Comparing Student Outcomes in Online vs. In-person Sections of an On-campus Computer Science Course

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Abstract

We present results from a quasi-experimental study comparing performance and sense of belonging between online ($N = 212$) and in-person ($N = 116$) sections of the same computer science class, where all students were residential and physically present on campus. When we view the class as a whole, we find that the performance of students on all formative assessments (pre-lecture activities, in-class activities, homework, coding projects) is statistically equivalent. While performance on exams is statistically significantly higher in the in-person section even after controlling for students' incoming GPA (2.4 percentage points higher when compared with students in the online section, $p = 0.028$), we find no statistically significant difference in students' final weighted average score (the advantage for in-person students reduced to 1.2 percentage points with $p = 0.067$). When we disaggregate by gender, we find that women in the online section outperform the women in the in-person section. Men's, underrepresented minorities', and first-generation students' performance follow the same trends as the whole class. Sense of belonging was measured by surveys at the beginning and end of the course. Students were asked to respond to questions about their perceived comfort in the classroom, perceived isolation, and perceived support from course staff and other students. We note that the whole class's sense of belonging statistically increases from the beginning to the end of the semester in both sections. Furthermore, the increased sense of belonging is more pronounced in the in-person section. Based on our findings, we conclude that online sections for on-campus students may be an effective way to accommodate large class sizes, increased enrollment pressure, and students' need for flexibility, while not disadvantaging students' learning outcomes.

1 Introduction

Computer Science (CS) departments around the globe are experiencing a surge in enrollment in their courses by majors as well as non-majors [1, 2, 3, 4, 5]. Larger schools need to run courses with hundreds or thousands of students per term to meet demand. One challenge of these large classes is finding large enough spaces to hold class meetings. Offering online sections enables a course's enrollment to exceed its in-person meeting space. While online learning has been around for a long time, COVID-19 has made it mainstream, with almost three-quarters of college students (77% for public and 68% for private) taking at least one online course in the Fall of 2020 [6].

The literature comparing student performance in online and in-person classes lacks coherence.

For example, some researchers find that students taking in-person classes perform better [7, 8, 9, 10] while other studies find comparable performances across the two modalities [11, 12, 13]. Furthermore, studies have found positive [14, 15, 16, 17], negative [7, 18], and mixed results [19, 20] for student sentiment toward online testing.

In contrast, there exists a general consensus that students in online classes struggle with social interactions (student-to-student and student-to-instructor) [21, 13, 22, 23, 15] and experience a reduced sense of belonging [19, 20, 24, 25]. Furthermore, academics agree that the sense of belonging varies as a function of students' characteristics and demographics [26, 27, 28, 29, 30]. Finally, there is a consensus among instructors that online education is potentially detrimental for students' performance and level of engagement in class [31, 32, 33].

In spite of the recent burst of research on online vs. in-person instruction, there has been little that focuses on computer science students in particular. Because CS students tend to be technically savvy, there is a reason to believe that they might adapt to online courses better. In particular, we study CS students who are physically on campus, with the following two research questions:

RQ1: What is the effect of teaching modality (online versus in-person) on students' learning outcomes and their sense of belonging for on-campus students that retain their peer support networks and physical learning environments?

RQ2: How do demographics influence students' performance and sense of belonging with respect to teaching modality?

The rest of the paper is organized as follows. In Section 2, we present our quasi-experimental design and lay out the context of the research experiment. We then present the results of our analysis in Section 3 and, in Section 4, discuss the implications of these results, and how they may be advantageous to future courses employing an online or hybrid teaching approach. Finally, we conclude.

2 Methods

The research study was conducted at a large public residential research university during the Fall 2022 semester. The data was collected from a upper-division undergraduate required course in the computer science department, which included a basic programming course as a prerequisite. Students, who were all on campus, had the option to enroll in either an online or an in-person section, both offered by the same instructor, at the same time, and using the same materials.

The course followed a flipped format, where students had to complete pre-lecture assignments (a combination of videos, text, and short checkpoint questions) and corresponding homework sets every week. The only difference between the two sections was the way in which the students had to complete the "in-class" activities. For the in-person section, students were required to come to the classroom during lecture time and work in teams to complete computer-based activities. The students in the online section did not have any attendance requirement and could complete the same in-class activities asynchronously, but still in groups.

