The Effects of Teaching Modality on Collaborative Learning: A Controlled Study

Sophia Yang*, Yongjoo Park†, and Abdussalam Alawini‡
Department of Computer Science
University of Illinois at Urbana-Champaign
Email: *sophiay2@illinois.edu, †yongjoo@illinois.edu, ‡alawini@illinois.edu

***Abstract*—This Research Full Paper presents our findings of studying the effects of teaching modality on collaborative learning by comparing data from two sections of a Database Systems course offered simultaneously, with one offered fully face-to-face in a classroom setting while the other is offered online through a flipped-classroom model. Both sections utilized a collaborative learning approach where students work on group activities for part of the class meeting. Since the two sections were almost identical except for the teaching modality, we are provided with a unique opportunity to study the effect of teaching modalities on collaborative learning. As part of this study, we analyze four crucial data sources: 1) student performance data from the grade book 2) student performance data from the online learning management platform 3) an end-of-semester survey given by the instructor and 4) an end-of-semester survey given by the university. We extract insights on the impact of teaching modalities on collaborative learning in order to identify factors that can enhance collaborative learning. We also study the effect of teaching modalities on students' performance. We visualize our findings to differentiate between the two modalities, and draw on the strengths of each section to establish recommendations for the instructors for course improvement efforts.**

***Index Terms*—Teaching Modalities, Collaborative Learning, In-person teaching, online teaching, Database Systems**

I. Introduction

Given the start of the COVID-19 global pandemic in early 2020, the rapid shift to an online delivery model for all educational levels alike resulted in a huge disruption in students' learning advancement [1].

Both instructors and students alike found themselves having to adjust to teaching and learning online, overcoming obstacles and stressors including increased technological demands and distractions. Course logistic and design changes may last well after the pandemic ends, given the new-found "norm" of increased flexibility between differing modalities.

Presented with this situation, we originate our research work from a desire to explore and analyze the effects that teaching modality have on students' learning, collaboration, and social wellness. We collect data from the Fall 2021 offering of a Database Systems course available to both upper-level undergraduate and graduate students with a total enrollment of over 470 students. Our data comes from two sections of the course offered simultaneously by two different instructors with one section offered fully face-to-face in a classroom setting, and the other offered fully remotely over Zoom. Since the two sections were very similar except for the teaching modality, instructor, a few course assignments, and the class size (with in-person section registration capacity limits), we are provided with a unique opportunity to study the effect of teaching modalities on collaborative learning.

As part of this study, we analyze several crucial data sources: 1) student performance data from the grade book, including group activities, homework assignments, course exams, and the course project, 2) student performance data from PrairieLearn, an online learning management platform with built-in auto-grader functionalities [17], 3) data collected from an end-of-semester survey completed by student participants to gauge teaching and learning effectiveness across the online and in-person sessions, and 4) The university's Instructor and Course Evaluation System's (ICES) survey results. Survey questions on the latter two data sources include Likert scale [10] questions with 5 options, multiple-choice questions, as well as free-response questions for more contextual feedback.

This study aims to investigate the impact of teaching modalities on collaborative learning, students' performance, and their sense of belonging. Thus, we attempt to identify initial answers to the following research questions: RQ1) *How does teaching modality impact collaborative learning?* RQ2) *Would different teaching modalities impact students' performance?*, and RQ3) *What effects does teaching modalities have on students' sense of belonging?*

Our paper is structured as follows: 1) An overview of the Database course structure from which we collected our data, 2) A related works survey so that our contribution is clear, 3) An overview of what each data source contains, and how we plan to utilize it in our analyses, 4) Our results and findings, 5) A summary of our findings, and 6) A highlight of the limitations and possible future work opportunities.

II. Course Structure and Teaching Modalities

The Database course covers topics, such as Structured Query Language (SQL) [3], MongoDB (a document-oriented NoSQL query language) [2], Neo4j/Cypher (a graph-based query language) [16], relational database design (entity-relationship diagrams and design theory), relational algebra, database indexing, transaction processing, and query optimization techniques.

