means that female students account for approximately 28% of students with prior AP Computer Science experience. Male students are more likely to have prior AP Computer Science experience, and thus are more likely to pursue cs19.

3.3.2 Choosing to Take an Introductory CS Course

Students ranked a series of statements on how strongly each one influenced their decision to take an introductory computer science course. Responses were collected on a 5-point Likert scale, from "Strongly disagree" (1) to "Strongly agree" (5). Students were also given the opportunity to elaborate on their reasons for taking an introductory computer science course in a free-response question. Figure 3.2 gives an overview of student responses to this question.

In general, students appear to take introductory computer science courses because they are interested in the material, want to develop new skills, or intend to concentrate in computer science. The free responses give similar results; for example, one student wrote that "I thought it would be good to explore computer science and see if it was something I would be interested in studying." Another student said that "It was always something that seemed cool, despite having no idea what coding was even like."

3.3.3 Choosing a Specific Intro Sequence

Students were asked to rank a series of factors on how strongly each one influenced their decision in choosing which introductory course to take. Responses were collected on a 5-point Likert scale, from "Not at all" (1) up to "A great deal" (5).

Figure 3.3 gives a summary of the responses. Each histogram is scaled by frequency rather than exact count, to allow for better comparison across the groups with different numbers of responses.

Each of the factors is summarized below, with (*) denoting a statistically significant result. Note that significant results do not mean that the factor was significant in a student's decision; rather, significant

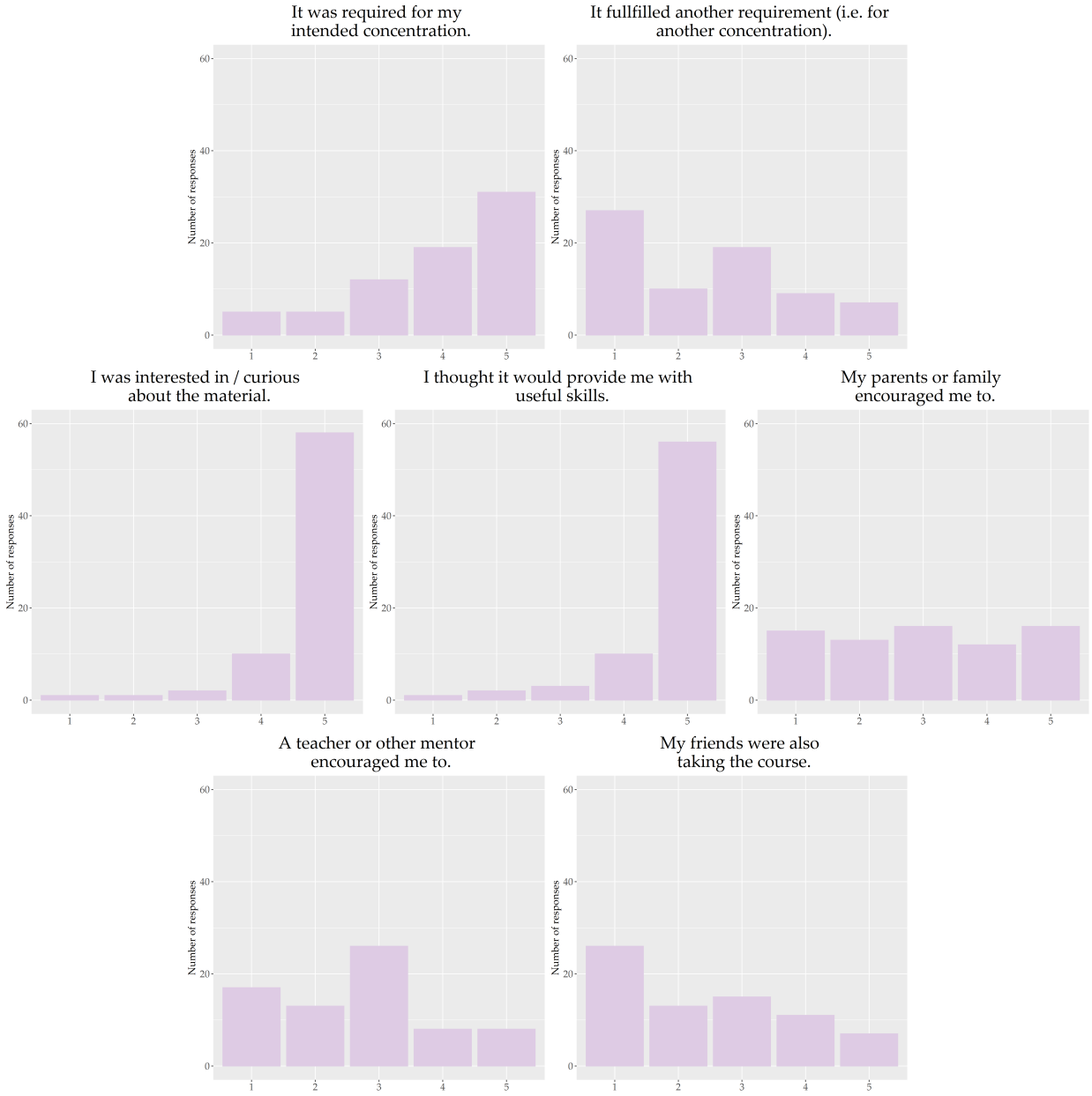


Figure 3.2: Frequency histograms of student responses to which factors influenced their decisions to take an introductory computer science course. The y-axis measures the number of student responses. The x-axis corresponds to each of the 5 points on the Likert scale. (1) corresponds to "Strongly disagree," (2) to "Somewhat disagree,", (3) to "Neither agree nor disagree," (4) to "Somewhat agree," and (5) to "Strongly agree."

results indicate that there is a difference in the relative importance of this factor between students who choose different introductory courses.

Course professor (*). While course professor seems to strongly influence decisions for cs15 and cs19 students, it is not as important for cs17 students. This might indicate that cs15 and cs19 students find the course professor particularly engaging.

Course TA staff. These rankings appear to skew towards lower numbers, particularly so for cs19 students, which indicates that the course's TA staff does not tend to be an important factor when students choose an introductory course. This is likely because students do not interact much with TAs in the first two weeks of the semester, which is when they make their decision of which course to take. The difference between intro courses was nearly significant.

Other students in the course. Rankings for this factor also appear to skew towards lower numbers, which indicates that other students in the course do not strongly influence which intro course students choose to take.

Advice from students not associated with the course (*). Advice from students not associated with the course (i.e. upperclassmen, student organizations) is not a strong influence for cs19 students, while it does seem to influence cs15 and cs17 students (cs17 slightly more strongly than cs15). Upperclassmen likely advise students to take the introductory sequence they took, especially if they enjoyed their experience in the course. As many major student organizations in the department, such as the Department Undergraduate Group (DUG), are coordinated by students who took cs15 and cs17, students who seek advice from these groups are likely to be directed towards these courses (particularly cs17, as the DUG is largely run by students who took cs17).

Advice from professors/faculty. Advice from professors and faculty was largely not a significant influence, as the responses tend to skew towards lower numbers. Students likely have not yet had time to develop relationships with faculty members, other than their faculty advisors, and thus are unable to seek out faculty advice.

Advice from the Brown CS "Which Introductory Course Should I Take?" page. Responses about this page were mixed, thought slightly skewed towards not influencing students' decisions. Students may not be aware of the existence of this page when making their decision, which could account for the lower scores.

Lecture style and structure in this course (over the other courses). Students generally sit in on the lectures of each of the intro courses during shopping period to help inform their decision. cs15 is taught mostly using slides, and is well-known for incorporating skits into lectures (especially in the first few classes). cs17 is somewhat slower-paced and uses both slides and live coding; cs19 uses no slides, mostly relying on live coding. The influence of lecture style and structure appears to be mixed, though somewhat skewed towards not not being a strong influence (especially for cs19 students).

Structure of the assignments in this course (over the other courses) (*). Assignments in cs15 are project-based; students are tasked with building large games over the course of several weeks. cs17 also has some projects, but a majority of the assignments are weekly homeworks, with each homework consisting of several smaller problems. cs19 assignments have a much quicker turnaround, often less than a week, with each focusing on a single problem. This assignment structure tends to be a strong influence for cs15 students, a moderate influence for cs17 students, and a weak influence for cs19 students. This implies that students who choose cs15 are particularly drawn to the large, game-based projects in the course, which indicates they have a prior interest in these kinds of applications of computer science.

Material covered in this course (over the other courses). cs15 focuses on teaching object-oriented design and basic programming principles, while cs17 and cs19 have a stronger emphasis on functional

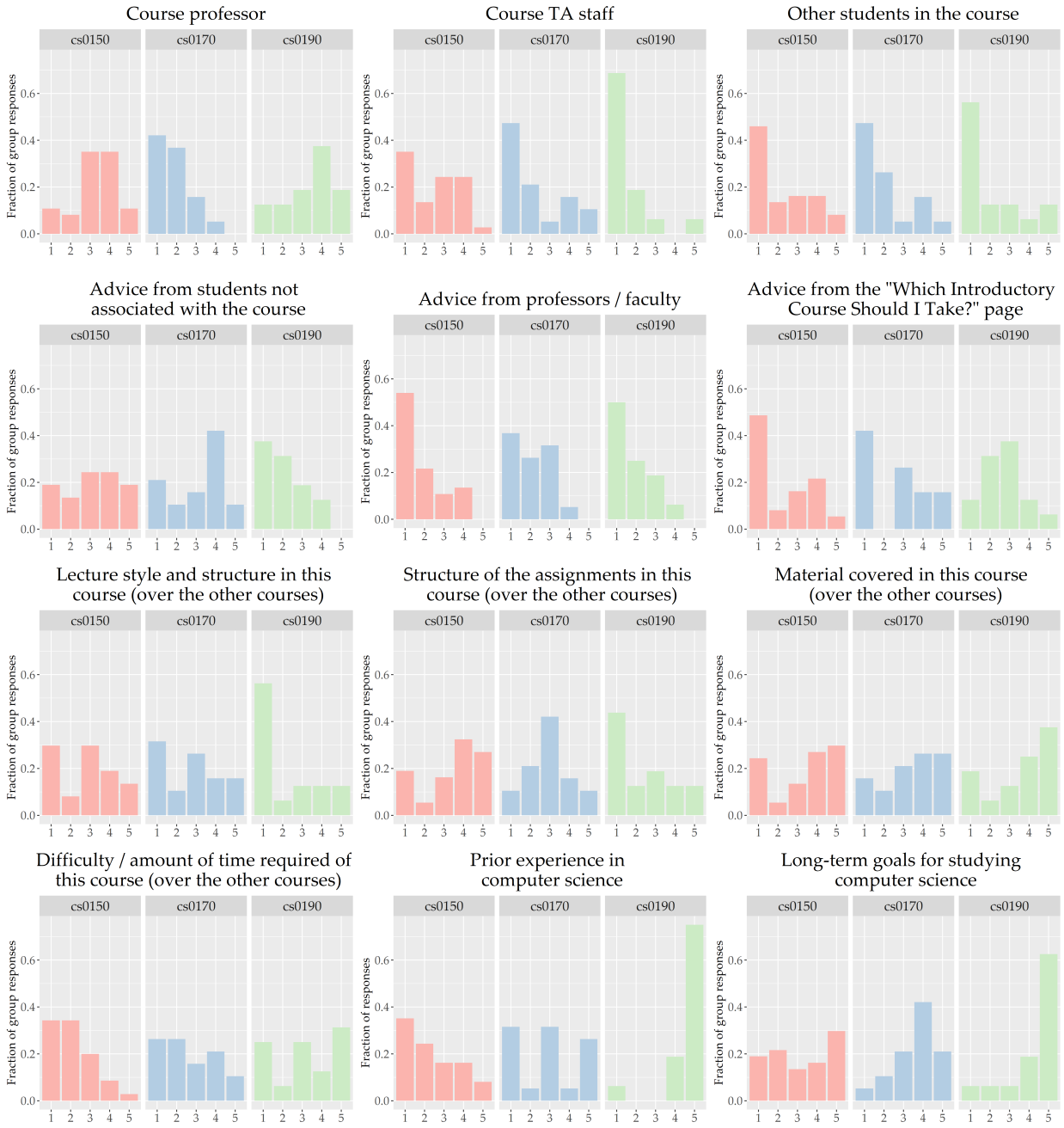


Figure 3.3: Histograms of how strongly each factor influenced students to choose their introductory course, divided by introductory course. The y-axis measures the fraction of students in each course (cs15, cs17, and cs19) that responded in each category, not the actual number of students. Red corresponds to cs15, blue to cs17, and green to cs19. The x-axis corresponds to each of the 5 points on the Likert scale. (1) corresponds to "Not at all," (2) to "A little," (3) to "A moderate amount," (4) to "A lot," and (5) to "A great deal."

programming and theory. However, the material covered in each intro sequence appears to be a mixed influence on students' decisions; while it is part of many students' decisions, it is not always a strong factor in their decision.

Difficulty/amount of time required of this course (over the other courses). cs15 and cs17 both have a reputation as time-intensive courses, while cs19 is somewhat less time-intensive. While cs15 and cs17 students tend not to weight the difficulty/time commitment of the course highly, it is slightly more scattered for cs19 students. This implies that cs19 students do consider the lighter workload when choosing to take cs19 over the other options. The difference between the courses is close to, but not statistically significant.

Prior experience in computer science (*). cs19 students tend to indicate that prior experience in computer science is a strong factor in their decision, while it is more variable for cs15 and cs17 students. As discussed previously in Section 3.3.1, students in cs19 tend to have prior experience. Thus, students who have prior experience choose cs19 largely because of their prior experience — they want the challenge of the accelerated pace, and they want to move into upper-level courses more quickly.

Long-term goals for studying computer science (*). Rankings for this factor tend to skew high, indicating that long-term goals play a large factor in students choosing which intro sequence to take. This factor is strongest for cs19 students, followed by cs17 students, followed by cs15.

Free responses. As above, students were also given the opportunity to elaborate on their reasons for choosing a specific introductory course in a free-response question.

Several students who chose cs15 highlighted the assignments in the course. One student wrote, "I thought cs15 would be the most fun because we get to create games and I am interested in graphics." Students also indicated a desire to learn Java, as well as the fact that cs15 has no exams, as factors in their decision.

One student who chose cs17 emphasized "the phrase of 'no magic' that [the] instructor used in the first class and the syllabus," as well as their belief that the instructor would be more effective. Another cs17 student wrote, "I was told cs15 wasn't a course for 'serious CS students' which I think was misleading to me."

cs19 students indicated that they wanted the challenge of the accelerated course, as well as a desire to complete the sequence in one semester so they could have room to take other courses (both in computer science or not). For example, one student wrote, "I wanted to challenge myself and learn CS faster, especially since I do not have a lot of space in my schedule as a prospective engineer."

Other identified factors. Students indicated several other major factors for choosing specific introductory sequences. In particular, several students in all introductory sequences discussed timing conflicts or preferred time slots as part of their decision.

In addition to this, one student who chose cs15 also highlighted the gender ratio in the different intro sequences as a factor in their choice.

> I was accepted into cs19 through the summer placement process, but I chose cs15 over cs19 largely because of the gender demographics in the students (cs15 has, at my estimation, at least 50% girls, while cs19 had around 5%. I just didn't feel comfortable in cs19 because of that). The faster (presumably less-thorough) pace of cs19 compared to the cs15/cs16 intro sequence was also a factor in my choice.

3.3.4 Continuing with CS after the Intro Sequence

Figure 3.4 shows student responses to questions about how much computer science they intended to take before taking their intro course, and near the end of their first-semester intro course. Responses

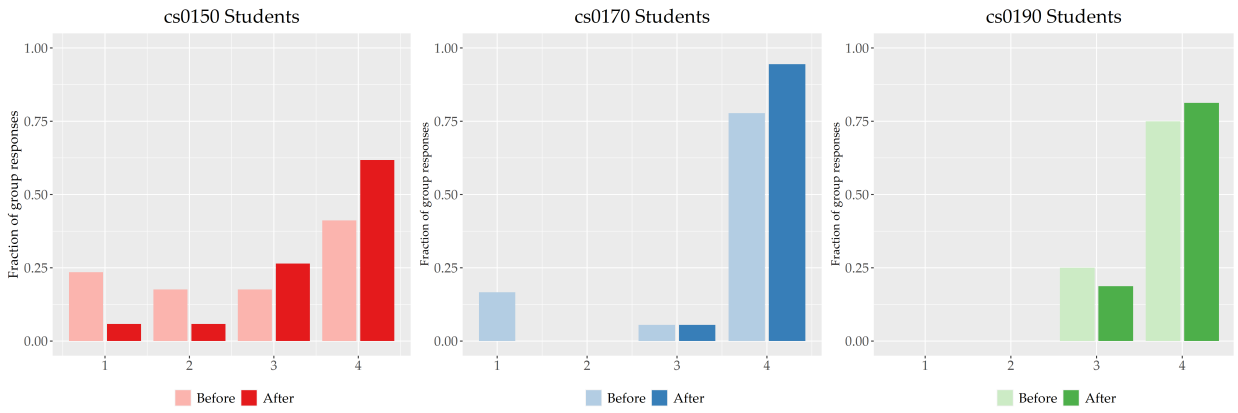


Figure 3.4: Students responses about how much computer science they intend to study, both before the first-semester introductory course (labeled as "Before") and towards its end (labeled as "After"). The *y*-axis represents the fraction of students in each course who responded in each category, not the actual number of students. (1) corresponds to just one semester-long intro course; (2) corresponds to the full introductory sequence; (3) corresponds to a few upper-level courses; and (4) corresponds to concentrating in computer science.

were collected on a 4-point Likert scale, from "just this semester-long course" (1) to "concentrating or joint-concentrating in computer science" (4).

Overall, after taking the first semester introductory course, more students intend to concentrate in computer science than before the intro course. Broken down by intro course, the difference between before and after is significant for cs15 students, but not significant for cs17 and cs19 students (though a majority of these students already intend to concentrate in computer science beforehand).

We also compared plans for continuing to pursue computer science across the different intro sequences. The difference between the students in different intro courses before taking the course is significant, and a post-hoc test found that cs15 students are significantly different from cs17 and cs19 students. In other words, cs15 students are less likely to intend to concentrate in computer science before taking the course.

After taking the first-semester intro course, the difference between intro courses is smaller, but still significant. cs15 students are still significantly different from cs17 students, but neither is significantly different from cs19. This means that, after the first-semester intro course, cs15 students are nearly as likely as cs19 students to intend to concentrate in computer science, who are nearly as likely as cs17 students to intend to concentrate.