During lecture time, students enrolled in the in-person section were able to get help from 6 teaching assistants that were moving around the classroom (20:1 student-instructor ratio). The online

students had the option to join a Zoom meeting during lecture time, supported by 11 teaching assistants (same 20:1 student-instructor ratio), where they could work with their teams in breakout rooms, and request assistance from course staff when needed. However, students in the online section were also able to complete the same activity with their groups at a time of their choosing during the lecture day, either in person or remotely.

While the online section did not have any maximum capacity, the in-person section was capped at 170 (the number of seats in the classroom). Students were given the flexibility to move between sections during the first two weeks of classes, providing them with the opportunity to decide which format fit best their learning style or other personal preferences. In this study, 116 students registered for the in-person section, while 212 students registered for the online section, substantially reducing the demand for additional classroom space. Both sections had similar incoming average student GPAs (3.79 and 3.75 for in-person and online sections respectively; not significant, Cohen's $d = 0.13$ and $p = 0.25$).

2.1 Class demographics

Table 1 provides an overview of the distribution of the number of students by gender, underrepresented minority (URM) status, and first-generation (first-gen) status in the two sections of the course (online and in-person). Additionally, for all three demographic markers, the table also displays their average GPAs at the start of the semester for both sections. There was no significant statistical difference between GPAs for any of the groups.

	# students		Average GPA	
	online	in-person	online	in-person
Female	55	34	3.74	3.72
Male	157	82	3.75	3.81
URM	12	8	3.62	3.61
not-URM	200	108	3.75	3.80
first-gen	25	6	3.83	3.62
not-first-gen	187	110	3.74	3.80

Table 1: Distribution of students by different demographic markers.

Analyzing by academic standing, the students in the in-person section of the course had 19% freshmen, 59% sophomores, 15% juniors, and 7% seniors. On the other hand, the students in the online section of the course had 12% freshmen, 49% sophomores, 30% juniors, and 9% seniors.

2.2 Assessment setup

The course had formative assessments in the form of pre-lecture activities, in-class activities, and homework. Additionally, students also had to complete 5 short coding projects during the semester. These assessments were delivered through an open-source software platform that enables question randomization, unlimited attempts, automated grading, and instant feedback [34]. For these formative assessments, students had unlimited retry opportunities on all questions for full credit, receiving instant feedback for each attempt.

For summative assessment, students took six bi-weekly exams. The exams were computer-based using the same software platform and were run in a proctored computer lab. The exams included both short answer questions and programming questions.

For each assignment type, we fit an ordinary least squares (OLS) model of the form,

$$y_i = \beta A_i + \alpha \, \text{GPA}_i + \gamma \tag{1}$$

where the left-hand-side value y_i is the average score that student i received for an assignment type, A_i is an indicator variable that is 1 if student i was in the online section, and 0 if in the in-person section, and GPA_i is the incoming GPA of student i. We are interested in estimating the parameters β and α, that can be interpreted as follows:

- α: The coefficient corresponding to the ability of student i
- β: The score advantage for students in the online section, over the in-person section