Our data comes from two sections of the course offered in Fall 2021 simultaneously by two different instructors with one section offered fully face-to-face in a classroom setting, and

the other offered fully remotely over Zoom. The first section offered a classroom model where students completed their collaborative learning (group) activities immediately following their in-person lecture, during the class meeting time. The second section utilized a flipped-classroom model in which students may view the recorded lecture content online for up to a week before completing their collaborative learning activities in Zoom breakout rooms during the class meeting time. Both sections of the course utilized a collaborative learning approach where students work on group activities for part of the class session. Students remain to work with the same group members for the semester with whom they complete the final project with. Students self-form their own groups, and a few students who cannot find a group to join are randomly assigned together to form a group. This results in a relatively controlled environment in that both the instructors utilized the same teaching materials, including the textbook, lecture notes, homework assignments, in-class group activities for collaborative learning, and exams, and followed an almost identical curriculum during the same time period (Fall 2021). The in-person section had a few modifications in their curriculum by excluding a few group activity assignments, and the Neo4j-related assignments. To account for these differences, we have excluded those assignments for our online section from our data analyses.

Throughout the semester, there are six written and/or coding homework assignments where students are given approximately 1-2 weeks to finish. Students are also given group activities to complete during the class session; for the first two weeks, groups were randomly assigned. After the first two weeks, students then worked with their semester-long project group members. Both sections (online and in-person) of the course shared the same exams. Both sections also required students to work on a semester-long project to develop database-centered web applications using relational database systems.

III. Related Works

Kuwabara et al.'s work aims to discover the effects of collaborative learning activities on students' learning outcomes and their perceptions of workload division between their group members [7]. Kuwabara et al. includes the traditional classroom, online, and hybrid modalities in their research work to study whether collaborative learning techniques expand to these different modalities [7]. The evaluation is mainly founded on the students' self-reported perceptions of their course-specific learning outcome mastery [7]. Kuwabara et al. mentions several limitations to their study, which the opportunities for improving this work include conducting a replication study while including the students' performance (grade book) data, comments from teaching evaluations, etc. [7] Our study includes such data for analyses.

Wang et al. studied the effects and advantages of virtual level manipulative (VLM) on students' mental engagement and perceptions on collaborative learning [15]. Cognitive load, flow experience, and task involvement were evaluated for three collaborative modalities (one VLM per student, one VLM per group, and one VLM per class) [15]. Our work studies the effects that teaching modalities have on collaborative learning, instead of collaborative modalities.

Francescato et al. studied the effects of collaborative learning in both online and face-to-face offerings of a two month seminar for psychology students [4]. This study compares the online and traditional classroom teaching modalities, in which the findings were based on a 26 question multiple choice exam (to measure performance) and a Perceived Knowledge Questionnaire with 7-point Likert scale questions (with students' self-reported data) [4]. Our research work studies the effects of teaching modality on collaborative learning and student performance over a longer period of time (August - December 2021) within a more extensive workload course.

Solimeno et al. examines the efficacy of face-to-face and computer-supported collaborative learning in increasing Master's students' academic performance, and whether students' and teachers' traits may affect students' performance [12]. Traits of teachers that were examined include their highest degree and experience in teaching the online and face-to-face modalities [12]. Student characteristics that were examined include learning strategies, psychological variables, and personality traits [12]. Our research includes more granularity in our student academic performance data, and we measure their characteristics (for example, sense of belonging to the course, perceptions of group member collaboration, etc.) based upon Likert scale questions and open-ended comments to provide feedback about their experience. Although Solimeno et al. looks at both the students and teachers' traits, we focus on student characteristics and outcomes independent from the teacher [12].

Streveler and Smith present the Content-Assessment-Pedagogy (CAP) triangle to help guide instructors in their course redesign decisions [13]. They distinguish collaborative learning apart from cooperative learning, and include a series of questions one should ask to ensure that the course design aligns with the content, assessment, and pedagogy [13]. Laal and Ghodsi define collaborative learning, and observes that it typically leads to higher academic achievement and stronger social competence [8]. Limperos et al. analyzed how various modes of delivery for online courses impacted students' sense of belonging in the course and towards the instructor [9]. Kampwirth and Bates explored various previous studies regarding teaching modality preferences and their impacts, and describes their limitations [6].