These results imply that students who do not intend to concentrate in computer science are more likely to choose cs15. Because cs15 focuses more on practical programming foundations and less on theory, this makes sense — students take cs15 to learn about programming, without planning to take additional computer science courses. However, many students decide to take upper-level courses or concentrate after completing cs15, which indicates that they enjoyed their experience in the course and thus want to continue studying computer science.

Figure 3.5 allows us to look more closely at students' experience in their intro courses. Students were asked to rank a number of factors on how positively or negatively each one influenced their desire to pursue additional computer science courses.

Each of these factors is summarized below, with (*) again indicating a statistically significantly different response between students in each introductory sequence.

Intro course faculty (*). Though a majority of students rated the intro course faculty as a positive influ-

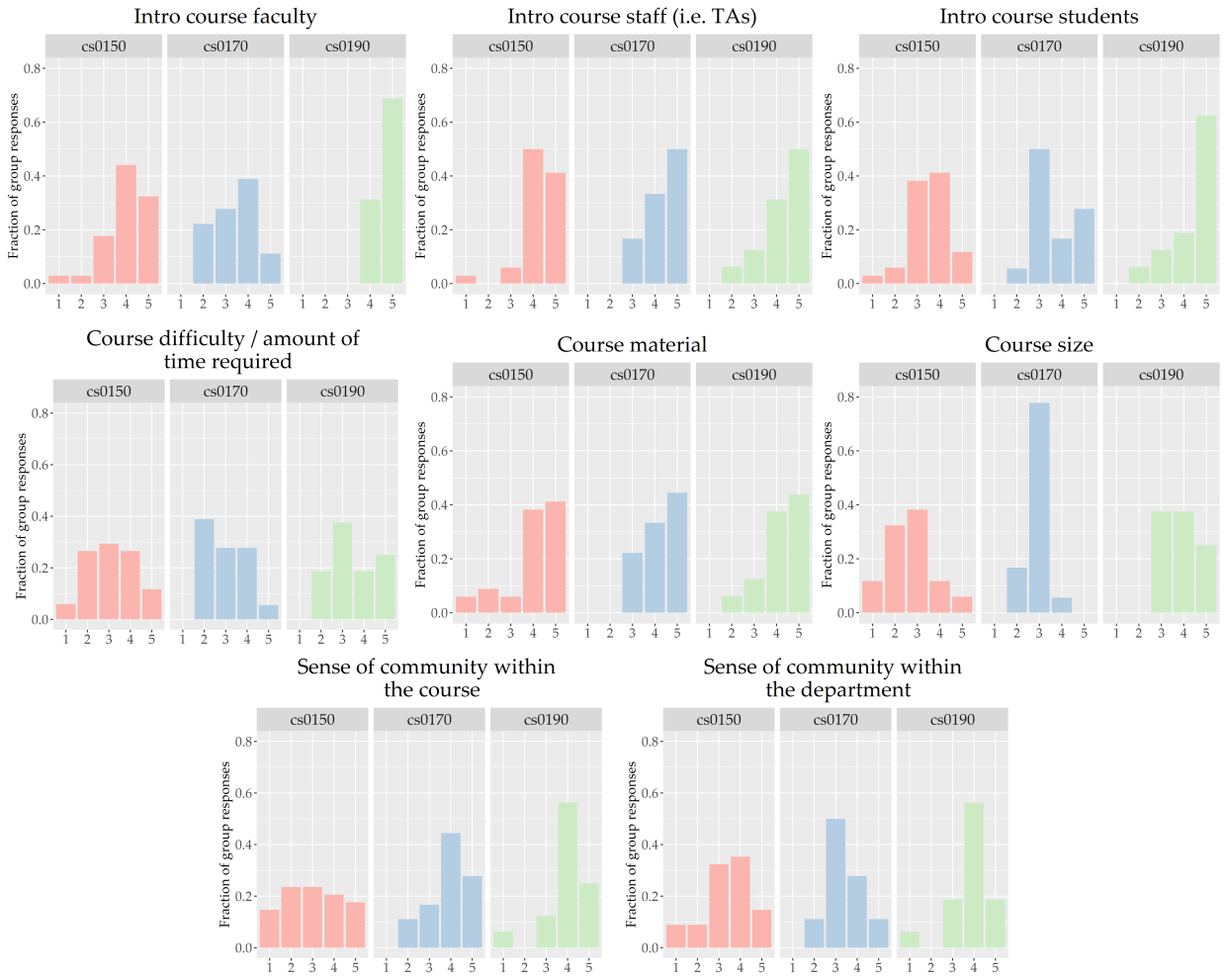


Figure 3.5: Histograms of how strongly each factor influenced students to want to pursue additional computer science, divided by introductory course. The y-axis measures the fraction of students in each course (cs15, cs17, and cs19) that responded in each category, not the actual number of students. Red corresponds to cs15, blue to cs17, and green to cs19. The x-axis corresponds to each of the 5 points on the Likert scale. (1) corresponds to "Very negative," (2) to "Somewhat negative," (3) to "Neither positive nor negative," (4) to "Somewhat positive," and (5) to "Very positive."

ence on their decision to study more computer science, CS19 students view faculty most favorably, followed by CS15, then by CS17.

Intro course staff (i.e. TAs). The difference between the intro courses was not significant, but all three groups skew towards positive or strongly positive. This indicates that intro course TAs have a strong positive influence on encouraging students to continue pursuing computer science.

Intro course students (*). CS19 students largely find that the other students in their course positively influence their decision to study more computer science, whereas CS15 or CS17 students are relatively neutral.

Course difficulty/amount of time required. Student responses about the effect of course difficulty in the intro courses were mixed; some students enjoy the difficulty and challenge of the intro courses, while others find it too demanding. The difference between intro courses was not significant.

Course material. A majority of students in all three intro courses found the material to positively influence their desire to continue studying computer science.

Course size (*). While CS19 students are neutral or positive about the size of their course, CS17 students are almost entirely neutral about it, and CS15 students find it to be a neutral or negative effect. This significant difference is likely due to CS19's smaller class size, as the smaller class size is a positive influence on students' experience in the course.

Sense of community within the course (*). While CS17 students tend rate their sense of community within the course as a positive influence, CS15 students tend to rate it as neutral or negative, with CS19 students somewhere in between. The difference between CS15 and CS17 students' sense of community within their course is statistically significant.

Sense of community within the department. For students in all intro courses, their sense of community within the department is a neutral or slightly positive factor in their desire to take more CS courses.

Free responses. As with other questions, students were also given the opportunity to elaborate on additional factors in their introductory course experience that influenced their desire to continue studying computer science.

Students mostly elaborated on the factors discussed above. One found that the field "seemed a lot more interesting and had a lot more unique opportunities [than] I initially believed." Another found that the course was simply too much work: "I really enjoy the material and people involved[,] but it can be way too much time, effort, and stress for someone who does not want to continue CS for their entire life and is taking it as more of a hobby."

While some students praised the organization of the courses, others found it to be discouraging. One student wrote, "CS17is a poorly designed class[,] but I like CS enough to ignore it and hope it gets better." Several students also praised their TAs for their help and hard work: "My TAs were my role model throughout the course, and they have helped me the most when I was struggling with hard assignments. I learned a lot from watching them debug with a calm attitude, catching errors, and explaining hard concepts to me. I want to become like them in the future."

3.4 Analysis

In this section, I will discuss how the results found in the previous section help us answer the question of why students choose a particular intro sequence, and how that choice influences their desire to continue pursuing computer science.

Because of the wide variety in responses, I did not formally code student responses to the free response questions, so I cannot produce quantitative summaries of the free response data here. Instead, I will focus

mainly on students' responses to the Likert scale-style questions.

cs15 students tend to rank the structure of assignments in the course as a strong influence in their decision. Several students mentioned that the game- and graphics-oriented projects, lack of exams, and use of Java drew them to the course. We found that female-identifying students enroll in cs15 at higher rates than the overall population, which might indicate that more female-identifying students are drawn to these types of assignments. Furthermore, cs15 students are significantly less likely to come into the course intending to continue studying computer science. This indicates that they may be taking it simply to get some experience with computer science, or to test whether this is something they want to continue studying.

There is no single factor that seems to be a strong influence for cs17 students. While some students highlighted the course professor, assignments, and "no magic" policy, these factors tend to be rated as moderate or weak influences in most cs17 students' decision. Students also rated advice from upperclassmen relatively highly; this could be because the student groups which students turn to for advice, such as the CS DUG, are coordinated by students who took cs17/cs18 and advise students to take the same sequence as them. One student did indicate that they took cs17 out of a belief that cs15 wasn't for "real CS students." This belief may be correlated with the fact that more students go into cs15 without an intention to continue studying CS, and cs15 students are not particularly motivated by long-term goals for studying CS when choosing an intro sequence.

cs19 students primarily choose to take cs19 because of their prior experience in and their long-term goals for studying computer science. Many of them cite the challenge of the accelerated pace, and that they want to move on to other courses more quickly (whether upper-level CS courses, or challenging courses in other departments). We found that significantly more students with prior experience from AP Computer Science A enroll in cs19, which corroborates the idea that students who choose to take cs19 do so because of their prior experience. Additionally, male-identifying students tend to choose cs19 over the other intro sequences; this is also related to prior experience, as male students are more likely to have prior experience in computing than female students.

In general, students don't find advice from professors and from the Brown CS website to be helpful in making a decision. However, advice from upperclassmen and student organizations was found to be very helpful, particularly for cs15 and cs17 students. cs19 students do not find advice from other students helpful, likely due to the summer placement exam; many will have already made their decision before arriving on campus. Additionally, students don't tend to be strongly influenced by the TA staff or other students in the course when making their decision, implying that the decision is not made with respect to the people associated with the course. This makes sense, as students have not yet worked closely with other students and TAs when they make their decision in the first few weeks of the semester.

One factor we did not explore in this study was the time slot of the courses; several students indicated this was a factor in their decision, as conflicts with other courses limited their options when choosing an intro sequence.

Students' experiences in all three first semester intro courses appears to encourage them to take more computer science courses than they originally intended. This effect is particularly strong in cs15 students, as many cs15 students do not intend to concentrate in computer science before taking cs15. A majority of cs17 and cs19 students already intend to concentrate in computer science before beginning the intro sequence.

Though one student cited the stress of the intro sequence as a negative influence on their desire to continue studying CS, survey responses were largely mixed on this issue, indicating that the difficulty and workload of the intro sequence neither strongly positively or strongly negatively affects students' plans to continue pursuing computer science. However, students in all courses tend to view both course TAs and course material very favorably in their desire to continue studying computer science. Most students also viewed their course professor as positive influences, with the strongest positive ratings for

cs19 students, followed by cs15, and then by cs17.

cs17 students tend to rate their sense of community within their course very positively; cs19 students also rate it somewhat positively, and both rate it more positively than cs15 students. This is likely due to the emphasis on pair programming within cs17 and cs19, which allows students to work with another and develop friendships within the course. cs15 has less of an emphasis on pair programming, which likely contributed to students feeling less strongly about their sense of community within the course.

cs19 students tend to view the other students in their course positively, as well as course size. cs15 and cs17 students, in comparison, tend to view these factors neutrally or negatively. This finding about course size is not particularly surprising; cs19 students likely enjoy the size of their course more than other students, given its smaller size. This smaller size, as well as the focus on pair-programming and partner exercises, may also contribute to a sense of camaraderie among students in the course.

3.5 Statistical Details

Only the tests that were statistically significant/near statistically significant are detailed below.

Demographics and Intro Sequence Choice

Gender. A Fisher's exact test on the data in Table 3.1 found that gender identity and choice of intro sequence were not independent ($p = 0.0040$). Post-hoc pairwise comparisons were significant (with the Benjamini-Hochberg correction) when comparing female/male students in cs15/cs19 ($p = 0.0063$) and female/other students in cs15/cs19 ($p = 0.046$). Additionally, the difference between female/male students in cs17/cs19 was almost significant ($p = 0.060$).

Prior experience. A Fisher's exact test on the data in Table 3.4 found that prior experience and choice of intro sequence were not independent ($p = 0.0065$). Post-hoc pairwise comparisons were nearly significant (with the Benjamini-Hochberg correction) when comparing students with AP CS A experience/no experience in cs15/cs19 ($p = 0.067$) and in cs17/cs19 ($p = 0.067$).

Choosing an Intro Sequence

Course professor. A Kruskal-Wallis H test showed the difference between intro courses to be statistically significant ($\chi^2(df = 2) = 18.47, p = 9.78e-05, \epsilon^2 = 0.26$). Responses from cs15 students had a mean rank of 42.08, cs17 students 19.32, and cs19 students 44.00 (where higher indicates a stronger influence on students' decisions). A post-hoc Dunn test found that cs17 was statistically different from the other two introductory courses ($\alpha = 0.05$).

Course TA staff. A Kruskal-Wallis H test found the difference between intro courses to be nearly significant, $\chi^2(df = 2) = 5.72, p = 0.057$.

Advice from students not associated with the course (i.e. upperclassmen, student organizations). A Kruskal-Wallis H test found the difference between intro courses to be statistically significant ($\chi^2(df = 2) = 7.21, p = 0.027, \epsilon^2 = 0.10$). Responses from cs15 students had a mean rank of 39.88, cs17 students 40.11, and cs19 students 24.41. A post-hoc Dunn test found that cs19 was significantly different from the other two intro courses ($\alpha = 0.05$), meaning that cs19 students found advice from other students less influential in their decision than other students.

Structure of the assignments in this course (over the other courses). A Kruskal-Wallis H test found the difference between courses to be significant ($\chi^2(df = 2) = 6.50, p = 0.039, \epsilon^2 = 0.092$). The mean rank for cs15 students was 41.99, for cs17 33.89, and for cs19 26.91. A post-hoc Dunn test found that while cs15

and cs19 were statistically different from one another, cs17 was not statistically different from either cs15 or cs19 ($\alpha = 0.05$).

Difficulty/amount of time required of this course (over the other courses). A Kruskal-Wallis H test found the difference between intro courses be nearly significant, $\chi^2(df = 2) = 5.69, p = 0.058$.

Prior experience in computer science. A Kruskal-Wallis H test found the difference in responses between groups to be significant ($\chi^2(df = 2) = 21.01, p = 2.75e-05, \epsilon^2 = 0.30$). The mean rank for cs15 students was 28.58, for cs17 35.13, and for cs19 56.44. A post-hoc Dunn test found that cs19 was significantly different from both cs15 and cs17 ($\alpha = 0.05$).

Long-term goals for studying computer science. A Kruskal-Wallis H test found a significant difference between the intro sequences ($\chi^2(df = 2) = 6.85, p = 0.033, \epsilon^2 = 0.097$). The mean rank for cs15 students was 31.80, for cs17 36.26, and for cs19 47.66. A post-hoc Dunn test found that while cs15 and cs19 were significantly different from one another, cs17 was not significantly different from either cs15 or cs19 ($\alpha = 0.05$).

Continuing with CS after the Intro Sequence

Before and after the intro course, cs15 students. A Wilcoxon-signed rank test found the difference for cs15 students was significant ($V = 11, p = 0.0016$); more students intend to study computer science after taking cs15 than before.

Before the intro course, all students. A Kruskal-Wallis H test found that the difference before the introductory course was significant ($\chi^2(df = 2) = 9.45, p = 0.0089, \epsilon^2 = 0.14$). The mean rank for cs15 was 28.00, for cs17 40.00, and for cs19 42.13 (where higher numbers indicate more students intend to take more computer science courses). A post-hoc Dunn test found cs15 to be statistically different from the others ($\alpha = 0.05$).

After the intro course, all students. A Kruskal-Wallis H test found that the difference after the introductory course was also significant ($\chi^2(df = 2) = 7.50, p = 0.023, \epsilon^2 = 0.11$). The mean rank for cs15 was 29.76, for cs17 41.22, and for cs19 37.00. A post-hoc Dunn test found cs15 and cs17 to be significantly different from one another, cs19 was not statistically different from either cs15 or cs17 ($\alpha = 0.05$).

Intro course faculty. A Kruskal-Wallis H test found the difference between intro courses to be statistically significant ($\chi^2(df = 2) = 16.46, p = 0.0003, \epsilon^2 = 0.25$). Responses from cs15 students had a mean rank of 34.22, cs17 students 22.56, and cs19 students 48.53 (where higher numbers mean a stronger influence). A post-hoc Dunn test found all three groups to be significantly different from one another ($\alpha = 0.05$).

Intro course students. The difference between the three courses is significant ($\chi^2(df = 2) = 8.85, p = 0.012, \epsilon^2 = 0.13$). cs15 students have a mean rank of 30.13, cs17 students 31.92, and cs19 students 46.69. A post-hoc Dunn test found cs19 to be significantly different from the other two courses ($\alpha = 0.05$).

Course size. A Kruskal-Wallis H test found significant differences between the three groups ($\chi^2(df = 2) = 17.11, p = 0.0002, \epsilon^2 = 0.26$). cs19 student responses have a mean rank of 50.88, cs15 of 27.96, and cs17 of 32.31. A post-hoc Dunn test found the cs19 student responses to be significantly different from the other two groups ($\alpha = 0.05$).

Sense of community within the course. The difference between course groups was statistically significant ($\chi^2(df = 2) = 8.04, p = 0.018, \epsilon^2 = 0.12$). The mean rank for cs15 students is 27.94, for cs17 40.50, and for cs19 41.69. Despite this, a post-hoc Dunn test found significant differences between cs15 and cs17 but not between cs15 and cs19 or between cs17 and cs19 ($\alpha = 0.05$).

Part 4

Intermediate Courses

Students enrolled in intermediate courses during Fall 2019 and Spring 2020 were surveyed about their experience in their intermediate courses. The courses we surveyed were:

- cs0330: Introduction to Computer Systems
- cs0320: Introduction to Software Engineering.

We asked students questions about how well prepared they felt for their intermediate courses, as well as how well they felt students from other intro sequences were prepared. Our goal with collecting and analyzing this data from intermediate students was to assess how well the introductory sequences prepare students for intermediate courses, as well as whether students perceive significant differences between the intro sequences in terms of preparation for intermediate courses.

4.1 Data

46 students enrolled in intermediate courses (specifically, cs0330 and/or cs0320) responded to our survey. Of these, 20 students completed cs15/cs16, 16 completed cs17/cs18, 9 completed cs19, and 1 completed cs0111/cs18. This last response was omitted from the analysis, as we chose not to study cs0111 in this project for reasons previously discussed.

37 students were enrolled in cs0330 during the Fall 2019 semester (15 from cs15/cs16, 15 from cs17/cs18, 7 from cs19) and answered questions about their preparation for the course. However, only 5 students completed questions about their preparation for cs0320, between both the Fall 2019 and Spring 2020 semesters. This may have been due to errors made during distribution of the survey. Many students filled out the survey during the fall semester, having only taken cs0330 but not cs0320. When the survey was sent out to cs0320 students in the spring, students were instructed not to fill out the survey again if they had already done so previously. Thus, any students who had taken cs0330 in the fall followed by cs0320 in the spring did not fill out the survey.