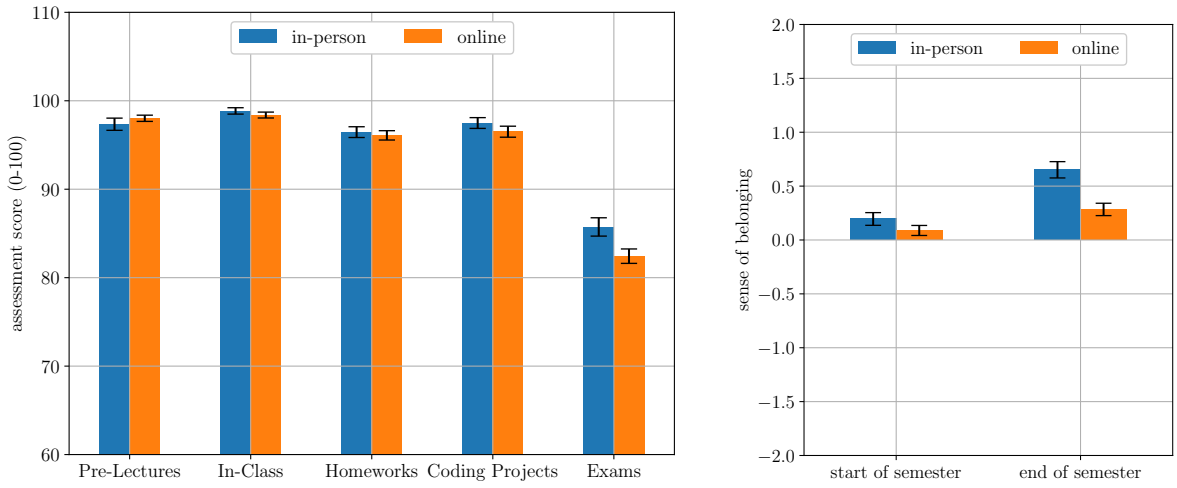
2.3 Sense of belonging surveys

In anonymous surveys administered at the start and end of the semester, students were asked to provide feedback regarding their overall sense of belonging, including questions about their perceived comfort in the classroom, perceived isolation, and perceived support. Questions on the pre-course survey were based on students' prior experiences in past computing courses (*Indicate your level of agreement with each of the following statements as they relate to computer science courses you have taken*). Questions on the post-course survey asked students to answer on their experiences in the current course (*Indicate your level of agreement with each of the following statements as they relate to this course*). Students were asked to respond to the following prompts:

1. I feel comfortable volunteering ideas or opinions in class.
2. Other students are helpful in reminding me when assignments are due or when tests are approaching.
3. I feel comfortable asking a question in class.
4. I have made friends in the lecture/discussion section/lab who I can turn to for help with course material.
5. I know very few people in the class.†
6. It is difficult to meet other students in class.†

Questions were presented on a 5-point Likert scale using the following options and numeric values: "Strongly disagree" (-2), "Disagree" (-1), "Neither agree nor disagree" (0), "Agree" (1), "Strongly agree" (2). Negatively phrased questions (marked with †) were reverse coded. Individual question scores were aggregated together to get a student's individual sense of belonging score between -2 and 2.

The collection of data from the course, survey, analysis, and publication in an aggregated anonymized form was approved by the institution's IRB. Online informed consent was collected from students at the beginning of the semester.



(a) (b)

Figure 1: (a) Average score for each assignment group and (b) average score for the sense of belonging at the start and end of the semester, for students in the online and in-person sections.

	β (online advantage in p.p.)	p
Pre-Lectures	0.92	0.168
In-Class Activities	-0.31	0.540
Homeworks	0.10	0.894
Coding Projects	-0.63	0.485
Exams	-2.38	0.027*

Table 2: Score advantage for students in the online section over students in the in-person section, measured in percentage points (p.p.) and controlling for student GPA. (*) indicates a statistically significant result with $p < 0.05$.

3 Results

We present the results of our experimental study in five parts. The first two subsections analyze the learning outcomes and sense of belonging across the entire course. Then, we disaggregate these results by gender, URM status, and first-generation status.

3.1 Performance (entire class)

We find that students in both treatments score similarly on non-exam assessment types, as shown in Figure 1a. On exams, students in the in-person section received on average a 2.4 percentage point advantage when compared to students in the online section (statistically significant, $p = 0.027$) after controlling for GPA. Table 2 presents the estimation of the β parameter for all assessment types after controlling for GPA.

When students' overall grades are computed using a weighted average, we find that there is no statistically significant difference between the treatments. In a linear regression (similar to Eq. (1)) using students' weighted average score as the variable y_i, the in-person section had a 1.2 percentage