IV. Methodology & Data Collection

We base our study on the Humanistic Learning Theory as we aim to promote a safe learning environment where the course lessons and materials focus on both the students' feelings and their intellect, hence studying the effects of course modality on students' sense of belonging [14]. Our research work was inspired and guided by Saiz et al.'s work which analyzes the impacts of course modalities on students' performance data, results in assessments on learning management sytems (LMS), and learning behaviors exhibited by the student

through their data [11]. The learning behavior criteria listed and used by Saiz et al. are similar to our dataset, including student performance data, time spent on tasks, results in assessments, etc. [11]

Our data comes from four sources: 1) students' grade book performance data (identifiers fully removed to protect their privacy) from Canvas [5] 2) PrairieLearn [17] assignments 3) an end-of-semester survey questionnaire available to all students for the opportunity to receive extra credit, released by the instructor and 4) an end-of-semester survey (ICES forms) available to all students of the campus for feedback on their instructor and teaching assistants' teaching effectiveness, released by the university.

The instructor's end-of-semester survey was made available to student participants the weeks leading to the end of the semester, while the university's ICES survey was made available upon the very conclusion of the course. The instructor's end-of-semester survey questionnaire was created to collect feedback in an effort to improve the course for future semesters. Student identifiers were not collected and were not linked to their responses in any way.

The ICES survey is sent to all students on campus, for each class they took in the current semester, and all responses and feedback about their course experience is kept strictly anonymous. This anonymous feedback is shared with the instructor after the course has ended, and the instructor has no control over the students' responses. Thus, we expect the ICES results to be more unbiased, as students may have an inclination of feeling pressured or incentivized to participate in or provide positive responses regarding the course in the instructor's end-of-semester survey. Despite this, the instructor's end-of-semester survey is valuable because the survey instrument targets to answer our research questions regarding teaching modality and collaboration, as well as students' sense of belonging to the course.

The grade book from both the face-to-face and online offering consists of the grades that students received for each course assignment, and their cumulative final grades. Both sections of the course use the same grading rubrics for assignments and exams to maintain consistency. We utilize this data to evaluate students' performance with respect to their course modality in order to analyze whether course modality has an effect on students' academic performance.

Next, we utilize the student data (with identifiers removed) from PrairieLearn assignments and group activities in order to analyze the collaborative learning component. Since group activities are graded on effort, the grade book archive data (which factors into students' final grades) shows the final grades received by students on their group activities. PrairieLearn showcases the grades evaluated by the auto-grader, and the number of attempts that students used to solve a particular group activity problem. The effort component of the grading is evaluated by course staff, with most students receiving full-credit as long as a reasonable level of effort was shown in their submissions (hence, group activity data from the grade book is not a good indicator of performance). Thus, we may leverage the PrairieLearn data to evaluate whether students struggled more on group activities based on the number of attempts that students submitted to solve the problems.

For the end-of-semester survey questionnaire released by the instructor, we received a total of 190 responses (out of 420 students) from the online section and 17 responses (out of 50 students) from the in-person section. The questionnaires aimed at getting feedback on how students felt about the course, what helped them learn, what students found useful or not useful, as well as students' sense of belonging. This data will be utilized to analyze whether students' sense of belonging had an impact on their collaborative learning component of the course, as well as their academic performance.

Lastly, for the end of semester survey released by the university (ICES evaluation forms), we received a total of 159 responses from the online section and 15 responses from the in-person section. The survey was hosted on the university website under the Center for Innovation in Teaching & Learning, and email reminders were sent to campus students to fill out one form for each class they took for the semester. The survey targets feedback on students' learning experience, and to better evaluate instructor and teaching assistants' teaching effectiveness. The survey consists of open-ended question for students to provide feedback and suggestions regarding the course and instructor's strengths and areas of improvement. We will take in students' feedback provided on these forms to tailor our recommendations for course improvements.