Given this lack of data about student preparation for cs0320, I chose not to perform statistical analysis on this data, focusing on a qualitative analysis instead.

Students enrolled in each of the intermediate courses (i.e. cs0330, cs0320) were asked to indicate their agreement with the following statements about their preparation for the course:

- My introductory sequence prepared me for these projects.
- My introductory sequence did not cover concepts that would have better prepared me for some significant portion of these projects.
- Students who took other introductory sequences are better prepared for these projects.

These questions were asked on a 5-point Likert scale, similar to many questions in the survey for introductory course students. (1) corresponds to “Strongly disagree,” (2) “Somewhat disagree,” (3) “Neither agree nor disagree,” (4) “Somewhat agree,” and (5) “Strongly agree.”

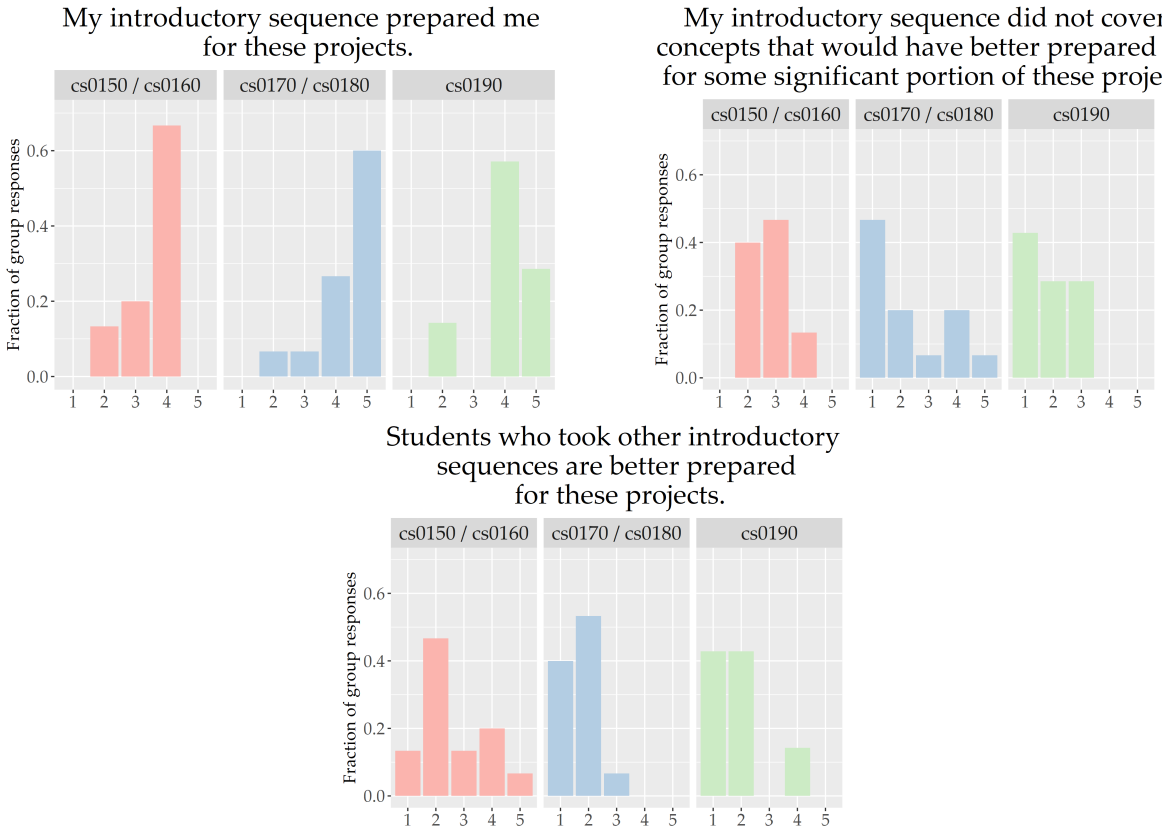


Figure 4.1: Histograms of how strongly students agreed with each statement. The y-axis measures the fraction of students in each group that responded in each category, not the actual number of students. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19. The x-axis corresponds to each of the 5 points on the Likert scale. (1) corresponds to "Strongly disagree," (2) to "Somewhat disagree," (3) to "Neither agree nor disagree," (4) to "Somewhat agree," and (5) to "Strongly agree."

4.2 Results

4.2.1 Preparation for cs0330

Figure 4.1 shows histograms of student responses about their experience in cs0330. These histograms are scaled by frequency rather than exact count, to allow for easier comparison across the groups with different numbers of responses.

While students who completed cs17/cs18 tended to strongly agree that their introductory sequence prepared them well for cs0330, cs19 students felt slightly less prepared, followed by cs15/cs16 students. The difference between cs15/cs16 and cs17/cs18 in particular is significant, indicating that cs17/cs18 students generally felt better prepared for cs0330 than cs15/cs16 students.

In response to the second question, a majority of cs17/cs18 and cs19 students disagreed with the statement that their introductory sequence didn't cover concepts that would have better prepared them for the projects in cs0330; in other words, most of these students felt that the concepts covered in their intro sequence prepared them for cs0330. cs15/cs16 responses were generally neutral. However, the difference between intro sequences was not significant.

The third question asked students whether they believed that students who took other introductory sequences were better prepared for the projects in cs0330. A majority of students from all sequences

disagreed with this statement. This sentiment appears to be strongest among cs17/cs18 students, as none of them agreed with the statement that students who took other introductory sequences were better prepared. This difference was found to be nearly significant.

Potential explanations for these results are discussed below in Section 4.2.3.

Statistics. Responses about whether students felt their introductory sequence prepared them for the projects in cs0330 were significantly different between intro sequences (Kruskal-Wallis H test, $\chi^2(df = 2) = 9.34, p = 0.009, \epsilon^2 = 0.26$). The mean rank for cs15/cs16 is 13.30, cs17/cs18 24.47, and cs19 19.50 (where higher numbers indicate stronger agreement with the statement that they were well prepared). A post-hoc Dunn test found that the difference in responses between cs15/cs16 and cs17/cs18 students was significant, though cs19 responses were not significantly different from either of the other two sequences ($\alpha = 0.05$).

Differences in responses about whether students believed students from other introductory sequences were better prepared for cs0330 were nearly significant (Kruskal-Wallis H test, $\chi^2(df = 2) = 5.98, p = 0.0501$).

4.2.2 Preparation for cs0320

Of the 5 responses received about cs0320, 3 were from cs19 students, and 2 were from cs15/cs16 students. A majority of the students felt that their introductory sequence prepared them for cs0320, thought one student from cs19 did not. However, there is little to no consensus among these students on the second and third questions. 2 of the 3 cs19 students believed that their intro sequence covered the necessary concepts to prepare them for the projects in cs0320, and that students in other intro sequences were not better prepared for the cs0320 projects, but the third student disagreed. The two cs15/cs16 students disagreed on their responses to the second and third question.

Given these results, it is difficult to draw conclusions about students' perceived preparation for cs0320. The data collected from the free response questions, discussed in Section 4.2.3, gives a more in-depth view of student perspectives on how well their introductory sequence prepared them for their intermediate courses.

4.2.3 Preparation for Intermediate Courses — Free Responses

Students answered several free response questions asking them to discuss their own preparation for their intermediate courses, as well as how they perceived the preparation level of students from other intro sequences. In particular, the questions they were asked to answer were:

- In what ways do you feel your introductory sequence prepared you for intermediate courses (i.e. cs0330, cs0320)?
- In what ways do you feel your introductory sequence did not prepare you for intermediate courses (i.e. cs0330, cs0320)?
- In what ways do you feel students in other introductory sequences were better prepared for intermediate courses?
- In what ways do you feel students in other introductory sequences were worse prepared for intermediate courses?

cs15/cs16 Students Students who completed cs15/cs16 highlighted the good coding habits they developed in their introductory courses as preparation for intermediate courses. In particular, they highlighted cs15/cs16's emphasis on design, OOP, generics, containment diagrams, and Java, which are utilized regularly in intermediate courses.

cs15/cs16 students felt under-prepared for intermediate courses in a variety of different ways. Several students wrote about the lack of collaboration in their introductory courses. One student wrote,

> I did not learn to have to work with code that other produce. While one-off projects can reduce the potential confusions when learning to code, I think it would have been important to emphasize even more in the curriculum that coders and engineers don't work in a vacuum all by themselves!

Students also discussed a lack of focus on debugging tools and learning how to effectively study for CS. Other students discussed the culture of fear-mongering and stress in their introductory courses. For example, one student wrote,

> cs15 was one of the most stressful times of my life, and on top of that, the results were so unsatisfactory that I considered not continuing in CS. I've come a long way and learned many things from my failure, but I'm not so sure that there wasn't a better way for me to be 'eased in' to CS, so to speak.

While some students felt there was no difference in preparation between the different introductory sequences, some cs15/cs16 students felt that students in cs17/cs18 were better prepared for intermediate courses through their experience in lower-level projects and functional paradigms. Many students also emphasized collaboration in other introductory sequences, writing that "since cs17/cs18has more pair programming assignments, I think they understood the dynamic of helping other people debug their code a bit better than the cs15/cs16 students." Some students also felt that cs19 students might be better prepared due to their prior experience in computer science. However, they also believed that students in cs17/cs18 and cs19 had less experience with Java and OOP, which they thought were important for intermediate courses (especially cs0320). One student wrote that even though they believe students in all introductory sequences were on an even playing field, they thought that "cs15/cs16 students had a better understanding of OOP compared to cs17/cs18 students, and. . . cs16 covered a couple of more algorithms that cs18 did not cover."

cs17/cs18 Students Students in cs17/cs18 generally wrote that the problem-solving skills and good coding practices they developed in the introductory sequence prepared them for their intermediate courses, especially style, debugging, considering edge cases, and planning for extensibility. One student wrote,

> I feel like I learned how to approach problems and break down challenging projects — in short, the intro sequence taught me how to DO computer science, even if it didn't teach me every single concept that might be necessary.

Other students highlighted more specific topics and skills, such as the server/socket experience in cs18, as helpful for projects in cs0330. Another student discussed cs17/cs18's exposure to multiple programming languages.

> cs17/cs18 gave taught many different kinds of languages[,] so I really understood how programming works rather than just one language like in high school. This made picking up C and other concepts a natural next step.

In response to how their introductory sequence did not prepare them for their intermediate courses, a few students wrote that they had no prior exposure to concepts like Assembly, signals, and multithreading, but also that they felt this prior exposure would not have been necessary (as the goal of cs0330 is to teach these concepts). Other students felt that they didn't write a lot of code in cs17/cs18, or that the intermediate courses were their "first time working alone on projects" (given that all projects in cs17/cs18 are pair-programmed). Very few students responded to this question, indicating that cs17/cs18 students generally did not feel under-prepared for their intermediate courses. This aligns with the results discussed earlier — of all three introductory sequences, cs17/cs18 students feel best prepared for cs0330.

cs17/cs18 students felt that students from cs15/cs16 might be better prepared due to their experience

with longer and larger projects. Given that cs17/cs18 tends to focus on smaller projects with little to no support code, students thought that

> cs15/cs16 probably wrote much larger volumes of code, [which] allowed them to be better prepared to finish projects with lots of support code (compared to cs17's 'no magic' approach).

In addition to this, one student wrote that students in cs19 might be better prepared for cs0330 because they were able to take an additional non-introductory sequence before cs0330 (during the spring semester of their first year). cs17/cs18 students did not believe that students in other introductory sequences were worse prepared, other than that they might have "weaker recursive/algorithmic foundations."

cs19 Students Similar to cs15/cs16 and cs17/cs18, students who completed cs19 also felt that the good coding practices and data structures they learned in their introductory sequence prepared them well for their intermediate courses. One student wrote that

> [cs19] taught me enough programming constructs for me to be able to start projects without having to look into cool data structures I haven't seen before so I can use them — I just follow habits I gained earlier. It also taught me good coding practices which have become very helpful.

Another student highlighted learning how to test their programs, and to think about the assignment before starting to write any code.

While cs19 students generally felt well-prepared for cs0330, two students wrote about their lack of preparation for cs0320. One wrote, "cs19 was all functional[,] so being thrown into Java in cs0320 was quite a jump that I had to work hard on." Though most cs19 are aware of this (and students with little-to-no OOP experience are encouraged to take cs18), the change in focus from cs19 to cs0320 was jarring to several students.

When asked about their perceptions of how students in other introductory sequences were better prepared, some cs19 students highlighted cs15's focus on Java and OOP as good preparation for cs0320. Other students discussed the longer and larger projects in cs15/cs16 and cs17/cs18, writing "since they had longer projects than my sequence did[,] they have more experience pacing themselves through our big projects now." Despite these benefits, cs19 students believed other introductory sequences had less emphasis on recursion, testing, good design, and problem solving.

4.3 Analysis

In general, students from all introductory sequences point to the good coding practices and data structures that they learned in their introductory courses. Despite the different approaches in all three sequences, students feel that the education in the intro sequence prepares them well to take on future programming projects and intermediate courses. cs17/cs18 students feel somewhat better prepared for cs0330 than cs15/cs16 students (with cs19 in the middle), which may be a result of their exposure to servers and sockets in cs18 and their experience collaborating with others through pair programming.

While we don't have enough data about cs0320 to determine which students feel better prepared for the course, several cs15/cs16 students emphasized their experience with Java and OOP. This indicates that they may feel better prepared for cs0320, particularly more so than cs19 students, who find the transition from cs19 to cs0320 very abrupt.

Part 5

Upper-Level Courses

Students enrolled in upper-level courses were surveyed about their experience in a subset of upper-level computer science courses. These courses included:

- cs1230: Introduction to Computer Graphics
- cs1300: User Interfaces and User Experience
- cs1320: Creating Modern Web & Mobile Applications
- cs1570: Design and Analysis of Algorithms
- cs1730: Design and Implementation of Programming Languages
- cs1950y: Logic for Systems.

In particular, we asked questions about how well prepared students felt for these courses, as well as how well they felt students from other intro sequences were prepared. Our goal with collecting and analyzing this data from upper-level students was to assess how well the introductory sequences prepare students for upper-level courses, as well as whether students perceive significant differences between the intro sequences in terms of preparation for these courses.

I hypothesized that students would perceive graphics- and software-focused courses to be better suited for cs15/cs16 students, given their introductory sequence's focus on visual applications and designing large systems. Additionally, students would perceive logic and theory courses to be better suited for cs17/cs18 and cs19 students, as these two sequences integrate theoretical foundations earlier and have a stronger focus on logic-based problem solving.

5.1 Data

A total of 57 students enrolled in upper-level courses responded to the survey. 7 of these did not complete the survey, leaving 50 responses about upper-level courses. Of these 50 students, 20 completed cs15/cs16, 15 completed cs17/cs18, and 15 completed cs19.

Figure 5.1 shows the number of students surveyed who have taken or are currently taking cs1230, cs1300, cs1320, cs1570, cs1730, and cs1950y, at the time of responding. Students were also asked about which courses they considered taking, but decided not to take; this is also displayed in Figure 5.1.

Note that I chose not to use this data to analyze the number of students enrolled in each of these courses by intro sequence. Instead, this analysis will be discussed in Part 7, using concentration declaration data.

Students who had taken each of the upper-level courses were asked to indicate their agreement with the following statements about their preparation for the course:

- I am satisfied with my performance in the class.
- My introductory sequence prepared me well for this course.
- I would have been better prepared for the material in this class if I had taken a different intro sequence.

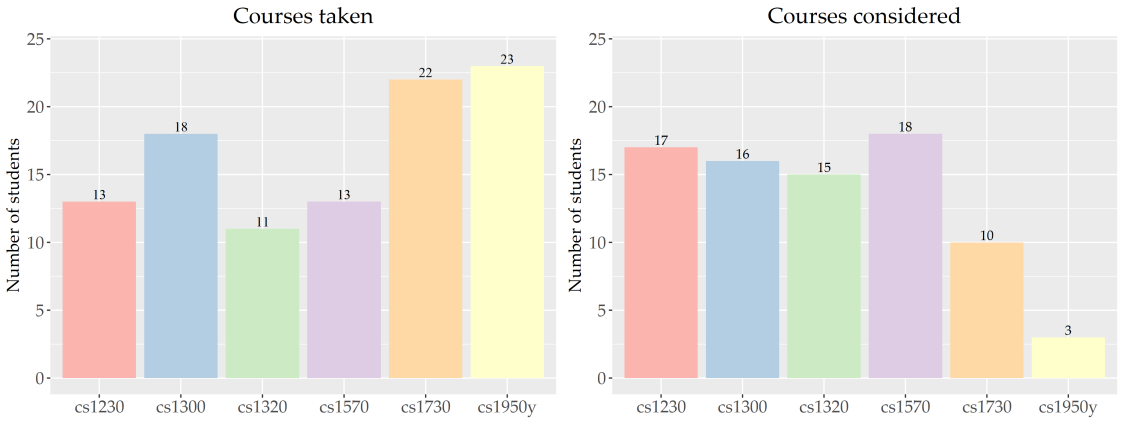


Figure 5.1: Frequency histograms of the courses upper-level respondents have taken / are taking, as well as the courses they have considered (but chose not to take). The y-axis represents number of respondents.

- My perception of which students would succeed in the course (i.e. from a specific intro sequence) changed after taking the class.

These questions were asked on a 5-point Likert scale. (1) corresponds to "Strongly disagree," (2) "Somewhat disagree," (3) "Neither agree nor disagree," (4) "Somewhat agree," and (5) "Strongly agree."

5.2 Methodology

As discussed previously in Section 3.2, the Kruskal-Wallis H test is a non-parametric test that allows for comparisons between two or more independent groups on an ordinal dependent variable [10]. There are some requirements for sample size in each of the independent groups; however, I was unable to find a consensus on what these requirements are. Some sources say that a sample size of less than 5 in each group is too small for the test statistic H to follow a chi-squared distribution, and thus the results of the test should be treated with caution [14]. However, other sources say H approximates the chi-squared distribution even if one or more of the groups has as few as 3 observations [9].

Thus, where appropriate, I have performed Kruskal-Wallis H tests on the responses provided about their experience in upper-level courses. However, where sample sizes are too small — particularly, where there are fewer than 3 responses from at least one intro sequence (independent group) — I have noted that the results of the test may not be meaningful and should be treated with caution.

5.3 Results

5.3.1 Student Perceptions of Intro Sequence Preparation for Upper-Level Courses

Upper-level respondents were asked to indicate their perceptions of whether each of these six upper-level courses were better suited to students who took a specific introductory sequence. These responses are displayed in Figure 5.2.