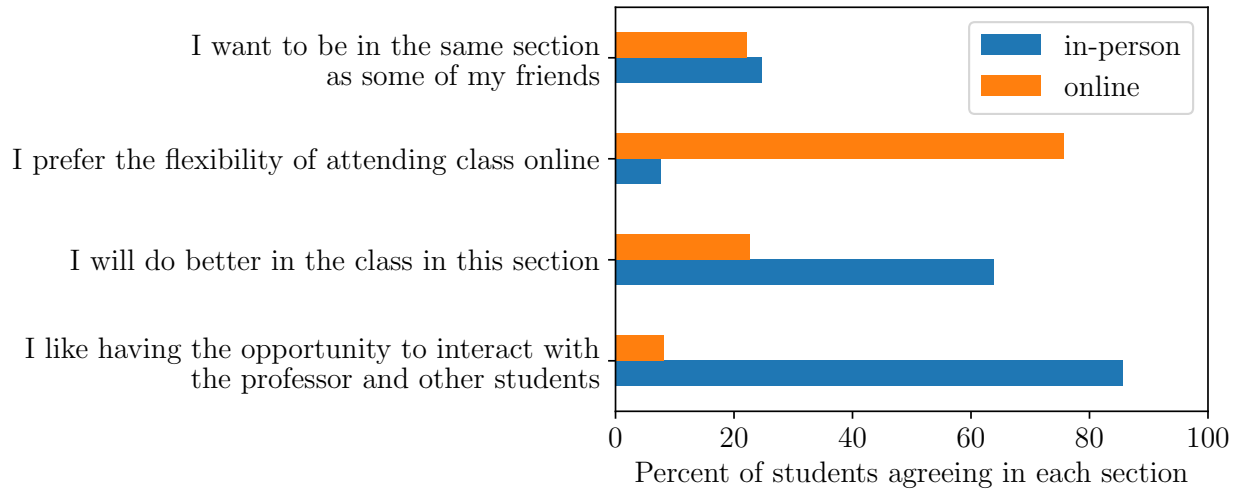


Figure 2: Survey results about reasons students selected their sections. The factors were independent; students could agree with any number of statements.

point advantage over students in the online section ($p = 0.067$). Additionally, re-computing the same regression analysis using standardized z-scores for the weighted score, we find a small effect size ($d = 0.16$).

3.2 Sense of Belonging (entire class)

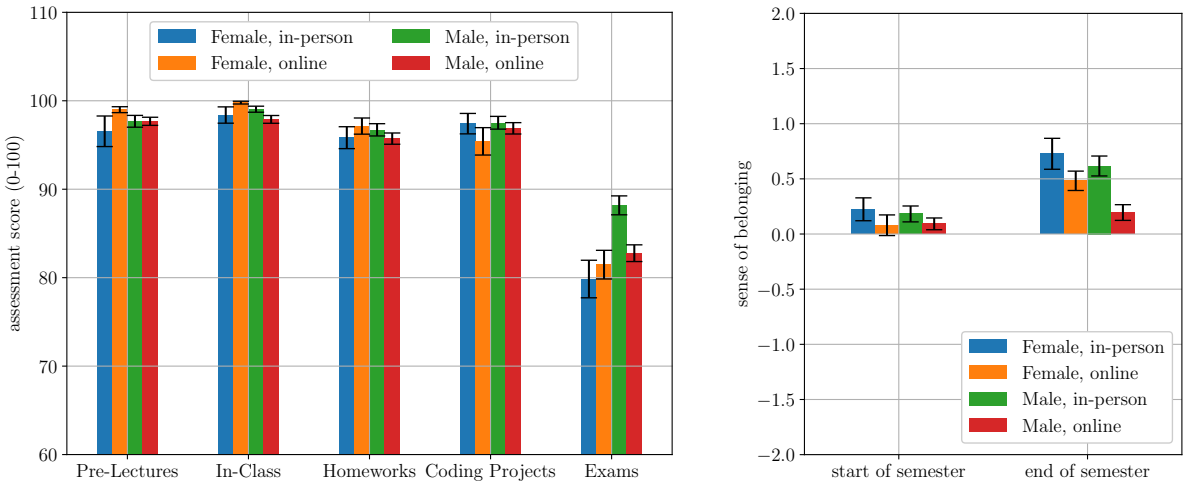
Our surveys suggest that, for the class as a whole, electing to take the online section represents a trade-off between flexibility and increasing one's sense of belonging. Figure 2 shows survey results collected during the first week of class.[1] Students selecting the online section report doing so for its flexibility (76%), whereas students in the in-person section are doing so for interaction with the instructor and peers (86%). A much larger fraction of the in-person section indicate that that section will help them do better in the course.

The sense of belonging survey results shown in Figure 1b are in line with in-class students' perceptions that they will get more interaction by attending the in-person section. While both sections report an increase in their sense of belonging, students in the in-person section experience a higher increase in their sense of belonging (0.45 points, $p < 0.001$) than the students in the online section (0.19 points, $p < 0.01$).

3.3 Disaggregation by Gender

In contrast to the class as a whole, when we disaggregate assessment scores by gender (Figure 3a and Table 3), we find that women in the online section out-perform women in the in-person section in all assessments except coding projects, but these differences are not statistically significant given the number of women in our sample. The performance of men largely mirrors the trends of the

[1] We believe that the small fraction of students from the in-person section claiming to prefer the flexibility afforded by attending online classes results from students changing sections after completing the survey, as students could freely switch between sections during the first two weeks of the semester.