V. Results

In this section, we present the aggregated findings from our data sources as follows: 1) Students' evaluation of the course and instructor 2) Students' preferred teaching modality and 3) Students' perception of their sense of belonging to the course. We then take a deeper dive into the quantitative evaluation of the 1) Students' overall performance and 2) Students' collaborative learning performance.

A. Course and Instructor Evaluation - Quantitative Analysis

Overall, the online section's students had indicated a higher level of teaching effectiveness, course quality, and course organization compared with the in-person section on the same corresponding 5-point Likert scale questions (1 = Very poor, 5 = Excellent) on the instructor's end-of-semester survey. The online section averaged 4.44, 4.42, and 4.32, while the in-person section averaged 4.24, 4.24, and 4.18 on the teaching effectiveness, course quality, and course organization factors, respectively (figure 2). The results were consistent with the ICES survey, where students indicated a higher rating (1 = Exceptionally Low, 5 = Exceptionally High) for the online section's teaching effectiveness and overall course quality, compared to the evaluations given for the in-person section (4.43 and 4.45 vs. 4.13 and 4.13, respectively). On a different 5-point Likert scale (scale: 1 = Very Little, 5 = A Great Deal) question asking students how much they have learned in the course, the online section had a slightly higher sore (4.64) than the in-person section (4.53), as seen in figure 2.

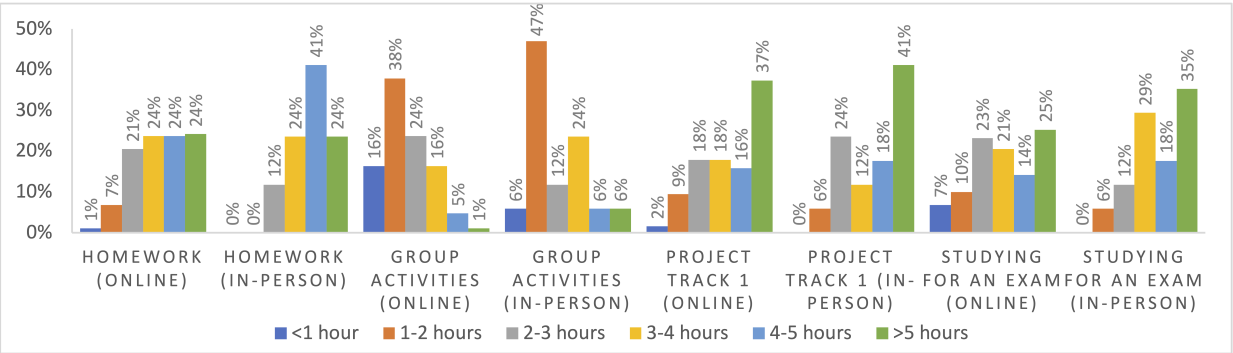

FIG. 1: This figure shows the average time spent per week on course components by students in the online and in-person sections, by categorical percentages. The main course components were analyzed, including homework assignments, group activity assignments, the semester-long group project, and exam study time.

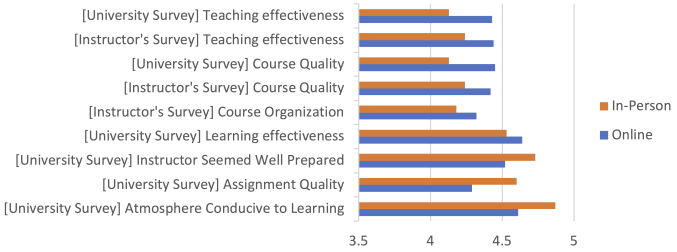

FIG. 2: Course and Teaching Evaluation Metrics from University ICES Form and End-of-Semester Survey.