Note that respondents were specifically asked about their perception *before* taking the course. Students who took each course were also asked to indicate whether their perceptions changed after taking the course; these responses will be discussed further below.

A majority of student perceived cs15/cs16 students to be either somewhat or strongly better suited for cs1230. For cs1300 and cs1320, though a large number of students felt the course was not better suited for

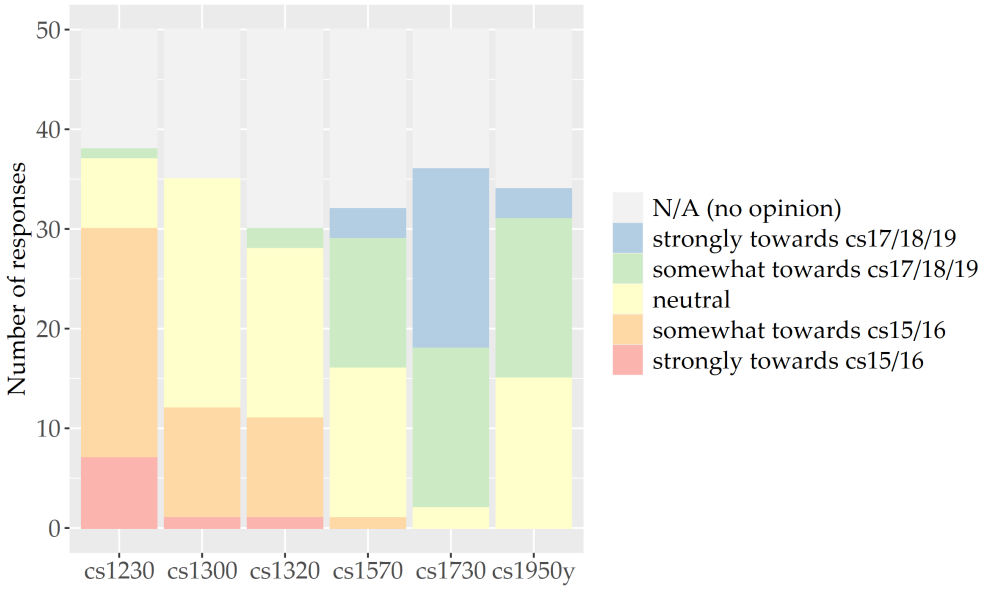


Figure 5.2: Student responses to the question: "Before taking or considering the course, my perception was that this course was better suited for students who took a specific introductory sequence."

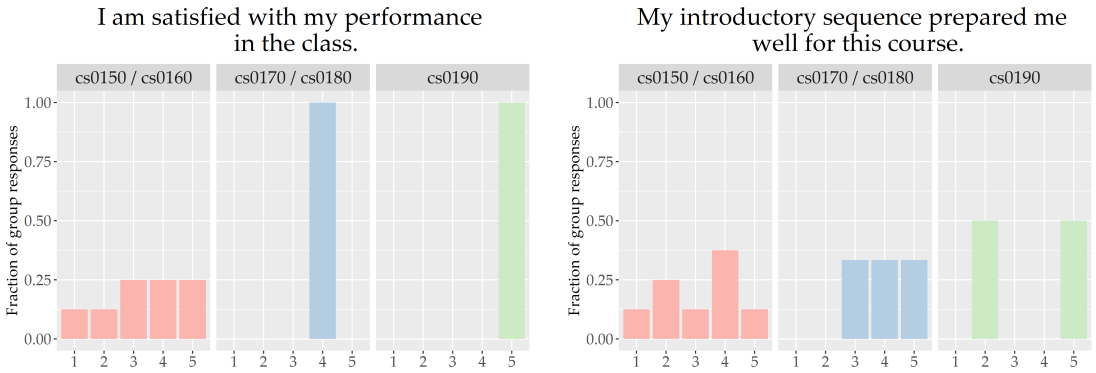
students from a particular introductory sequence (neutral or no opinion), those who did have an opinion tended to skew somewhat or strongly towards cs15/cs16.

In contrast to this, a majority of students perceive cs17/cs18 and cs19 students to be better prepared for cs1730. For cs1570 and cs1950y, though many students felt the course was not better suited for students from a particular introductory sequence (neutral or no opinion), those who did have an opinion tended to skew somewhat or strongly towards cs17/cs18 and cs19.

5.3.2 Preparation for cs1230

Figure 5.3 gives an overview of students' responses to questions about their experience in cs1230. Of the 13 students who indicated they had taken or were currently taking cs1230, 8 students took cs15/cs16, 3 took cs17/cs18, and 2 took cs19.

Running Kruskal-Wallis H tests on the responses to each of these questions revealed no significant differences between the introductory sequences; however, the sample sizes are just under the requirements outlined above for Kruskal-Wallis H tests, which means these results may not be particularly meaningful. Overall, students were satisfied with their performance in the course, and felt that their introductory



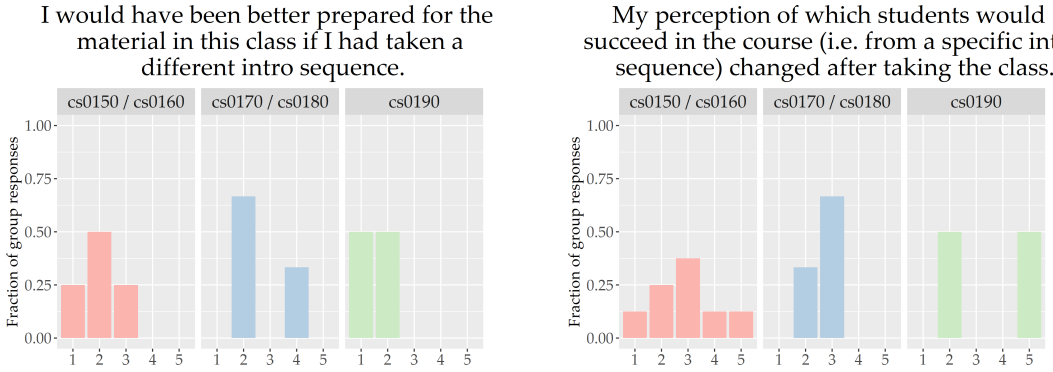


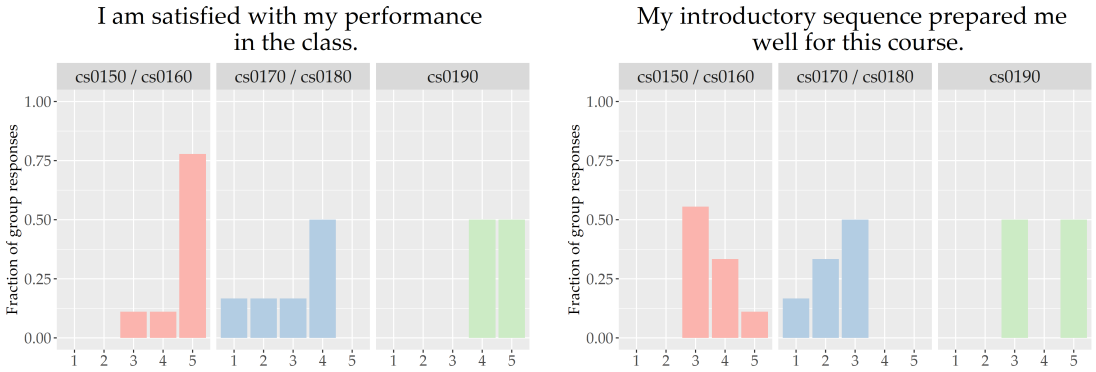
Figure 5.3: Histograms of student responses about their preparation for and experience in cs1230, Introduction to Computer Graphics. A total of 13 students responded about this course — 8 from cs15/cs16, 3 from cs17/cs18, and 2 from cs19. The *y*-axis measures the fraction of students from each group that responded in each category, not the actual number of students. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19. The *x*-axis corresponds to each of the 5 points on the Likert scale, from (1) "Strongly disagree" up to (5) "Strongly agree."

sequences prepared them well for the course. Additionally, students from all sequences tended to disagree that they would have been better prepared for cs1230 if they had taken a different intro sequence. Student responses about whether their perceptions of which students would succeed in the course changed were mostly neutral.

This results is somewhat surprising, and contrasts with student perceptions as discussed in Section 5.3.1. A majority of students believed this course would be better suited for students who took cs15/cs16, possibly due to cs15/cs16's emphasis on OOP and the fact that cs15 and cs1230 share the same professor. However, students who actually took cs1230 did not necessarily feel this was the case, as students from all three introductory sequences felt well prepared for the course. It is possible this is the result of the small sample size — only 3 students who completed cs17/cs18 and 2 students who completed cs19 responded to questions about cs1230. Section 7 will discuss the distribution of students taking upper-level courses and pathways, relative to the introductory sequences they selected.

5.3.3 Preparation for cs1300

Figure 5.4 gives an overview of these students' responses to questions about their experience in cs1300. Of the 17 students who indicated they had taken or were currently taking cs1300, 9 students took cs15/cs16, 6 took cs17/cs18, and 2 took cs19.



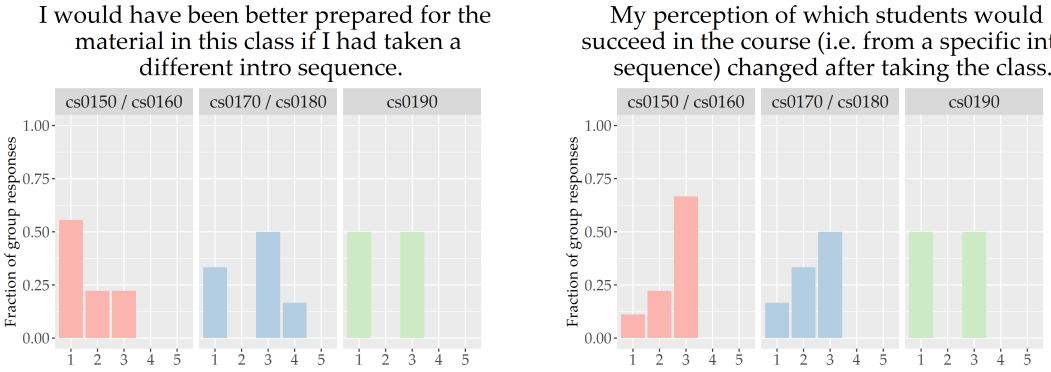


Figure 5.4: Histograms of student responses about their preparation for and experience in cs1300, User Interfaces and User Experience. A total of 17 students responded about this course — 9 from cs15/cs16, 6 from cs17/cs18, and 2 from cs19. The y-axis measures the fraction of students from each group that responded in each category, not the actual number of students. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19. The x-axis corresponds to each of the 5 points on the Likert scale, from (1) "Strongly disagree" up to (5) "Strongly agree."

Based on the graph, a majority of students were relatively satisfied with their performance in cs1300; however, the difference between the three sequences was statistically significant. In particular, the difference between cs15/cs16 and cs17/cs18 was significant, which indicates cs15/cs16 students are more satisfied with their performance.

Similarly, when asked about whether they believe their introductory sequence prepared them for cs1300, the difference in responses between the three sequences was significantly different. The difference between cs15/cs16 and cs17/cs18 is again significant, which indicates cs15/cs16 students feel better prepared for cs1300. However, the sample sizes (particularly for cs19) are just under the requirements outlined above for Kruskal-Wallis H tests, which means both of these results may not be particularly meaningful.

Differences in responses for the last two questions were not significant. A majority of students disagreed (or were neutral) that they would have been better prepared by a different introductory sequence, as well as that their perception of who would be better suited for cs1300 changed after taking the class.

These results indicate that cs15/cs16 students tend to feel better prepared for the assignments in cs1300, and they tend to be more satisfied with their performance in the class. Student perceptions align relatively closely with this; Figure 5.2 indicates that students who have an opinion believe that cs1300 is better suited for cs15/cs16 students. This may be because of the emphasis on visual and graphical applications in cs15/cs16; students may find this experience to be beneficial for assignments in cs1300. However, if this is the case, it is interesting that similar results were not found for cs1230. Students perceived cs1230 to be better suited for cs15/cs16 students for similar reasons, but students who took cs1230 did not find this to be the case.

Statistics. A Kruskal-Wallis H test found significant differences in student responses about whether they were satisfied with their performance in cs1300 ($\chi^2(df = 2) = 8.29, p = 0.016, \epsilon^2 = 0.52$). The mean rank for cs15/cs16 was 11.67, for cs17/cs18 4.58, and for cs19 10.25, with a higher number indicating stronger agreement with the statement that they were satisfied with their performance. A post-hoc Dunn test found that the difference between cs15/cs16 and cs17/cs18 was significant, though cs19 was not different from the other two ($\alpha = 0.05$). However, given the small sample size in the cs19 group, these results should be treated with caution.

Student responses about whether they believed their introductory sequence prepared them for cs1300

were also significantly different ($\chi^2(df = 2) = 7.01, p = 0.03, \epsilon^2 = 0.44$). The mean rank for cs15/cs16 was 10.94, for cs17/cs18 5.00, and for cs19 12.25, with a higher number indicating stronger agreement with the statement that they were well prepared for the course. A post-hoc Dunn test found that the difference between cs15/cs16 and cs17/cs18 was significant, though cs19 was not different from the other two ($\alpha = 0.05$). However, given the small sample size in the cs19 group, these results should be treated with caution.

5.3.4 Preparation for cs1320

Figure 5.5 gives an overview of students' responses to questions about their experience in cs1320. Of the 11 students who indicated they had taken or were currently taking cs1320, 5 students took cs15/cs16 and 6 took cs17/cs18. Note that no students who responded about cs1320 took cs19.

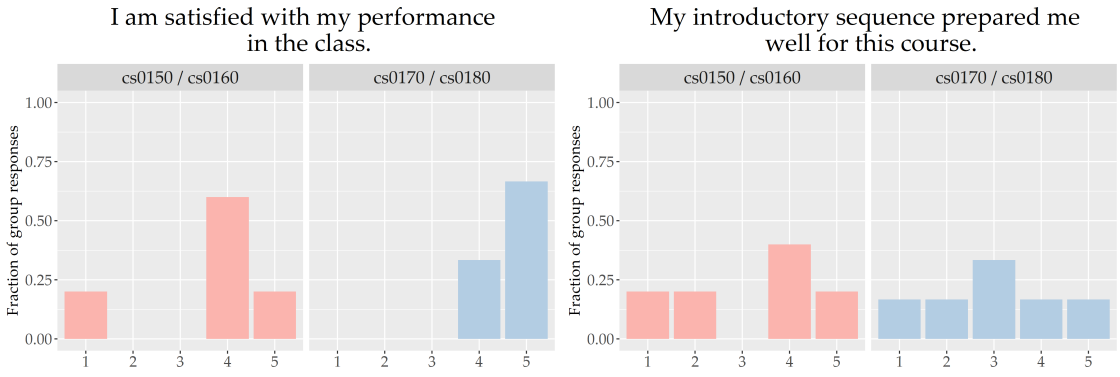
Because only students from cs15/cs16 and cs17/cs18 responded about cs1320, I used a Mann-Whitney U test to compare the two groups (rather than a Kruskal-Wallis H test). However, there were no significant differences between intro sequences in the responses to these questions. Students in cs15/cs16 and cs17/cs18 felt equally satisfied with their performance and equally prepared for the course. Students largely felt that they would not have been better prepared if they had taken a different intro sequence, and that their perception of who would succeed in the course did not change after taking the course.

Student perceptions (as discussed in Section 5.3.1) were slightly skewed towards cs15/cs16. This somewhat aligns with our results, as no students who completed cs19 indicated they had taken cs1320. In general, though, cs15/cs16 and cs17/cs18 students felt equally prepared for cs1320. Though cs15/cs16 and cs17/cs18 emphasize different topics during the introductory sequence, both cover concepts that are useful for web and mobile development (e.g. system design in cs15/cs16, server / client interaction in cs17/cs18), which likely contributed to these results.

5.3.5 Preparation for cs1570

Of the 13 students who indicated they had taken or were currently taking cs1570, 1 student took cs15/cs16, 5 took cs17/cs18, and 7 took cs19.

It is difficult to draw conclusions about the differences in students' preparation for cs1570, as the sample size of 1 for cs15/cs16 students means a Kruskal-Wallis H test is not meaningful. In general, students from all intro sequences generally were satisfied with their performance in the class, felt reasonably well prepared for the course, did not believe a different introductory sequence would have prepared them better, and did not change their perception of which students would succeed in the course.



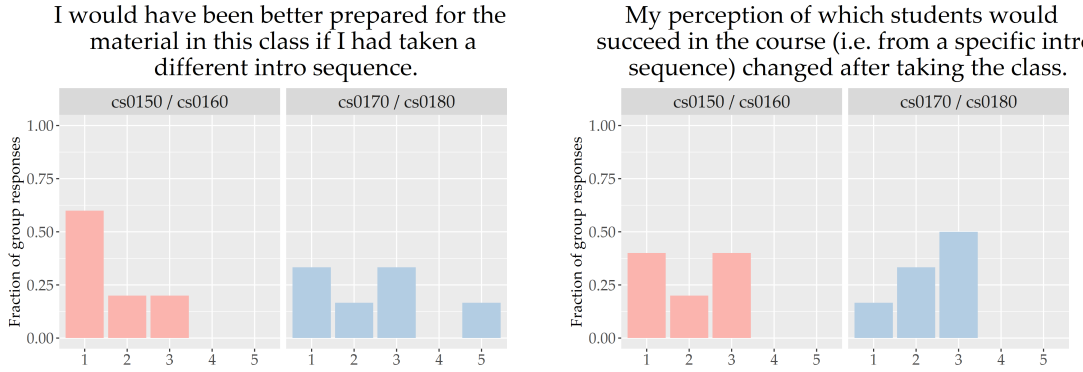


Figure 5.5: Histograms of student responses about their preparation for and experience in cs1320, Creating Modern Web & Mobile Applications. A total of 11 students responded about this course — 5 from cs15/cs16, 6 from cs17/cs18, and 0 from cs19. The y-axis measures the fraction of students from each group that responded in each category, not the actual number of students. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19. The x-axis corresponds to each of the 5 points on the Likert scale, from (1) "Strongly disagree" up to (5) "Strongly agree."