(a) (b)

Figure 3: (a) Average score for each assignment group and (b) average score for a sense of belonging at the start and end of the semester for students, in the online and in-person sections, split by gender.

	Female		Male	
	β	p	β	p
Pre-lectures	2.37	0.093	0.46	0.544
In-Class Activities	1.34	0.061	-0.89	0.164
Homeworks	1.15	0.401	-0.187	0.832
Coding Projects	-2.13	0.314	-0.05	0.958
Exams	1.18	0.528	-4.08	0.002*

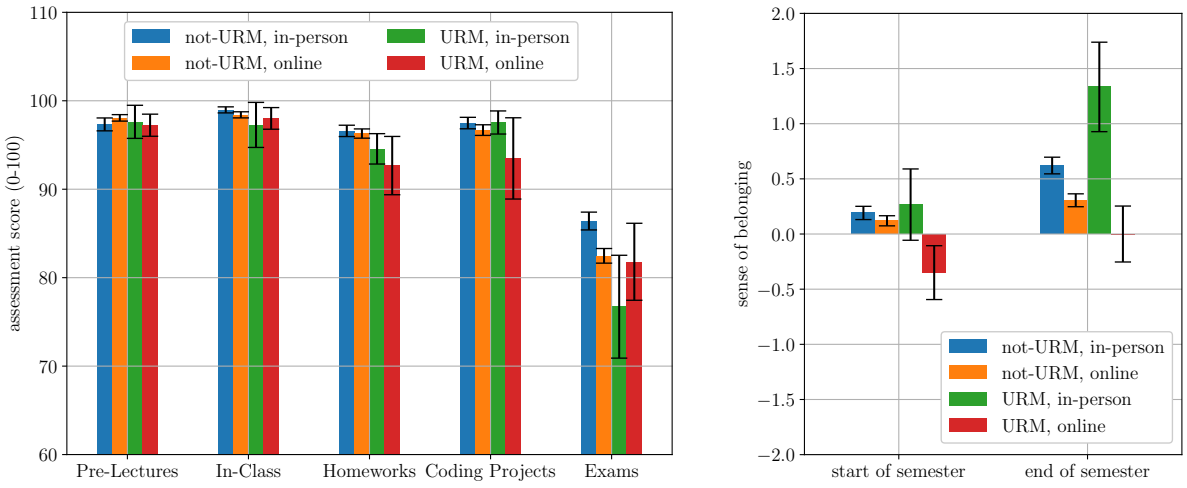
Table 3: Score advantage for students in the online section over students in the in-person section, measured in percentage points (p.p.) and controlling for student GPA. (*) indicates a statistically significant result with $p < 0.05$.

whole class.

With respect to sense of belonging, in-person women, online women, and in-person men all have comparable increases from the start to the end of semester, as shown in Figure 3b (0.50, 0.40 and 0.43 points, respectively; $p < 0.01$). Online men see substantially lower gains in sense of belonging (0.10 points; not significant with $p = 0.24$)

3.4 Disaggregation by Underrepresented Minority

When disaggregating by underrepresented minority identity, we find that URM students perform statistically equivalently in the two treatments (Figure 4a). While the lack of statistical significance may be a result of the low number of URM students ($N = 20$, less than 6% of our sample), there is no clear performance trend. On some assessments the online students performed better and in others the in-person students scored better, even after controlling for incoming GPA (Table 4).



(a) (b)

Figure 4: (a) Average score for each assignment group and (b) average score for sense of belonging at the start and end of the semester for students in the online and in-person sections.