On the other hand, the university ICES forms data also revealed pros for the in-person section over the online section. For instance, more in-person students felt that the instructor seemed well prepared for the class session (4.73 vs. 4.52 with 1 = No, 2 = Seldom, 3 = Neutral, 4 = Yes, 5 = Always), and that the assignments were well prepared, understandable, and mistake free (4.60 vs. 4.29 with 1 = Strongly Disagree, 5 = Strongly Agree). However, both sections of the course received identical assignments, so this discrepancy between the evaluation scores may be attributed to the students' perceptions of the course and/or the course modality. Furthermore, more in-person students believed that their instructor promoted an atmosphere conducive to learning (4.87 vs. 4.61 with 1 = Strongly Disagree, 5 = Strongly Agree) than the online section. These data are also presented in figure 2.

The in-person students found homework assignments to be more helpful than the online section on the 5-point Likert scale question (1 = "Wasted my time", 5 = "Extremely helpful, essential"); in-person students averaged 4.41 while online students averaged 4.24. With the same Likert scale, another survey question asks how helpful the lecture modality was for each section. The online section students received a survey question asking them to rate how much the pre-recorded pre-lecture videos helped them learn, while the in-person section students were asked to rate how much the in-class lectures helped them learn. Online students felt that the pre-lecture videos were more helpful (3.96 average) than the level of helpfulness in-person students felt for the in-person lectures (3.88 average). For other components of the course, such as the group activities, project track 1, project track 2, etc., both sections' students gave similar evaluation scores towards the effectiveness of these assignments towards their learning.

To put students' effort in the course into perspective with their evaluation, we analyzed the time students spent on each course component for both modalities, presented in figure 1. We observe that students in the in-person section tend to devote more time towards the homework assignments, with most students dedicating 4-5 hours weekly. The online section students have a more even distribution for the time allotted on homework assignments. Both sections' students most frequently worked on the group activities in their project teams for 1-2 hours weekly - approximately the time allotted during the class meeting session for the group activities. The semester-long project was the most time-consuming component of the course for both sections' students, with most devoting more than 5 hours per week.

B. Course and Instructor Evaluation - Qualitative Analysis

The students' feedback and testimonials regarding the course's strengths and suggestions from the university ICES survey were generally consistent with our findings from the end-of-semester survey. For example, students from both the in-person and online sections indicated that the pre-lecture videos were extremely effective at helping them learn the course material. Specifically, students from the online section provided as a suggestion to increase the number of pre-lecture videos available, so that they could see more worked-through examples of problems. They believed that the pre-lecture videos were *"comprehensive and summarized everything perfectly,"* at the same time. Similarly, in-person students indicated as a suggestion to *"record lectures and have videos to explain how to do certain problems,"* which essentially is the same concept as having pre-lecture videos being made available. This comes from students' desire to be able to refer back to lecture content, since students enjoy learning at their own pace, being able to pause, re-watch, or perform a Google search to clarify their confusion. Then, when students attend the class meeting (especially in the flipped-classroom model), they are provided with the opportunity to ask questions to solidify their understanding of the course material to optimize class-time usage.

Contrary to stereotypes of communication being negatively affected by online modalities, students had expressed in the ICES form that it was easy to communicate and ask questions to the instructor or teaching assistants. However, responses were generally tied with the sentiment that the instructor is exceptionally passionate, enjoys teaching, genuinely cares for his students, but also makes the course fun and engaging. Thus, we cannot conclude whether the students' perceptions of the communication factor was positively influenced by the instructor's attitude towards the course, and if so, by how much. We had a similar observation for the in-person section, where most of the comments involved noting that the instructor was very understanding and accommodating to students, and had positive energy to bring to the live lectures. Students seemed to have put a considerable value onto instructors' attitude towards teaching and their students.

Although students often mentioned technical difficulties negatively affecting their learning in the online section since it was challenging for them to pay full attention to lecture materials, in-person students expressed similar frustrations. Examples of online technical difficulties include frozen audio, frozen screen, bad internet connection, or a fast pace explanation that they did not catch onto. Examples of in-person technical difficulties include not being able to hear the instructor well across the classroom - students recommended the instructor to either speak more loudly or use a microphone.