5.3.6 Preparation for cs1730

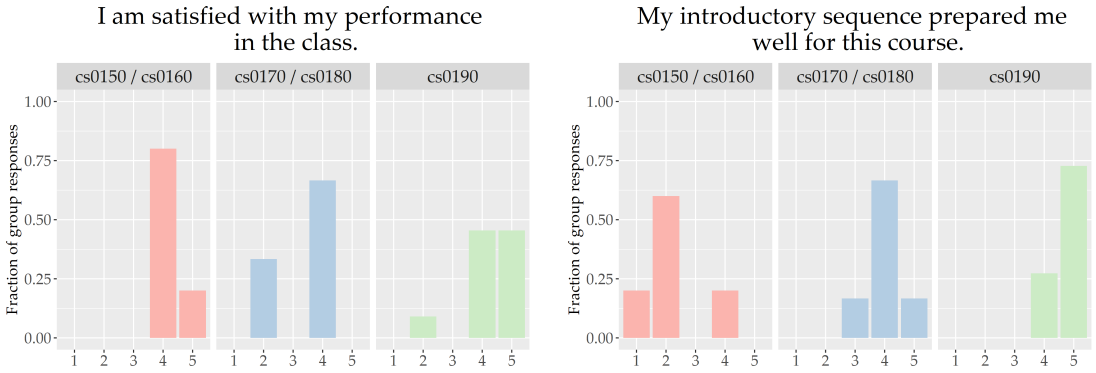
Figure 5.6 gives an overview of these students' responses to questions about their experience in cs1730. Of the 22 students who answered questions about cs1730, 5 students took cs15/cs16, 6 took cs17/cs18, and 11 took cs19.

A majority of students from all introductory sequences were satisfied with their performance in the class; the differences between sequences was not significant. However, while students from cs17/cs18 and cs19 felt well prepared for cs1730, students from cs15/cs16 tended to feel less prepared. The difference between cs15/cs16 and cs19 students was found to be significant (with cs17/cs18 in the middle).

Similarly, students from cs15/cs16 mostly agreed that they would have been better prepared for cs1730 if they had taken a different intro sequence, while students from cs17/cs18 and cs19 disagreed. This difference between cs15/cs16 and cs17/cs18/cs19 was significant.

Responses to the fourth question — about whether students' perceptions of who would succeed in cs1730 changed — were mixed. Though cs15/cs16 and cs17/cs18 students were relatively neutral, cs19 students disagreed with this statement, indicating their perceptions did not change significantly. However, the difference in these results was not significant.

These results mirror student perceptions from Section 5.3.1. Many students perceive cs1730 to be better suited for students who completed cs17/cs18 or cs19, and students who took the course feel the same way.



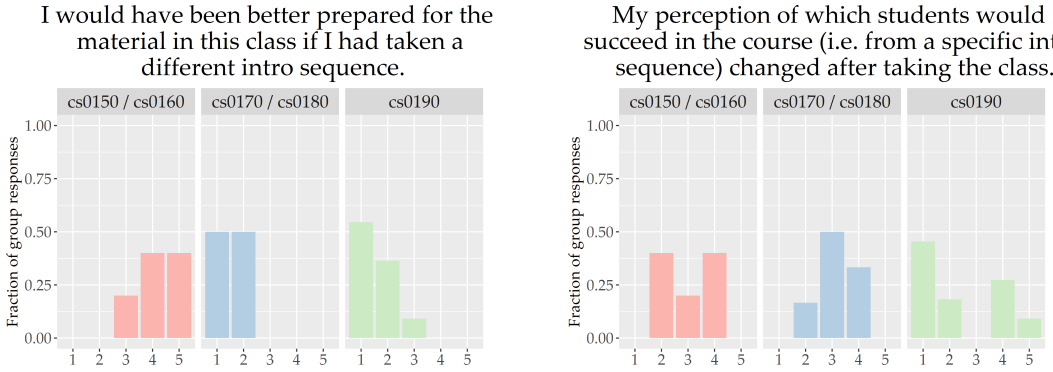


Figure 5.6: Histograms of student responses about their preparation for and experience in cs1730, Design and Implementation of Programming Languages. A total of 22 students responded about this course — 5 from cs15/cs16, 6 from cs17/cs18, and 11 from cs19. The y-axis measures the fraction of students from each group that responded in each category, not the actual number of students. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19. The x-axis corresponds to each of the 5 points on the Likert scale, from (1) "Strongly disagree" up to (5) "Strongly agree."

This is likely because the tools and languages covered in cs1730 are similar to those used in cs17/cs18 and cs19. Furthermore, because the professor for cs1730 also teaches cs19, students from cs19 may take the course because they enjoy the professor's teaching style and the subject, which makes them feel better prepared for the course.

Statistics. A Kruskal-Wallis H test found significant differences in student responses about whether their introductory sequence prepared them for cs1730 ($\chi^2(df = 2) = 13.22, p = 0.001, \epsilon^2 = 0.63$). The mean rank for cs15/cs16 was 3.90, for cs17/cs18 10.17, and for cs19 15.68, where higher numbers indicate stronger agreement with the statement that they were well prepared. A Dunn post-hoc test found the difference between cs15/cs16 and cs19 to be significant, with cs17/cs18 not significantly different from either of them ($\alpha = 0.05$).

Students responses about whether they would have been better prepared for cs1730 if they had taken a different intro sequence were also significantly different ($\chi^2(df = 2) = 12.05, p = 0.002, \epsilon^2 = 0.57$). The mean rank for cs15/cs16 was 19.90, for cs17/cs18 9.00, and for cs19 9.05, where higher numbers indicate stronger agreement with the statement (i.e. that they would have been better prepared by taking a different intro sequence). A Dunn post-hoc test found cs15/cs16 responses to be significantly different from cs17/cs18 and cs19 responses ($\alpha = 0.05$).

5.3.7 Preparation for cs1950y

Figure 5.7 gives an overview of students' responses to questions about their experience in cs1950y. Of the 22 students who answered questions about cs1950y, 7 students took cs15/cs16, 5 took cs17/cs18, and 10 took cs19.

Student responses about cs1950y were not significantly different across different introductory sequences. Students were generally satisfied with their performance in the class. cs17/cs18 and cs19 felt better prepared for the course than cs15/cs16 students, but the difference was not significant. A majority of students did not believe a different introductory sequence would have prepared them better; this response was particularly strong in cs17/cs18 students. Most students (especially from cs15/cs16 and cs17/cs18) did not change their perception of which students would succeed in the course, though a majority of cs19 students did find that their perceptions changed; however, this difference was not significant.

Given that students generally perceived cs1950y to be well suited for cs17/cs18 and cs19 students (from

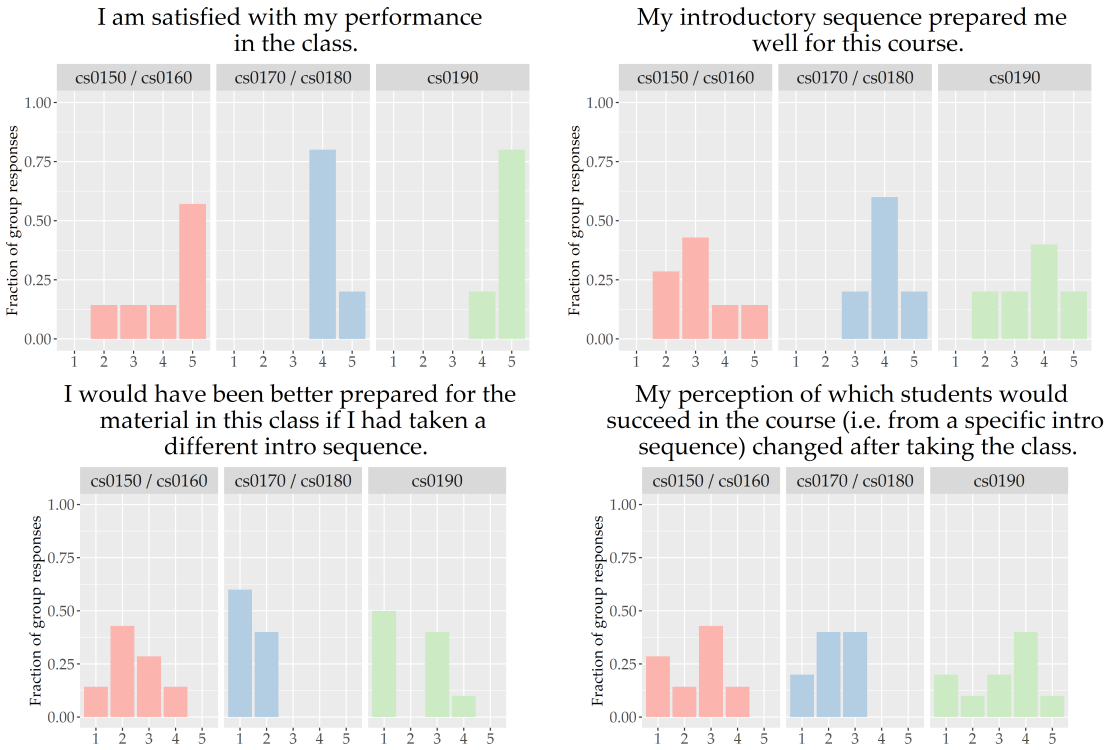


Figure 5.7: Histograms of student responses about their preparation for and experience in cs1950y, Logic for Systems. A total of 22 students responded about this course — 7 from cs15/cs16, 5 from cs17/cs18, and 10 from cs19. The y-axis measures the fraction of students from each group that responded in each category, not the actual number of students. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19. The x-axis corresponds to each of the 5 points on the Likert scale, from (1) "Strongly disagree" up to (5) "Strongly agree."

Figure 5.2), the result that students from all introductory sequences felt equally prepared for cs1950y is rather interesting. This may be because many of the tools used in cs1950y are similar to those used in cs17/cs18 and cs19, leading to perceptions that students from these courses are better prepared for cs1950y. However, the concepts studied in cs1950y are new for students from all three sequences, thus students who take the course do not feel advantaged or disadvantaged as a result of their intro sequence.

5.4 Analysis

In general, as I hypothesized, students perceive graphical and software-engineering based courses as better suited for cs15/cs16 students, while algorithms, theory, and logic based courses are thought to be better suited for cs17/cs18 and cs19 students. These perceptions may be a result of the style of assignments in the introductory courses — for example, because cs15 focuses on more graphical applications, students may believe cs15 students will be better prepared for graphical upper-level courses. Another influence may be the course professors; students might believe cs15 students are better suited for cs1230 because both are taught by the same professor, and similarly for cs19 students and cs1730.

These perceptions are somewhat aligned with student experiences in each of these courses. In particular, students who took cs15/cs16 are more satisfied with their performance in cs1300, and feel better prepared for the course, than cs17/cs18 students. In addition to this, students who took cs19 feel better prepared for cs1730 than students who took cs15/cs16. Furthermore, students who took either cs17/cs18

or cs19 did not feel that they would have been better prepared for cs1730 by a different sequence, while students who took cs15/cs16 felt the opposite.

Notably, student perceptions about cs1230, which were strongly skewed towards cs15/cs16, did not match the experiences of students who took cs1230. These students generally were satisfied with their performance in the course and felt well prepared for it, regardless of their intro sequence. The same is true of cs1950y, which was perceived to be skewed towards cs17/cs18 and cs19 but was not necessarily the case in student experiences.

These results may also be a factor of the number of survey responses received. Fewer than 25 students responded about each of these six courses, and several courses had very few responses from students who completed particular introductory sequences. For example, no cs19 students answered questions about cs1320, and only one cs15/cs16 student answered questions about cs1570. Given this small sample size, it is difficult to tell whether these results truly reflect student experiences in these courses, or whether they are an artefact of self-selection bias.

Part 6

Community

In addition to learning about students' preparation for their intermediate and upper-level courses, we wanted to investigate how the introductory sequence experience influenced students' feelings of community within the Brown Computer Science program. We asked intermediate and upper-level students to indicate what percentage of their community within the department came from the introductory sequence they took. Additionally, we asked them to elaborate in a free-response question on how their introductory sequence impacted their decision to pursue computer science and specific upper-level courses. Our hope is that analyzing this data will provide us with insights into how closely a students' introductory sequence is tied to their identity and sense of belonging within the department.

6.1 Methodology

Rather than using a Kruskal-Wallis H test here, I chose to use a Welch's ANOVA test. Because the Kruskal-Wallis H test is non-parametric, it is less powerful than a one-way ANOVA test [14]. It it is only recommended for ordinal data, such as the Likert scale responses utilized in Parts 3, 4, and 5 [14]. A one-way ANOVA test is recommended for continuous data, such as student responses about percentages of their community (on a 0-100 scale). However, it assumes the observations within each group are approximately normally distributed, and that standard deviations are equal across the groups (homoscedasticity) [16]. This is not the case in our data; the standard deviations are different across the groups, and the groups are not of equal size (i.e. unbalanced design). Thus, a Welch's ANOVA test is the best choice for this data, as it is more accurate for small sample sizes, an unbalanced design, and large variation in standard deviations [16]. The Tukey-Kramer test, which performs pairwise comparisons of means, is used as a post-hoc test for a one-way ANOVA [16]. The Games-Howell test is similar, but better suited as a post-hoc test for Welch's ANOVA [16].

6.2 Results

6.2.1 Intermediate Community

Intermediate course students were asked to indicate how much of their community within computer science took the same introductory sequence as them. These responses are shown in Figure 6.1.

cs15/cs16 students find that a median of 60% of their community within the computer science department took the same introductory course as them. This percentage is 50% for cs17/cs18 students, and 17% for cs19 students. The means are 61.06% for cs15/cs16, 56.53% for cs17/cs18, and 29.38% for cs19. The difference between the means of cs15/cs16 and cs19 was found to be significant, though cs17/cs18 was not significantly different from either.

This result indicates that students in cs15/cs16 may be developing more connections and friendships with one another than students in other intro sequences. This is somewhat surprising, given the emphasis on pair programming in cs17/cs18 and cs19 but not in cs15/cs16. However, this may also be a function of the number of students in each course; given that cs15 is a much larger course than both cs17 and cs19, cs15 students may find it easier to meet other students and develop connections.

Additionally, the undergraduate TA (UTA) program likely plays a role in the development of students' community within the Brown CS department. Many students begin TAing the introductory sequence

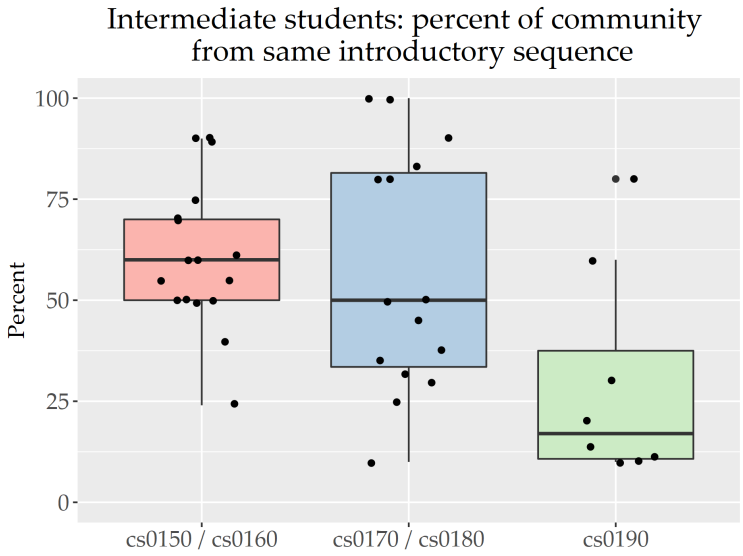


Figure 6.1: Intermediate student responses about the percent of their community within computer science that took the same introductory course as them. The y-axis represents the percentage of students' communities that took the same introductory sequence as them. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19.

starting in their sophomore year. This is also when students typically start to take intermediate courses such as cs0330 and cs0320. Thus, intermediate students are likely developing close relationships with their fellow TAs, who took the same introductory sequence as them, while also developing relationships with students in their intermediate courses, many of whom did not take the same introductory sequence. The number of TAs is dependent on course size, thus cs15/cs16 has the most number of TAs, followed by cs17/cs18 and cs19. The larger the TA staff, the more likely students are to find common interests and develop relationships with their fellow TAs.

Statistics. A Welch's ANOVA test found a significant difference between the means of student responses, $F(df = 2) = 4.16, p = 0.023$. A Games-Howell post-hoc test found only the difference between cs15/cs16 and cs19 to be significant ($p = 0.029$).

6.2.2 Upper-Level Community

Upper-level students were asked to answer the same question as intermediate students, indicating how much of their community within computer science took the same introductory sequence as them. These responses are shown in Figure 6.2.

cs15/cs16 students find that a median of 59.5% of their community within the computer science department took the same introductory course as them. This percentage is 47% for cs17/cs18 students, and 35.5% for cs19 students. The means are 58.67% for cs15/cs16, 52.20% for cs17/cs18, and 39.50% for cs19.

The pattern we saw in intermediate students still holds — upper-level students who completed cs15/cs16 tend to have a greater percentage of their community who took the same intro sequence than cs17/cs18, who in turn have a greater percentage than cs19. However, for upper-level students, this difference between introductory courses is not significant. Thus, students from all introductory sequences develop friendships with students who took the introductory sequence with them and with students who took other introductory sequences, likely through taking intermediate or upper-level courses with them.

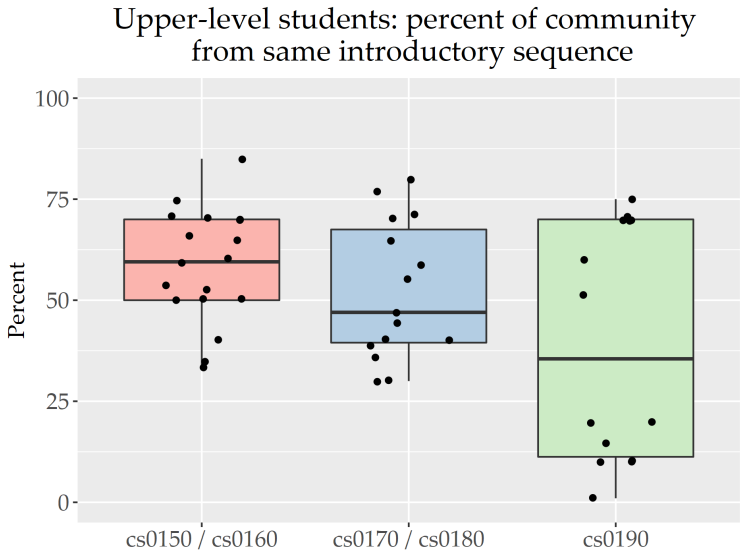


Figure 6.2: Upper-level student responses about the percent of their community within computer science that took the same introductory course as them. The y-axis represents the percentage of students' communities that took the same introductory sequence as them. Red corresponds to cs15/cs16, blue to cs17/cs18, and green to cs19.

The TA program likely plays a factor in this difference between intermediate and upper-level students. As we discussed earlier, many intermediate students TA their introductory courses, thus the size and makeup of their community is largely tied to their introductory sequence and the size of the TA staff. For upper-level students, however, many students TA their intermediate or upper-level courses, thus developing communities and relationships through these groups rather than their intro sequences. The slight differences in percentages between the three intro sequences might just be the result of the different sizes of the sequences.