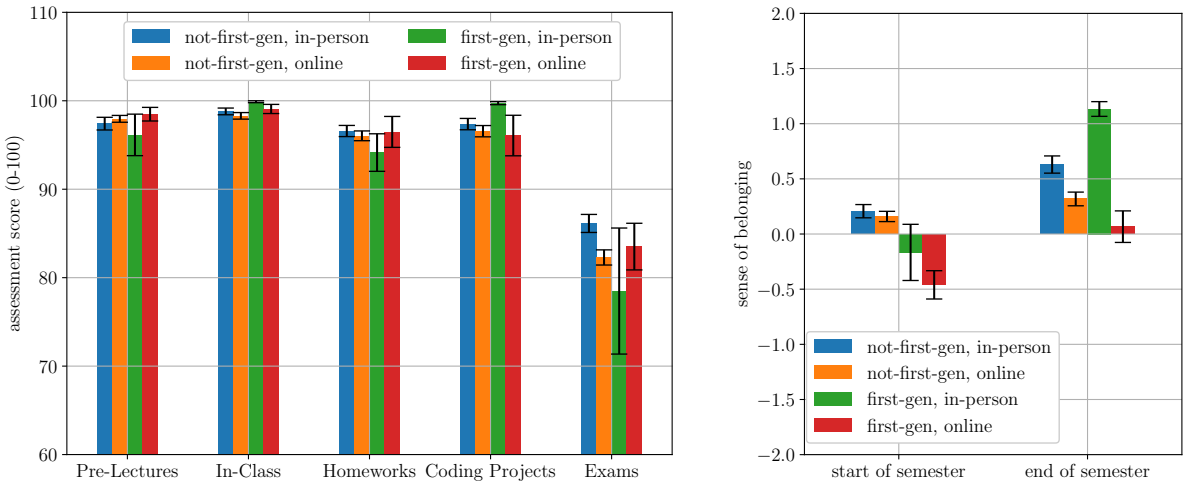
	not-URM		URM	
	β	p	β	p
Pre-lectures	1.04	0.137	-0.41	0.851
In-Class Activities	-0.36	0.479	0.745	0.779
Homeworks	0.22	0.777	-2.04	0.588
Coding Projects	-0.41	0.650	-4.18	0.468
Exams	-2.93	0.01*	4.75	0.339

Table 4: Score advantage for students in the online section over students in the in-person section, measured in percentage points (p.p.) and controlling for student GPA. (*) indicates a statistically significant result with $p < 0.05$.

While URM students had an increase in sense of belonging in both sections of the course (Figure 4b), we can see that there is a larger effect in the in-person section than the online section, however neither difference is statistically significant (1.06 point increase with $p = 0.087$ for URM in-person and 0.35 point increase with $p = 0.338$ for URM online). The increase in sense of belonging for non-URM students in the in-person section is also larger than for students in the online section (0.43 points, $p < 0.001$ versus 0.19 points, $p = 0.01$, respectively).

3.5 Disaggregation by First Generation Status

As we saw with URM students, when we disaggregate first generation students, we find no statistically significant differences between online and in-person treatments (Figure 5a and Table 5). Again, this lack of significance can be attributed to small sample size. While there is no clear trend in performance across assessments in raw scores, when we control for incoming GPA we see the general trend is toward first generation students performing better with the in-person treatment.



(a) (b)

Figure 5: (a) Average score for each assignment group and (b) average score for a sense of belonging at the start and end of the semester for students in the online and in-person sections.

	not-first-gen		first-gen	
	β	p	β	p
Pre-lectures	0.93	0.190	1.81	0.374
In-Class Activities	-0.25	0.646	-1.08	0.342
Homeworks	0.13	0.868	-0.84	0.798
Coding Projects	-0.31	0.734	-7.04	0.120
Exams	-2.56	0.023*	-2.63	0.515

Table 5: Score advantage for students in the online section over students in the in-person section, measured in percentage points (p.p.) and controlling for student GPA. (*) indicates a statistically significant result with $p < 0.05$.

Similar to URM students, first-generation students seem to get disproportionate benefits to sense of belonging from participating in the in-person section. As shown in Figure 5b, while both in-person and online sections see improvements in the measure, first-generation in-person students experience a 1.3 point increase ($p < 0.01$) compared to 0.5 points ($p < 0.01$) for online students. A similar trend is observed when comparing not-first-generation in-person and online students (0.42 point increase with $p < 0.001$ versus 0.16 points with $p = 0.038$, respectively).

4 Discussion

The above results help us answer our two research questions.

RQ1. What is the effect of teaching modality (online versus in-person) on students' learning outcomes and their sense of belonging for on-campus students that retain their peer support networks and physical learning environments?