We received various course suggestions on the ICES evaluations, applicable to both teaching modalities. Students suggested an increase in the number of auto-graded problems on assignments, because students found the immediate feedback from the auto-grader extremely helpful to their learning. They found that concepts they personally excel at were generally represented by these types of questions. Additionally, students expressed that they found demoing worked-through examples during the class meeting time being helpful, and to instead maximize the class meeting time with such types of instruction rather than synchronous group work on the group activity assignments. They preferred to have the group work done either 1) asynchronously or 2) during discussion or lab sections (which currently do not exist), as they found it difficult to interact with group members through Zoom.

C. Preferred Teaching Modality

We surveyed students on whether they would have rather taken the course with a different modality - specifically, whether they would like to have pre-recorded lecture videos released to them ahead of time or live lectures during the course meeting time (flipped-classroom online vs. traditional modality). Interestingly, we see from figure 4 that students from both sections chose the status-quo modality they took the course as their preference. This leads us to wonder whether this resulted from the students' habituation of taking the course in their status-quo modality, or because students were able to successfully register for their preferred modality in the first place. Additionally, it raises questions including "will students be more successful if they were allowed to switch to a different modality after the semester had begun?" and "what are the measures that can be taken to support the students who wishes to adjust their status-quo modality?"

We compiled testimonials from students (italicized below) to compare the pros and cons of each course modality in order to provide suggestions for future modalities. For students supporting the flipped-classroom online modality, with pre-lecture videos recorded and released a week ahead of time, we observed a few motifs: 1) Time flexibility 2) Pace and mental load, and 3) Frequency. For time flexibility, students expressed that the online pre-lecture videos were *"easy for preparation,"* while also *"[giving them] more flexibility to choose when to study."* Since the pre-lecture videos were recorded and divided by concept, they were generally shorter, ranging from 5 to 25 minutes. Students indicated that they enjoyed this factor, and we observed that in-person students expressed that they *"often found [themselves] watching the other sections' lectures. [They] liked that they were shorter."* This desire to optimize for time efficiency was also seen in factors non-related to how the lectures were delivered, but simply because students preferred *"having less travel time to / from lectures."*

For the pace and mental load factor, students repeatedly mentioned that the online structure of the videos *"helps me to pause the video and take breaks"* because *"sitting through a 1.25 hour lecture is really hard for [them]."* As a result of being able to play and pause the video at the students' desired pace, students who struggle with the content presented will have *"more time to digest the topic if it is difficult."* This generally helped the students to take detailed notes on the video lectures as well, without falling behind as they might in an in-person setting. For the frequency factor, students commonly expressed that they *"would like to be able to re-watch [the lectures],"* which helped them review for exams or prepare for the written homework assignments. If they had missed anything that was taught in the lecture the first time around watching the recording, they were able to watch it again in order to catch the concepts a bit deeper.

For students supporting the in-person modality, we also observed a few motifs: 1) the amount of interactions and syncing with group members 2) focus and commitment, and 3) level of comfort asking questions. Most students indicated that they *"strongly prefer live lectures, because recorded lectures extremely lack interactions and opportunities for making clarifications,"* since lectures were pre-recorded and discussions were held as a large gathering over Zoom [18]. Many students also expressed their dislike towards using Zoom as a means to delivering online lecture. In-person students appreciated the opportunity to sync with their group members, and to work on the group activity assignments together in the classroom, decreasing the chances for free-riders in the team. A few online students indicated that *"some team members did not do the group activities, others did them in chunks, others did them late,"* revealing team sync issues to collaborate on the group assignment, as some members only completed the work individually while others did not complete it at all.