One notable difference between upper-level student responses (Figure 6.2) and intermediate student responses (Figure 6.1) is that the median percentage for cs19 substantially increased. This is somewhat interesting; students who completed cs19 develop more connections with other cs19 students in their upper-level courses, rather than in the intro course itself. However, the variance in cs19 students' communities is rather large, which indicates that the makeup of their communities differs substantially between students.

6.2.3 Free Responses on Experiences in the Introductory Sequences

Intermediate and upper-level students were also given the opportunity to discuss how their introductory sequence ultimately influenced their decision to continue studying computer science.

cs15/cs16 Students

Intermediate Students. In general, intermediate student responses about cs15 in particular were mixed, with some students indicating that they really loved the course, and others writing that it discouraged them or adversely affected their mental health. However, students generally had high praise for cs16, with many saying the course encouraged them to continue taking computer science courses and pursue it as a concentration.

Several students discussed their struggles with cs15, and how overcoming these challenges solidified their decision to study computer science.

> I sometimes wonder if I'd be more confident if I took another introductory sequence (i.e., not cs15). But ultimately I reject that idea — I don't think it's an admission of failure to accept that I would have struggled in any of my first CS classes, and I definitely can't speak for the experiences of others in different introductory sequences. I would say the introductory sequence was definitely a mixed bag for me — it made me doubt myself... and what I was capable of, and for the first time I couldn't scrape things together at the end and move on. I think there was value in that, though, and I believe those experiences of vulnerability and uncertainty were what solidified my passion for CS in ways I never would have felt had I been cruising. Now I know I'm here because this is truly what I want to do, not because I like the feeling of turning in successful work and being good at something. A double-edged sword of sorts, I guess, but it's why I'm here today.

One student didn't know that there were other options for introductory computer science, but still found that their experience in cs15 was a positive influence.

> "I think this might have been the best course for me since it was focused around making games and things that are relatively fun to play with or look at, so for a freshman who really liked the notion of 'making things,' this might have been the best course...[W]hile I struggled a lot for the first 2 months of the course, it impacted my decision to pursue computer science because at the end it made me feel like CS was accessible to me, and not some impossibly complicated 'STEM' field."

Upper-Level Students. Many cs15/cs16 students highlighted the focus on visual applications and building large programs in cs15, which initiated their interest in computer science and encouraged them to take similar courses, such as cs1230, cs0320, and cs1950n/cs1950u (game engines).

However, several students did not find that their experience in cs15/cs16 significantly influenced their decision to take upper-level courses. One student wrote that while they enjoyed the introductory sequence, which led them to decide to concentrate in CS, it "has had no impact on which courses I take." Another student wrote that "Often it feels arbitrary to me. I feel much more impacted by the higher-level courses I've taken."

cs17/cs18 Students

Intermediate Students. Responses about cs17/cs18 were similarly mixed. Many students wrote that they really enjoyed cs17, which encouraged them to continue taking computer science courses and even switch concentrations. Another student highlighted the community in the course as well, saying that "my introductory sequence itself, per se, hasn't really impacted my course decisions — but the people I met in it have." However, other students felt that the intro sequence "gave me the impression that future classes were very difficult, very stringent on collaboration, and help was scarce [in TA hours]. I still believed that CS was [going to] be different, so I stuck with it."

One student in particular highlighted the functional programming approach in cs17/cs18.

> I loved cs17/cs18, and I don't think I would have liked cs15/cs16 nearly as much. The cs17/cs18 approach to introducing CS — focusing on the kind of thinking more than the skill of programming — is what made me interested in concentrating, what keeps me interested in learning about the field beyond just learning to write programs by reading specifications and language documentation.

Upper-Level Students. Students who took cs17/cs18 discussed a number of different factors that positively influenced their decision to continue studying computer science — in particular, the focus on recursion, logic, and algorithms, as well as the professor for cs18.

> I really liked how math/algorithms/logic based cs17 was[,] and that helped me realize that CS is really an academic discipline and not just about software engineering.

However, many students found that even though their experience in cs17/cs18 encouraged them to take more computer science classes, it did not significantly influence the upper-level courses they decided to take.

Several students who took cs17/cs18 discussed their negative experience with the community in the course. Some students found the culture — especially the focus on "grind[ing] hard to get a good internship" — discouraged them from concentrating in computer science entirely, while others decided to look past it and continue with upper-level CS courses.

> I took cs17/cs18 without prior CS experience and felt extremely unconfident in my CS skills after, mostly due to a somewhat toxic environment that the class had. I think this stemmed also from my own confidence issues and was based largely on my perceived notion that everyone in the class already had experience while I didn't[,] so I felt like I was very inferior. The introductory sequence I chose greatly impacted my mentality[,] but after trying out a few upper level courses and succeeding in them, I've since been able to overcome most of my insecurities.

cs19 Students

Intermediate Students. Many intermediate students from cs19 spoke highly of the course professor, stating that his discussion of application of topics covered in class encouraged them to take more courses, including courses taught by the same professor. However, one student expressed the opposite opinion, particularly about the culture of the course: "The culture in cs19 was so garbage that it made me want to quit CS. The one-upmanship perpetuated by some of the 'vocal' kids in that class was very frustrating."

Upper-Level Students. Several cs19 students wrote that their experience in cs19 piqued their interest in programming languages and logic. For example, one student wrote that "cs19 directly encouraged me to take cs1950y, which ultimately supported my interest in formal methods and logic-based programming in other courses like cs2951o [Foundations of Prescriptive Analytics]." Other students felt that their experience in cs19 negatively influenced their decision to continue studying computer science, discouraging them from getting involved in the department and taking challenging classes.

6.3 Analysis

In analyzing this data, we wanted to investigate how students' communities within the Brown CS department are shaped by the introductory sequences. Overall, students tend to develop friendships with students in their introductory sequences, but as they move into intermediate and upper-level courses, they build relationships with students who took other introductory sequences.

For intermediate students, those who completed cs15/cs16 found that significantly more of their community took the same intro sequence as them than those who completed cs19, with cs17/cs18 in the middle. While this difference still exists in upper-level students, it is not significant. This implies that once students move into upper-level courses, their communities are not significantly different depending on which introductory sequence they took.

The fact that cs15/cs16 students indicate the highest percentage of their community from their introductory sequence is relatively surprising, given both cs17/cs18's emphasis on pair programming and cs19 students' positive opinion of their classmates (as seen in Part 3). This may be a result of the larger size of the course — cs15/cs16 students may be more likely to meet people they connect with through the course. Additionally, this may be affected by the UTA program. Intermediate students often TA their

introductory sequence and develop friendships with fellow TAs. The larger the TA staff, the more close relationships students develop with their fellow TAs, which increases the percentage of their community that took the same introductory sequence as them.

Interestingly, the median percentage for cs19 students increased from intermediate students to upper-level students. This might indicate that cs19 students don't develop many close relationships with other cs19 students during the course, but develop these relationships in upper-level courses.

Students' free responses about their experiences in the introductory sequences were mixed. Many students enjoyed the material, community, and professor of the introductory courses, and many found that their experience in their intro courses encouraged them to take similar upper-level courses — visual applications and software engineering for cs15/cs16 students, and algorithms and logic for cs17/cs18 and cs19 students. However, several students felt that their introductory course experience didn't influence them to take specific upper-level courses, but it did encourage them to continue pursuing computer science in general.

On the other hand, many students also found the difficulty, stress, and culture in their introductory sequences discouraging. While some students pushed past this challenge and found the experience in upper-level courses much more enjoyable, others were so discouraged by the intro sequence experience that they no longer wanted to concentrate in computer science. This is common across all three introductory sequences, which indicates that while there are significant improvements to be made, students have similar experiences regardless of which introductory sequence they take.

Part 7

Concentration Declarations

In addition to the survey responses collected from current students, we analyzed anonymous concentration declaration data collected from Brown's advising platform, Advising Sidekick (ASK). Our goal is to investigate if there is any correlation between a student's introductory sequence and their trajectory through the Brown Computer Science program — in particular, their degree program choices (i.e. A.B. vs. Sc.B.), as well as which upper-level pathways they choose to follow.

7.1 Data

When students declare their concentration, typically in April of their second year, they must fill out a concentration declaration on ASK. In their concentration declaration, students indicate which program plan they intend to pursue. For studying pursuing computer science, these options include a Bachelor of Arts (A.B.) or Bachelor of Science (Sc.B.) in Computer Science, A.B. or Sc.B. in Computational Biology, A.B. or Sc.B. in Computer Science-Economics, Sc.B. in Applied Mathematics – Computer Science, and Sc.B. in Mathematics – Computer Science [2].

Students also complete a course contract, which includes the courses they intend to take to complete the requirements for their chosen concentration [4]. This includes courses they have already taken and any courses they intend to take in future semesters.

All students who concentrate in Computer Science are required to complete an introductory sequence, several intermediate courses (three for A.B. students, and five for Sc.B. students), and upper-level courses. The upper-level requirements are organized into a collection of pathways, with each representing a well-defined field within computer science. Each pathway specifies a list of core courses, a list of related courses (including graduate-level courses), and up to three mandatory intermediate courses. To complete a pathway, students must take one core course, another core or related course, and all mandatory intermediate courses. A.B. students must complete one pathway, plus additional upper-level courses to reach a total of nine courses. Sc.B. students must complete two pathways, plus additional upper-level courses to reach a total of fifteen courses. Sc.B. students must also complete an additional capstone course [4].

There are currently eleven pathways for students to choose from [5]. These pathways are:

- Artificial Intelligence/Machine Learning (AI/ML)
- Computational Biology (Comp. Bio.)
- Computer Architecture (Comp. Arch.)
- Data (Data)
- Design (Design)
- Security (Security)
- Software Principles (Software)
- Systems (Systems)
- Theory (Theory)
- Visual Computing (Visual Comp.)
- Self-Designed Pathway (Self-Designed).

The anonymized data consists of the last two years of concentration declarations, i.e. students who declared their concentrations in 2018 and 2019 (graduating in 2020 and 2021). This includes 197 A.B. declarations and 260 Sc.B. declarations in Computer Science; it does not include any joint concentrations such as Applied Math – Computer Science or Computer Science – Economics. Only students who filled out their concentration declaration as expected were included in my analysis. Those who made significant

errors, such as declaring more than two pathways or indicating more than one introductory sequence, were omitted.

Concentration requirements are formatted as a series of nested JSON objects. Each course included by a student in their concentration declarations is also formatted as a JSON object. I parsed this data using Python scripts, which can be found at *https://github.com/shawnaness/concentration-data*. All statistical analysis and graphs were done in R.

7.2 Results

7.2.1 Choice of Degree Program

To measure the relationship between a student's intro sequence and the degree program they choose to pursue, I tallied the number of students in each degree program by the introductory sequence they indicated in their declaration.

Table 7.1 gives the breakdown of the two degree options (A.B. and Sc.B.) by intro sequence. This information is also displayed in Figure 7.1. Table 7.2 shows the same data, but each intro sequence is broken down by degree program. Finally, Figure 7.2 compares the percentage of students from each intro sequence who declare an A.B.

Table 7.1: Fraction and number of students from each degree program who took each introductory sequence. For comparison, the rightmost column is the 2019-2020 enrollment numbers for the last course in the intro sequence, i.e. cs16, cs18, and cs19.

	A.B.	Sc.B.	Combined	2019-2020 Enrollment
cs15/cs16	0.69 (136)	0.43 (111)	0.54 (247)	0.54 (272)
cs17/cs18	0.18 (35)	0.32 (81)	0.26 (116)	0.34 (172)
cs19	0.13 (26)	0.25 (64)	0.20 (90)	0.12 (59)
Total	197	256	453	503

Table 7.2: Fraction and number of students from each introductory sequence who declared each degree program.

	cs15/cs16	cs17/cs18	cs19	Combined
A.B.	0.55 (136)	0.30 (35)	0.29 (26)	0.43 (197)
Sc.B.	0.45 (111)	0.70 (81)	0.71 (64)	0.57 (256)
Total	247	116	90	453

The relationship between introductory sequence and choice of degree is not independent. In particular, cs15/cs16 students choose to pursue an A.B. significantly more frequently than cs17/cs18 and cs19 students. Figure 7.1 shows that while students from cs15/cs16 make up a significant majority of A.B. students (69%), the distribution of Sc.B. students from each of the three introductory sequences is much more even. In Table 7.2, we see that cs15/cs16 students choose to pursue an A.B. or an Sc.B. in approximately equal proportions. Meanwhile, cs17/cs18 and cs19 students largely choose to pursue an Sc.B. (70% and 71%, respectively).

This aligns with the results we found in Part 3. Students who take cs15/cs16 are more likely to not intend to concentrate in computer science before taking the introductory sequence; many students then decide to concentrate in computer science after taking the intro sequence. These students likely decide to pursue an A.B. rather than an Sc.B., allowing them to take fewer upper-level computer science courses and

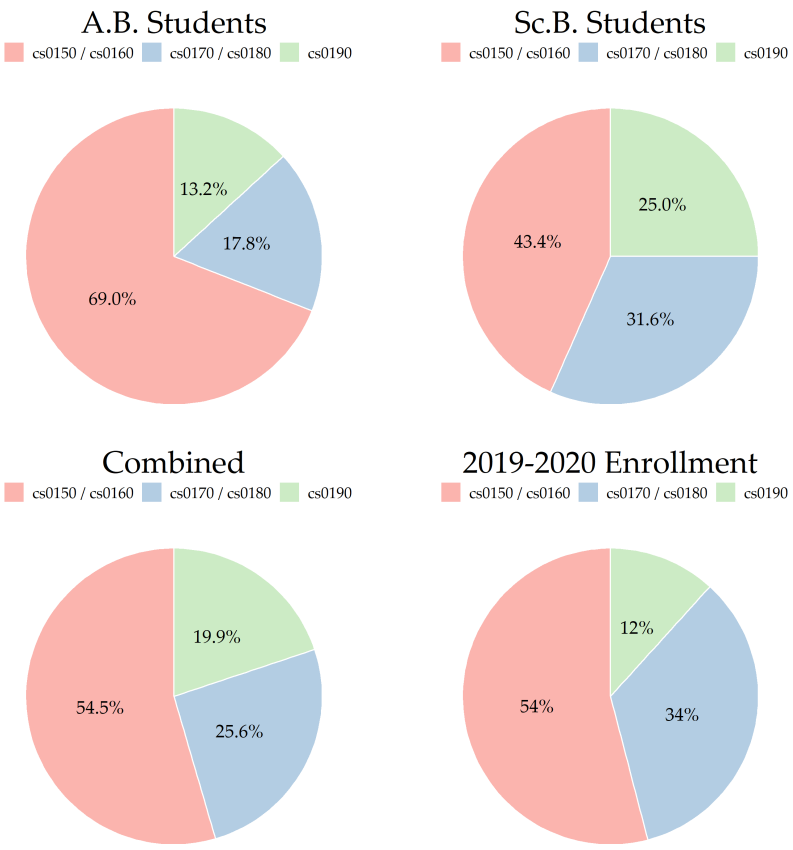


Figure 7.1: Percentage of students in each degree program who took each introductory sequence. The bottom-right graph shows the 2019-2020 enrollment numbers for the last course in the intro sequence, i.e. cs16, cs18, and cs19.

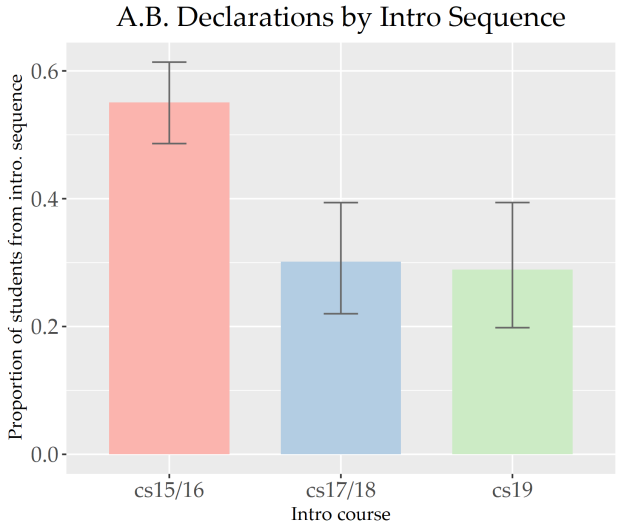


Figure 7.2: Proportion of students from each introductory sequence who declare an A.B., with error bars representing 95% confidence intervals. cs15/cs16 students declare an A.B. significantly more frequently than cs17/cs18 and cs19 students.

pursue other interests and concentrations. Meanwhile, students in cs17/cs18 and cs19 are more likely to intend to concentrate in computer science before starting the introductory sequence. These students thus likely already intend to take many upper-level CS courses, which means they might be more likely to pursue an Sc.B. over an A.B..

Statistics. A Fisher's exact test found that the proportions of students who declare each degree program are different among the three introductory sequences (p = 3.16e-7). Pairwise comparisons (with a Benjamini-Hochberg correction) found that cs15/cs16 is significantly different from cs17/cs18 (p = 2.99e-5, Cramer's $V = 0.23$) and cs19 (p = 3.62e-5, Cramer's $V = 0.23$). However, cs17/cs18 and cs19 are not significantly different.

7.2.2 Pathways Declared

Table 7.3 gives the breakdowns of students from each intro course who declared each of the eleven pathways. Recall that A.B. students declare only one pathway, while Sc.B. students declare two. Students who declared more than the expected number of pathways for their degree program were omitted from the analysis.

Figures 7.3 and 7.4 show this same data in graphical form. I chose to display fraction of students rather than numbers to allow for easier comparison between the introductory sequences, which have different numbers of students.

Table 7.3: Fraction and number of students from each introductory sequence who declare each pathway in their concentration declaration.