Our study found that students in both online and in-person sections had a comparable academic

performance on formative assessments, with a slight advantage for in-person students on exams. The overall weighted scores, however, did not show any statistical advantage for either modality. One can conclude that the online section can offer the same academic quality as the in-person section of the course, at least for computer science students living on campus that elect to take an online course. This finding has two exciting implications: first, CS departments can offer optional online sections of courses so as to manage their classroom footprint in spite of high demand with confidence that students can excel in that format, and, second, students who want the flexibility that an online section provides can do so with little concern that it will negatively impact their performance.

While academic achievement was comparable between online and in-person modalities, there was a notable difference in students' sense of belonging, with students in the in-person section reporting a higher increase in their sense of belonging on the end-of-semester survey. The trade-off between flexibility and the sense of belonging observed in this study has important pedagogical implications for the design and delivery of on-campus courses. While online sections may offer increased flexibility, they may also compromise students' sense of belonging, which is a critical factor for academic success and student retention. As such, faculty must carefully consider the interplay between teaching modality and students' academic outcomes and sense of belonging while designing their courses.

In addition to the findings of this current study, we have conducted similar analyses of student performance using data from two previous semesters of the same course, and found consistent results. Likewise, no significant difference was found between the academic performance of students in the online section and those in the in-person section. This makes us more comfortable in claiming that the results of our current study are reproducible, and that the lack of substantial difference in academic achievement between online and in-person sections for resident students may be a consistent trend. Further research should be conducted to investigate the generalizability of these findings across other courses and institutions.

RQ2. How do demographics influence students' performance and sense of belonging with respect to teaching modality?

Disaggregating the results of our study by gender, we find that women tend to perform better in academic activities in the online section compared to the in-person section, although the difference is not statistically significant. This finding is consistent with prior research on stereotype threat, which suggests that women may feel more pressure and anxiety in traditionally male-dominated fields, such as computer science. By taking classes in an online setting, gender becomes less salient, and women may feel more comfortable and less stressed, which could explain their better academic performance.

Interestingly, women don't seem to incur the sense of belonging penalty that men do from taking the online section. This, too, might be attributable to the aforementioned stereotype threat; the online section still provides a woman access to participating in a group where she can demonstrate her competence and make genuine connections with other students, but allows her to avoid any negative interactions from a large male-dominated classroom. Whatever the cause, it seems that the online option may be particularly valuable for women.

While we failed to find any statistically significant performance differences between online and in-person students in URM and first-generation students, there seems to be large sense of belonging benefits for these populations in participating in the in-class section. Our study provides no data on why this is occurring. Two hypotheses are: (1) these students have weaker social networks within CS, so participating in the in-person section provides them more opportunity to build those social networks and hence increase their sense of belonging, and (2) participating in person with the instructor present has significant impact on their sense of belonging. We note that these students are susceptible to stereotype threat in the same way that women are, and it is noteworthy that we see radically different responses between women and URM/first generation students. Based on our findings, we recommend that instructors and programs encourage underrepresented minority students and first-generation students to attend the in-person section of the course.

5 Limitations

One important limitation of our study is that it is not a randomized controlled trial and should not be interpreted as such. Students self-selected into either the online or in-class section. As suggested by the survey data in Figure 2, students provide reasons for their selection of section, so it would be naive to consider the selection random.

As such, it is important to interpret the results as describing how students that elect to take an online section perform in that section and feel about that section. Our data provides no insight about how students that would elect to take in-person courses would perform if forced to take an online course or how they would feel about it. As such, our data provides only partial support for departments considering running purely online courses.

Finally, our data was collected from a single computer science course at a highly-selective research university in the United States. While we have no reasons to believe that the trends we observed wouldn't generalize to other contexts, we expect that the difference in the reported sense of belonging would vary by context. In particular, the course we studied uses a flipped pedagogy where "lecture" time is used for students to work collaboratively in teams to solve challenging problems; students in the online section similarly complete these problems in groups (either in person or on Zoom) outside of the designated lecture space. It could be that this element is an important contributor to these findings, and they do not generalize to a course using a non-active pedagogy.

6 Conclusion

Based on the findings from this upper-level CS course, we believe that computer science departments can feel comfortable offering online sections of courses to students that want the flexibility that they facilitate, if their primary concern is student performance. We found no statistically significant difference in the overall performance of students that elect to take a course online relative to those that elect to take it in person. Taking courses online may, however, have a substantial negative impact on a student's sense of belonging. This effect is particularly pronounced for underrepresented minority students and first generation students, but not present in women.

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