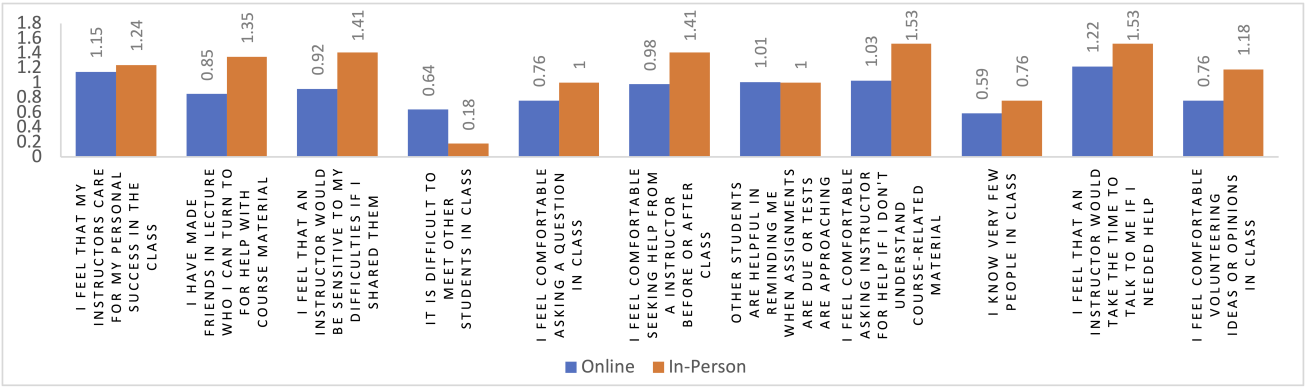

FIG. 3: Sense of Belonging Evaluation from Instructor's End-of-Semester Survey
Scale Legend: -2 = Strongly disagree, -1 = Disagree, 0 = Neither agree nor disagree, 1 = Agree, 2 = Strongly agree

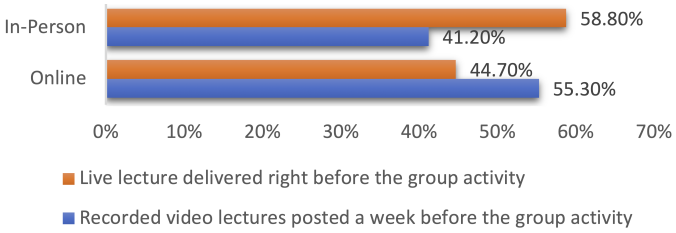

FIG. 4: Responses for Preferred Modality

Students felt a higher level of commitment and were better focused while attending in-person lectures, because *"live lectures are more engaging and prevent procrastination."* Some students describe this as a result of the social pressure to attend lectures and to be an active participant, drowning out other sources of distractions more common on Zoom lectures, such as phone usages or performing household tasks (given that their video cameras were not required to be turned on). By interacting with their peers in-person and being more active in the course, students felt more comfortable with asking questions when they met challenges in their learning. Students expressed that it felt easier to reach out and ask the instructor during or after the live lectures, compared to remote gatherings on Zoom where they felt more self-conscious. Students indicated that a smaller class size could facilitate with easier interactions and resolve some of these challenges.

D. Sense of Belonging

We initially hypothesized that the students' sense of belonging within the course may be affected by their status-quo course modality, so we included a section on our survey instrument involving various 5 point Likert-scale (-2 = Strongly disagree, -1 = Disagree, 0 = Neither agree nor disagree, 1 = Agree, 2 = Strongly agree) questions targeted at measuring students' sense of belonging. From figure 3, we observe that students' from both sections felt a similar level of personal care from the instructor regarding their personal success, felt that their peers were equally helpful in reminding them about upcoming deadlines for assignments or approaching exams, and knew very few people in the course.

However, students in the in-person section agreed significantly more that they had made friends in the course who they could turn to for help with course material compared with the online section (1.35 vs. 0.85 avg) (figure 3), and they were considerably more comfortable volunteering ideas or opinions in class. This indicates a higher level of peer-to-peer engagement for the in-person section, which also offers a higher level of sense of belonging with regards to instructor interactions, with notably larger proportions of students feeling that the instructor is reachable (i.e. the student feels comfortable seeking help before or after class, and feels comfortable asking for help if they do not understand course-related material). More in-person students felt the instructor would be more sensitive to their difficulties had they shared them, indicating that the in-person modality helps to foster a stronger bond and sense of trust between the students and their perceptions of their instructor (since both sections indicated a similar level of care from the instructor towards their success).

E. Students' Overall Performance - Quantitative Analysis

We include the aggregated average percentages of course components from the grade book in table I. By comparing the average course grades of students between the two sections, we do not see a significant difference in students' overall academic performance in this big picture. Group activities #5, 15, 16, 20, and 21 were excluded from the online section for analysis, since the in-person section did not include these assignments. These exclusions apply to table II as well.