	A.B.			Sc.B.			Combined		
	cs15/cs16	cs17/cs18	cs19	cs15/cs16	cs17/cs18	cs19	cs15/cs16	cs17/cs18	cs19
AI/ML	0.36 (46)	0.41 (12)	0.50 (12)	0.64 (67)	0.71 (53)	0.68 (41)	0.49 (113)	0.63 (65)	0.63 (53)
Comp. Bio.	0.01 (1)	0.00 (0)	0.04 (1)	0.03 (3)	0.04 (3)	0.00 (0)	0.02 (4)	0.03 (3)	0.01 (1)
Comp. Arch.	0.01 (1)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (1)	0.00 (0)	0.00 (1)	0.01 (1)	0.00 (0)
Data	0.08 (10)	0.03 (1)	0.08 (2)	0.17 (18)	0.16 (12)	0.10 (6)	0.12 (28)	0.13 (13)	0.10 (8)
Design	0.16 (20)	0.07 (2)	0.04 (1)	0.29 (30)	0.11 (8)	0.03 (2)	0.22 (50)	0.10 (10)	0.04 (3)
Security	0.05 (6)	0.07 (2)	0.08 (2)	0.13 (14)	0.13 (10)	0.23 (14)	0.10 (20)	0.12 (12)	0.19 (16)
Software	0.04 (5)	0.03 (1)	0.04 (1)	0.18 (19)	0.20 (15)	0.30 (18)	0.10 (24)	0.15 (16)	0.23 (19)
Systems	0.05 (6)	0.10 (3)	0.17 (4)	0.17 (18)	0.35 (26)	0.33 (20)	0.10 (24)	0.28 (29)	0.29 (24)
Theory	0.02 (3)	0.00 (0)	0.00 (0)	0.05 (5)	0.07 (5)	0.15 (9)	0.03 (8)	0.05 (5)	0.11 (9)
Visual Comp.	0.21 (27)	0.21 (6)	0.04 (1)	0.33 (34)	0.23 (17)	0.17 (10)	0.26 (61)	0.22 (23)	0.13 (11)
Self-Designed	0.02 (2)	0.07 (2)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.01 (2)	0.02 (2)	0.00 (0)
Number of Students	127	29	24	104	75	60	231	104	84

In general, for both the A.B. and Sc.B. degree programs, AI/ML is the most popular pathway by far, with Visual Comp., Systems, and Design also very common.

For A.B. students, cs15/cs16 students tend to declare the Design pathway in greater proportions than other students. cs17/cs18 and cs19 students tend to declare AI/ML and Systems in greater proportions, with cs19 students even greater than cs17/cs18. However, a Fisher's exact test shows that these distinctions for A.B. students are not significant.

For Sc.B. students, the results are similar. cs15/cs16 students tend to declare Design and Visual Comp. more frequently than other students. cs17/cs18 and cs19 students declare Systems much more than cs15/cs16 students, with cs19 students especially choosing to pursue Security, Software, and Theory more than other students. These differences are significant, which indicates that for Sc.B. students, their choice of introductory sequence does influence their choice of pathways.

Post-hoc pairwise tests with a Benjamini-Hochberg correction found that cs15/cs16 students declare Design more frequently than cs19 students, and cs19 students declare Security, Software, Systems,

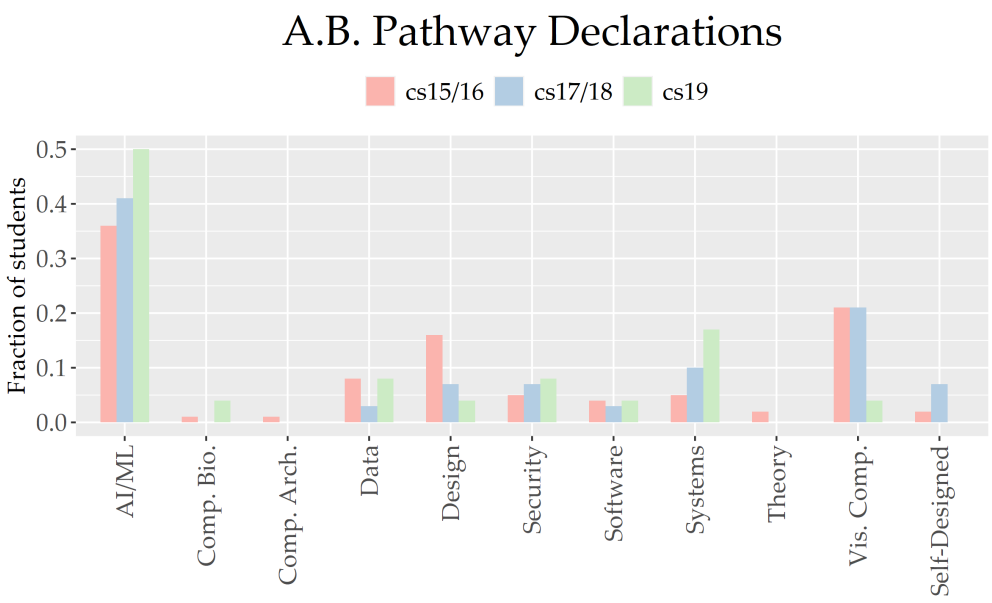


Figure 7.3: Fraction of A.B. students from each introductory sequence who declare each pathway. Each student declares one pathway. The y-axis measures the fraction of students from each introductory sequence, not the actual number of students. Red represents cs15/cs16, blue cs17/cs18, and green cs19.

and Theory more frequently than cs15/cs16 students. cs15/cs16 students also declare Design more frequently than cs17/cs18 students, and cs17/cs18 students declare Systems more frequently than cs15/cs16 students.

Statistics. For students completing an Sc.B., a Fisher's exact test found the difference in pathway declarations between introductory sequences to be statistically significant ($p = 0.001$).

For post-hoc tests, I ran Fisher's exact tests on each pair of introductory sequences and pathways, using the Benjamini-Hochberg correction (as outlined in Section 3.2). Comparing AI/ML vs. Design for cs15/cs16 students and cs19 students was significant ($p = 0.012$). Results were also significant for cs15/cs16 and cs19 students when comparing Design vs. Security ($p = 0.010$), Design vs. Software ($p = 0.0067$), Design vs. Systems ($p = 0.0040$), and Design vs. Theory ($p = 0.0063$). Additionally, comparing AI/ML vs. Systems for cs15/cs16 students and cs17/cs18 students was significant ($p = 0.019$).

Note that a Fisher's exact test, similar to a Chi-square test, assumes that the individual observations are independent. A.B. pathway declarations are independent, as students only declare one pathway each. However, Sc.B. pathway declarations are not independent; students must declare two distinct pathways, which is equivalent to choosing two without replacement. We ultimately decided that a Fisher's exact test was still the best choice for the data, but this is something to account for when analyzing our results.

Sc.B. Pathway Pairs

Because Sc.B. students declare two pathways rather than just one, we also wanted to look at which pathway pairs were most common. Given the many combinations of pathway pairs, we chose not to break this data down by intro sequence, and instead to analyze pathway pairs in aggregate to better understand what combination of interests are most popular among students. Table 7.4 indicates the pairs of pathways that Sc.B. students pursue.

There is no particular pair of pathways that is significantly more popular than others; however, a large

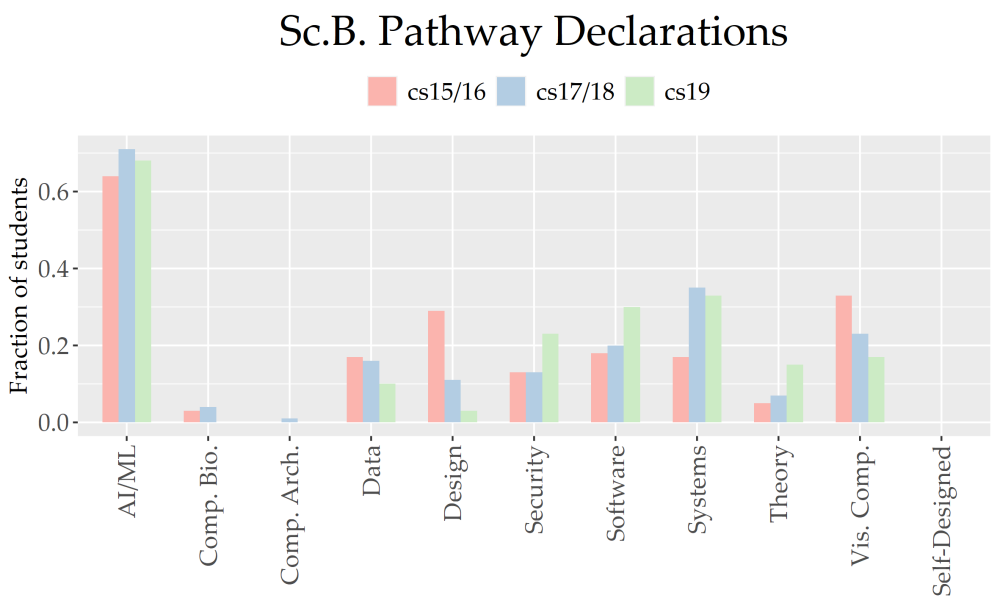


Figure 7.4: Fraction of Sc.B. students from each introductory sequence who declare each pathway. Each student declares two pathways. The y-axis measures the fraction of students from each introductory sequence, not the actual number of students. Red represents cs15/cs16, blue cs17/cs18, and green cs19.

Table 7.4: Number of Sc.B. students who declare each pair of pathways (total number of students = 242).

	Comp. Bio.	Comp. Arch.	Data	Design	Security	Software	Systems	Theory	Visual Comp.
AI/ML	4	1	24	20	18	22	31	11	31
Comp. Bio.	x	0	0	1	0	0	0	0	1
Comp. Arch.	x	x	0	0	0	0	0	0	0
Data	x	x	x	1	2	5	1	0	3
Design	x	x	x	x	3	1	1	0	14
Security	x	x	x	x	x	2	11	2	0
Software	x	x	x	x	x	x	12	4	7
Systems	x	x	x	x	x	x	x	3	6
Theory	x	x	x	x	x	x	x	x	0

majority of students combine AI/ML with another pathway. The most popular of these are AI/ML+Systems, AI/ML+Visual Comp., and AI/ML+Data. Popular pairs that don't include AI/ML include Design+Visual Comp., Software+Systems, and Security+Systems.

7.2.3 Pathways Touched

To some extent, students declare their pathways out of convenience, organizing the courses they have already taken and are interested in taking into the given categories. In order to get a more accurate measure of what upper-level courses and topics students are interested in, we tallied the pathways that students touched in their concentration declarations. We define *touching a pathway* as taking at least one of the core courses of that pathway. For example, if a student takes at least one of {Introduction to Cryptography and Computer Security (cs1510), Software Security and Exploitation (cs1650), Introduction to Computer Systems Security (cs1660)}, they are counted as having touched the Security pathway. Because each student is counted at most once in each pathway, regardless of how many core courses they take, we chose to combine A.B. and Sc.B. pathway declarations for this analysis.

There are four courses which are core in multiple pathways; these courses are counted towards each of

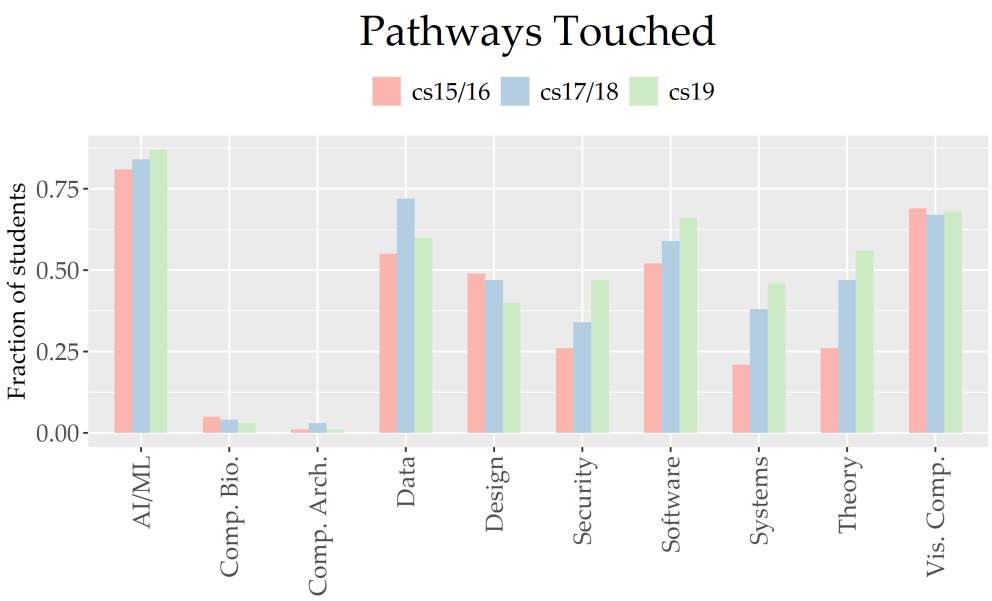


Figure 7.5: Fraction of students from each introductory sequence who touch each pathway, where "touching" a pathway is defined as taking at least one core course in that pathway. There are four courses which are double-counted, as they are core courses in two pathways. The y-axis measures the fraction of students from each introductory sequence, not the actual number of students. Red represents CS15/CS16, blue CS17/CS18, and green CS19.

the pathways, and thus are double-counted in the data. These courses are:

- CS1300 (DESIGN and VISUAL COMP.)
- CS1370 (DESIGN and VISUAL COMP.)
- CS1420 (AI/ML and DATA)
- CS1850 (AI/ML and COMP. BIO.).

Additionally, note that the SELF-DESIGNED pathway is omitted, as there are no core courses for the SELF-DESIGNED pathway (students must propose courses to fulfill this pathway).

Figure 7.5 shows the fraction of students that touch each pathway. Students in all pathways appear to take courses in AI/ML most frequently, followed by VISUAL COMP., DATA, and SOFTWARE.

CS15/CS16 students take courses in DESIGN at slightly higher rates than other students. However, while CS15/CS16 students (especially those who pursue an SC.B.) appear to declare the VISUAL COMP. pathway more frequently than other students, students from all introductory sequences take core courses in VISUAL COMP. at approximately equal rates.

CS17/CS18 and CS19 students take courses in SECURITY, SOFTWARE, SYSTEMS, and THEORY more often than CS15/CS16 students. In addition to this, CS17/CS18 students appear to take courses in DATA at higher rates than other students.

The differences in pathways touched between the introductory sequences was significant. Post-hoc pairwise tests with a Benjamini-Hochberg correction found that while CS15/CS16 students take courses in DESIGN more than CS19 students, CS19 students take courses in SYSTEMS and THEORY more frequently than CS15/CS16 students.

Statistics. A Fisher's exact test found the difference in pathways touched between introductory sequences to be statistically significant ($p = 0.0060$). For post-hoc tests, I ran Fisher's exact tests on each pair of introductory sequences and pathways, using the Benjamini-Hochberg correction (as outlined in Section 3.2). Comparing Design vs. Systems for cs15/cs16 and cs19 was significant ($p = 0.048$), as was comparing Design vs. Theory for cs15/cs16 and cs19 ($p = 0.048$).

7.3 Analysis

There is a correlation between students' introductory sequences and their choice of degree program; cs15/cs16 students are more likely to pursue an A.B., while cs17/cs18 and cs19 students are more likely to pursue an Sc.B. However, this seems to be correlated with students' goals before taking the introductory sequence. Students tend to come into cs15 planning not to take many courses in computer science. Taking cs15/cs16 encourages many of them to concentrate in computer science, but they likely intend to take fewer upper-level CS courses, which leads them to declare an A.B. In contrast, cs17/cs18 and cs19 students often start the intro sequence intending to take many upper-level courses and concentrate in computer science. This corresponds to these students declaring an Sc.B.in higher numbers. Thus, this correlation we found between introductory sequence and choice of degree program is likely mostly a factor of students' goals before taking the intro sequence, and not substantially influenced by the intro sequence experience itself.

We did find some differences in the pathways students choose to pursue by their intro course. However, though we see this difference when measuring across all pathways, the differences in individual pathways is only significant for a few pathways. In particular, Sc.B. students who completed cs15/cs16 are significantly more likely to pursue Design than cs17/cs18 and cs19 students, while cs17/cs18 students are more likely to pursue Systems than cs15/cs16 students, and cs19 students are more likely to pursue Security, Software, Systems, and Theory than cs15/cs16 students. When we consider the upper-level courses students take through the pathways they touch (not just the ones they declare), cs15/cs16 students pursue Design courses more frequently than cs19 students, who pursue Systems and Theory courses more frequently than cs15/cs16 students.

These results imply that there is some difference in the pathways students choose to pursue by the introductory sequence they take. cs15/cs16 students gravitate towards higher-level design courses, while cs17/cs18 and cs19 gravitate towards lower-level systems and theory courses. Thus, the introductory sequence a student takes can serve as a useful indicator of their interests in computer science. Given student responses about their experiences in the introductory sequences, this seems to be both a factor of their prior interests before taking the intro sequence, and the assignments and material covered in the intro sequence. Many cs15/cs16 students have a prior interest in visual applications and software development, which is made stronger by their experience in the introductory sequence. However, many cs17/cs18 and cs19 students have no prior interest or experience in systems and theory, but find that their introductory sequence piques their interest in these topics.

Part 8

Discussion

8.1 Limitations

As with any qualitative research study, we faced several limitations throughout this project.

There is inherently some self-selection bias in this project, as only students with strong opinions about the introductory sequences are likely to respond to the survey. Additionally, the survey we distributed to students was entirely voluntary; we provided no compensation for students who completed the survey. This may account for the 72 students who only partially completed the survey, as they had no incentive to answer all of the questions.

Our survey design and distribution methods may also have biased the results. The structure and phrasing of the questions may have skewed student responses in a way that is not truly representative of their underlying opinions. The survey was also distributed to students in each course through different methods and at slightly different times, depending on the method of communication each professor preferred and when they were able to send emails/post on discussion boards. This may have affected how many students responded from each course.

As discussed in Section 2.1, waiting for IRB review (which we ultimately did not need) artificially delayed our timeline. We were unable to distribute the survey to students until late November/early December 2019, though we had intended to distribute it much earlier in the semester. Furthermore, our collection of responses in the spring semester was cut short by the COVID-19 pandemic. We had also intended to ask CS department faculty for their input on the project, including any additional questions they wanted to explore using the data we collected; these plans were also unfortunately disrupted by the pandemic.

8.2 Future Work

This project focused mainly on students' opinions and decisions about various courses in the Brown CS program. In the future, focus groups with students in each of these course levels (introductory, intermediate, and upper) may provide additional insights into these opinions and decisions. We also did not quantitatively measure students' preparation for or performance in intermediate and upper-level courses. A technical assessment could be conducted to determine differences in students' understanding of important computer science concepts across introductory sequences. This would serve as a more quantitative measure of how well the introductory sequences prepare students for intermediate and upper-level courses.

Another possible direction for future work could be to use different methods of statistical analysis. In particular, regression analysis may be an interesting tool to consider, especially if data is collected on a continuous scale rather than an ordinal one.

8.3 Conclusions

In this project, we sought to answer a number of questions about how the different introductory computer science sequences affect students' trajectories through the Brown Computer Science program. I will address each of the questions below, and discuss the conclusions we can draw from our analysis.

Why do students choose to study computer science, and what factors do they consider when choosing a specific introductory sequence?

Students choose to study computer science for a variety of reasons; the strongest reasons seem to be an interest in the material, and a belief that learning computer science will give them useful skills.

When choosing between the introductory sequence options, students who have a prior interest in the visual and interactive applications of computer science tend to choose cs15. Choosing cs15 is also correlated with female-identifying students, as well as students who do not initially intend to concentrate in computer science.

There is no single major factor that influences students to choose cs17, though the course professor, assignment structure, "no magic" policy, and advice from upperclassmen are all relatively strong factors. Students who intend to concentrate in computer science but have little prior experience tend to gravitate towards cs17.

Students who choose cs19 do so largely because they have prior experience and intend to concentrate in computer science. Choosing cs19 is correlated with male-identifying students, and students who have prior experience, particularly from AP Computer Science A.

How does the introductory sequence affect the intermediate and upper-level courses students choose to take, as well as their preparation for these courses?

After taking the first semester introductory course, students in all sequences intend to take more classes in and concentrate in computer science. This effect is especially strong for cs15 students, as many of them did not originally intend to study computer science before starting cs15.

Students in all intro sequences find that the course professor, TAs, and material are strong positive influences on their decision to continue studying computer science. cs17 students also highlight their sense of community within the course, which is likely fostered by the emphasis on pair programming. cs19 students highlight the other students in the course and the small course size, which likely contributes to a sense of camaraderie among students in the course. However, some students also find the workload and stress of the introductory sequence to negatively affect their desire to continue studying CS.

Intermediate students feel that their introductory sequences prepared them for intermediate courses by instilling good coding habits, as well as teaching basic algorithms and data structures. Out of the three sequences, cs17/cs18 students feel best prepared for cs0330, likely due to their experience with servers/sockets and collaborating with others. cs15/cs16 students feel well prepared for cs0320 because of their experience with Java and object-oriented programming, though this is only a qualitative observation due to a small sample size.

Upper-level students generally feel somewhat equally prepared for their upper-level courses. cs15/cs16 students feel better prepared for courses like cs1300 than cs17/cs18 students, and cs17/cs18 and cs19 students feel better prepared for courses like cs1730 than cs15/cs16 students. Students feel equally prepared for other courses, such as cs1230, cs1320, cs1570, and cs1950y. However, this result may be due to the small sample size of upper-level students who have taken each course, so it is difficult to draw particularly meaningful conclusions about student experiences in upper-level courses.

How does the introductory sequence affect the degree program and areas of interest that students choose to pursue?

Students who take cs15/cs16 pursue an A.B. in much higher proportions than cs17/cs18 and cs19 students, while these students tend to pursue an Sc.B.. This aligns with students' goals for studying computer science before taking the intro sequence, as cs15/cs16 students were less likely to intend to concentrate in CS and thus may choose to take fewer courses.

Students who complete CS15/CS16 are more likely to pursue courses in the DESIGN pathway, while CS17/CS18 and CS19 students are more likely to pursue courses in SYSTEMS and THEORY. Given that CS15/CS16 students have a prior interest in design and visual applications of computing, this is likely a function of both their prior interests and their experience in the intro sequence. However, many CS17/CS18 and CS19 students attribute their interest in algorithms and logic to their introductory sequence, rather than a prior interest in the topic. Their interest in systems courses may also be correlated with their introductory sequence — CS17/CS18 and CS19 students feel better prepared for CS0330 than CS15/CS16 students, which might lead to them enjoying the course more and thus choosing to take similar upper-level courses.

What are students' perceptions about how well each introductory sequence prepares students for further computer science courses? Do students perceive significant differences between each of the intro sequences?

Students' perceptions of the differences between intro sequences align closely with the actual differences between intro sequences, and in some cases are more extreme than the actual differences.

Students believe that courses like CS1230, CS1300, and CS1320 — all graphics and software-engineering based courses — are better suited for students who completed CS15/CS16, while courses like CS1570, CS1730, and CS1950Y— which are more focused on algorithms and logic — are better suited for CS17/CS18 and CS19 students. This somewhat aligns with responses from students who have taken these courses, particularly for CS1300 and CS1730. Additionally, CS15/CS16 students do pursue DESIGN courses more frequently, and CS17/CS18 and CS19 students do pursue SYSTEMS and THEORY courses more frequently. However, students' actual sense of preparation in many courses, such as CS1230 and CS1950Y, actually do not differ significantly between intro sequences, despite student perceptions that they would.

How does the introductory sequence experience affect students' feelings of community and fit within the department?

Students' communities within computer science consist of both students who took the same introductory course as them, and students who took other introductory courses. The former is likely the result of meeting students in the introductory sequence, as well as TAing the introductory sequence, while the latter is likely the result of taking intermediate and upper-level courses with students from other introductory sequences. CS15/CS16 students have the largest percentage of their community within the department from their intro sequence; this is likely a factor of course size, as students meet and connect with more students in a larger course.

Some students find the stress, difficulty, and culture of the intro sequence discouraging, with several even deciding to no longer concentrate in computer science as a result of this experience. However, a majority of students generally enjoy the material, the professor, and the community of their introductory sequences. For some students, their experience inspires them to take upper-level courses about similar topics; for others, their experience in the intro sequence encourages them to continue studying computer science, but not to take specific upper-level courses.

Appendix A

Survey Questions

A.1 Demographics

Have you taken or are you currently taking an introductory computer science course at Brown? (i.e. cs0111, cs0150, cs0170, or cs0190)
(Please note that this survey is intended only for students who have taken/are taking an introductory computer science course at Brown! If you didn't/aren't, we appreciate your interest nonetheless.)

- ○ Yes
- ○ No

What is your class year?

- ○ 2023
- ○ 2022.5
- ○ 2022
- ○ 2021.5
- ○ 2021
- ○ 2020.5
- ○ 2020
- ○ 2019.5

What is your gender identity?

_____

What is your race/ethnicity? Select all that apply.

- □ White
- □ Hispanic or Latinx
- □ Black or African American
- □ East Asian
- □ South Asian
- □ Southeast Asian
- □ Middle Eastern
- □ American Indian or Alaska Native
- □ Native Hawaiian or Pacific Islander
- □ Other _____

Which of the following best describes your status as a first-generation college student?

- □ I am the first in my immediate family to attend college.
- □ At least one person in my immediate family attended college.
- □ I am the first person in my immediate family to study/work in Computer Science.
- □ At least one person in my immediate family studied/works in Computer Science.
- □ At least one person in my immediate family studied/works in STEM, but not Computer Science.
- □ I have a close relative or role model (not in my immediate family) who studied/works in Computer Science.
- □ I have a close relative or role model (not in my immediate family) who studied/works in STEM, but not Computer Science.
- □ Other _____

Which of the following best describe your prior exposure to computer science before college? Select all that apply.

- □ AP Computer Science A
- □ AP Computer Science Principles
- □ At least a year of non-AP Computer Science courses
- □ Less than a year of non-AP Computer Science courses
- □ Participated in a summer program
- □ Regularly scheduled extracurricular program (e.g. after school program)
- □ Non-regularly scheduled extracurricular program (e.g. one-time workshop)
- □ Scratch/block-style programming
- □ Self-taught (elaborate below)
- □ None
- □ Other _____

Are you currently enrolled in an intro course, intermediate course, or upper-level course?
If you are currently enrolled in an intro course and intermediate/upper-level course, please select introductory course. If you are enrolled in both an intermediate and upper-level course, please select which level you'd most like to comment on.

- ○ Introductory course (cs0111, cs0150, cs0170, cs0190)
- ○ Intermediate course (cs0330)
- ○ Upper-level course (cs1000+)

A.2 Introductory Course Students

Which intro course are you currently taking?

- ○ cs0111
- ○ cs0150
- ○ cs0170
- ○ cs0190

To what extent did each of the following statements influence your decision to take an introductory computer science course?

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
It was required for my intended concentration.	○	○	○	○	○
It fulfilled another requirement (i.e. for another concentration).	○	○	○	○	○
I was interested in/curious about the material.	○	○	○	○	○
I thought it would provide me with useful skills.	○	○	○	○	○
My parents or family encouraged me to.	○	○	○	○	○
A teacher or other mentor encouraged me to.	○	○	○	○	○
My friends were also taking the course.	○	○	○	○	○

Please elaborate on any of the above/explain any other reasons for taking an introductory computer science course.

How strongly did each of the following factors influence your decision to choose this particular intro course (over the other intro courses)?

	Not at all	A little	A moderate amount	A lot	A great deal
Course professor	○	○	○	○	○
Course TA staff	○	○	○	○	○
Other students in the course	○	○	○	○	○
Advice from students not associated with the course (i.e. upperclassmen, student organizations)	○	○	○	○	○
Advice from professors/faculty	○	○	○	○	○
Advice from the Brown CS "Which Introductory Course Should I Take?" page	○	○	○	○	○
Lecture style and structure in this course (over the other courses)	○	○	○	○	○
Structure of the assignments in this course (over the other courses)	○	○	○	○	○
Material covered in this course (over the other courses)	○	○	○	○	○
Difficulty/amount of time required of this course (over the other courses)	○	○	○	○	○
Prior experience in computer science	○	○	○	○	○
Long-term goals for studying computer science	○	○	○	○	○

Please elaborate on any of the above/explain any other reasons for choosing this intro course (over the other intro courses).

Before the semester began, how much additional computer science did you intend to take beyond this course?

- ○ Just this semester-long intro course (i.e. cs0111, cs0150, cs0170, cs0190)
- ○ Only the second semester continuation of my current course (i.e. cs0112, cs0160, cs0180)
- ○ A few intermediate or upper-level courses here and there, but not concentrating
- ○ Concentrating or joint-concentrating in computer science

At this point in the semester, how much additional computer science do you intend to take beyond this course?

- ○ Just this semester-long intro course (i.e. cs0111, cs0150, cs0170, cs0190)
- ○ Only the second semester continuation of my current course (i.e. cs0112, cs0160, cs0180)
- ○ A few intermediate or upper-level courses here and there, but not concentrating
- ○ Concentrating or joint-concentrating in computer science

How has each of the following influenced your desire to pursue additional computer science after this course?

	Very negative	Somewhat negative	Neither positive nor negative	Somewhat positive	Very positive
Intro course faculty	○	○	○	○	○
Intro course staff (i.e. TAs)	○	○	○	○	○
Intro course students	○	○	○	○	○
Course difficulty/amount of time required	○	○	○	○	○
Course material	○	○	○	○	○
Course size	○	○	○	○	○
Sense of community within the course	○	○	○	○	○
Sense of community within the department	○	○	○	○	○

Please elaborate on the above or explain more reasons that have influenced your decision.

A.3 Intermediate Course Students

Which introductory sequence did you take?

- ○ cs0111/cs0180
- ○ cs0150/cs0160
- ○ cs0170/cs0180
- ○ cs0190

Do you intend to/are you concentrating in Computer Science? If so, indicate your intended or declared concentration:

- ○ Computer Science A.B.
- ○ Computer Science Sc.B.
- ○ Joint concentration (e.g. APMA-CS, CS-Econ, Math-CS, Computational Biology)
- ○ Not concentrating

I chose to study computer science because:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I like learning about the field.	○	○	○	○	○
The courses required of the concentration are interesting.	○	○	○	○	○
Studying computer science will allow me to make an impact on society.	○	○	○	○	○
Studying computer science will allow me to make a lot of money.	○	○	○	○	○
The job market for this field is promising.	○	○	○	○	○
My friends are also studying computer science.	○	○	○	○	○
Professors/faculty influenced my decision.	○	○	○	○	○
My family influenced my decision.	○	○	○	○	○
I will be successful in computer science courses.	○	○	○	○	○

Please elaborate on the above/explain any other reasons for studying computer science.

_____

Before you started the introductory sequence, how much computer science did you intend to take?

- ○ Only one introductory course (i.e. cs0111, cs0150, cs0170), but not the full sequence
- ○ Only the introductory sequence (i.e. cs0150/cs0160, cs0170/cs0180, cs0190)
- ○ A few intermediate or upper-level courses here and there, but not concentrating
- ○ Concentrating or joint-concentrating in computer science

After completing your first semester intro course, how much additional computer science did you intend to take?

- ○ None
- ○ Only the second semester continuation of the intro course (i.e. cs0112, cs0160, cs0180)
- ○ A few intermediate or upper-level courses here and there, but not concentrating
- ○ Concentrating or joint-concentrating in computer science

Which intermediate courses have you taken? Include any courses you are currently taking.

- □ cs0330 - Introduction to Computer Systems
- □ cs0320 - Introduction to Software Engineering

For students who have taken/are taking cs0330: When I think about the projects in cs0330, I feel:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
My introductory sequence prepared me for these projects.	○	○	○	○	○
My introductory sequence did not cover concepts that would have better prepared me for some significant portion of these projects.	○	○	○	○	○
Students who took other introductory sequences are better prepared for these projects.	○	○	○	○	○

For students who have taken/are taking cs0320: When I think about the projects in cs0320, I feel:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
My introductory sequence prepared me for these projects.	○	○	○	○	○
My introductory sequence did not cover concepts that would have better prepared me for some significant portion of these projects.	○	○	○	○	○
Students who took other introductory sequences are better prepared for these projects.	○	○	○	○	○

In what ways do you feel your introductory sequence prepared you for intermediate courses (i.e. cs03330, cs0320)?

_____

In what ways do you feel your introductory sequence did not prepare you for intermediate courses (i.e. cs03330, cs0320)?

_____

In what ways do you feel students in other introductory sequences were better prepared for intermediate courses?

_____

In what ways do you feel students in other introductory sequences were worse prepared for intermediate courses?

_____

When you think of your community within Computer Science, what percentage of your community took the same introductory sequence as you?

(Sliding scale, 0 – 100)

How has your introductory sequence impacted your decision to pursue computer science/specific upper-level courses?

_____

A.4 Upper-Level Course Students

Which introductory sequence did you take?

- ○ cs0111/cs0180
- ○ cs0150/cs0160
- ○ cs0170/cs0180
- ○ cs0190

Do you intend to/are you concentrating in Computer Science? If so, indicate your intended or declared concentration:

- ○ Computer Science A.B.
- ○ Computer Science Sc.B.
- ○ Joint concentration (e.g. APMA-CS, CS-Econ, Math-CS, Computational Biology)
- ○ Not concentrating

I chose to study computer science because:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I like learning about the field.	○	○	○	○	○
The courses required of the concentration are interesting.	○	○	○	○	○
Studying computer science will allow me to make an impact on society.	○	○	○	○	○
Studying computer science will allow me to make a lot of money.	○	○	○	○	○
The job market for this field is promising.	○	○	○	○	○
My friends are also studying computer science.	○	○	○	○	○
Professors/faculty influenced my decision.	○	○	○	○	○
My family influenced my decision.	○	○	○	○	○
I will be successful in computer science courses.	○	○	○	○	○

Please elaborate on the above/explain any other reasons for studying computer science.

_____

Which of the following upper-level courses have you taken? Include any courses you are currently taking.

- □ cs1230: Introduction to Computer Graphics
- □ cs1300: User Interfaces and User Experience
- □ cs1320: Creating Modern Web & Mobile Applications
- □ cs1570: Design and Analysis of Algorithms
- □ cs1730: Design and Implementation of Programming Languages
- □ cs1950y: Logic for Systems

Which of the following courses have you considered taking, but decided not to take?

- □ cs1230: Introduction to Computer Graphics
- □ cs1300: User Interfaces and User Experience
- □ cs1320: Creating Modern Web & Mobile Applications
- □ cs1570: Design and Analysis of Algorithms
- □ cs1730: Design and Implementation of Programming Languages
- □ cs1950y: Logic for Systems

For each of the following: Before taking or considering the course, my perception was that this course was better suited for students who took a specific introductory sequence.

	Strongly towards cs15/16	Somewhat towards cs15/16	Neutral	Somewhat towards cs17/18/19	Strongly towards cs17/18/19	N/A (no opinion)
cs1230: Introduction to Computer Graphics	○	○	○	○	○	○
cs1300: User Interfaces and User Experience	○	○	○	○	○	○
cs1320: Creating Modern Web & Mobile Applications	○	○	○	○	○	○
cs1570: Design and Analysis of Algorithms	○	○	○	○	○	○
cs1730: Design and Implementation of Programming Languages	○	○	○	○	○	○
cs1950y: Logic for Systems	○	○	○	○	○	○

The following section will ask a series of questions about each of the courses you've taken.

For students who have taken/are taking cs1230: For cs1230, Introduction to Computer Graphics:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am satisfied with my performance in the class.	○	○	○	○	○
My introductory sequence prepared me well for this course.	○	○	○	○	○
I would have been better prepared for the material in this class if I had taken a different intro sequence.	○	○	○	○	○
My perception of which students would succeed in the course (i.e. from a specific intro sequence) changed after taking the class.	○	○	○	○	○

For students who have taken/are taking cs1300: For cs1300, User Interfaces and User Experience:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am satisfied with my performance in the class.	○	○	○	○	○
My introductory sequence prepared me well for this course.	○	○	○	○	○
I would have been better prepared for the material in this class if I had taken a different intro sequence.	○	○	○	○	○
My perception of which students would succeed in the course (i.e. from a specific intro sequence) changed after taking the class.	○	○	○	○	○

For students who have taken/are taking cs1320: For cs1320: Creating Modern Web & Mobile Applications:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am satisfied with my performance in the class.	○	○	○	○	○
My introductory sequence prepared me well for this course.	○	○	○	○	○
I would have been better prepared for the material in this class if I had taken a different intro sequence.	○	○	○	○	○
My perception of which students would succeed in the course (i.e. from a specific intro sequence) changed after taking the class.	○	○	○	○	○

For students who have taken/are taking cs1570: For cs1570, Design and Analysis of Algorithms:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am satisfied with my performance in the class.	○	○	○	○	○
My introductory sequence prepared me well for this course.	○	○	○	○	○
I would have been better prepared for the material in this class if I had taken a different intro sequence.	○	○	○	○	○
My perception of which students would succeed in the course (i.e. from a specific intro sequence) changed after taking the class.	○	○	○	○	○

For students who have taken/are taking cs1730: For cs1730: Design and Implementation of Programming Languages:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am satisfied with my performance in the class.	○	○	○	○	○
My introductory sequence prepared me well for this course.	○	○	○	○	○
I would have been better prepared for the material in this class if I had taken a different intro sequence.	○	○	○	○	○
My perception of which students would succeed in the course (i.e. from a specific intro sequence) changed after taking the class.	○	○	○	○	○

For students who have taken/are taking cs1950y: For cs1950y, Logic for Systems:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I am satisfied with my performance in the class.	○	○	○	○	○
My introductory sequence prepared me well for this course.	○	○	○	○	○
I would have been better prepared for the material in this class if I had taken a different intro sequence.	○	○	○	○	○
My perception of which students would succeed in the course (i.e. from a specific intro sequence) changed after taking the class.	○	○	○	○	○

When you think of your community within Computer Science, what percentage of your community took the same introductory sequence as you?

(Sliding scale, 0 – 100)

How has your introductory sequence impacted your decision to pursue computer science/specific upper-level courses?

_____

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