For group activity assignments, students from both sections were graded for completion and effort. Both sections also worked with their semester-long project group members for

	Homework	Group Activity Completion	Group Activity Accuracy	3-Credit Project	4-Credit Project	Exam	Overall
Online Section	91.59%	96.05%	97.85%	96.60%	90.53%	91.18%	94.32%
In-Person Section	91.86%	96.19%	73.77%	97.42%	95.50%	89.86%	93.93%

TABLE I: Students' Overall Academic Performance by Course Modality. Group Activity Completion: final grades students received based on effort. Group Activity Accuracy: percentage scores that students received from the auto-grader.

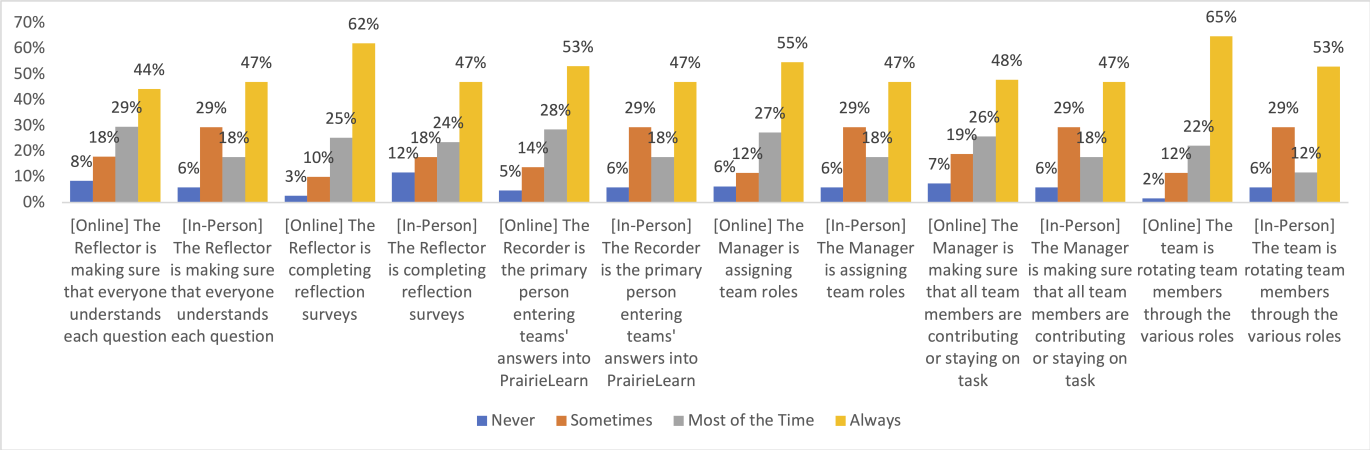

FIG. 5: Group Activities Collaboration Evaluation - This figure displays a comparison between both teaching modalities for the students' evaluation of their group members fulfilling their responsibilities.

the majority of the semester; a similar completion rate was observed for both sections as well (figure I). For the 4-credit section available to graduate students only, students had to complete an additional project track requirement involving various literature review critiques. The in-person section consistently had a higher grade average of 95.50% compared with the online section's average of 90.53%.

F. Collaborative Learning Performance - A Quantitative View

For the collaborative learning component, we analyze the group activity team role evaluation data. We observed that the online students displayed a higher level of engagement according to figure 5, compared to the in-person students. The in-person section had a higher proportion of students indicating that only sometimes did their group members deliver their role responsibilities. On the other hand, the online section had more students indicating that members on their team fulfilled their role responsibilities most of the time.

In PrairieLearn, student assignments are divided and categorized into various modules to be completed throughout the semester (1st column of table II). Since the in-person section did not cover Neo4j course topics, Neo4j-related assignments were excluded from our analyses for consistency. We also excluded group activities 5, 15, and 16 from the online section, since the in-person section did not include these assignments. We exclude group activity 6 and 14 from both sections, and one question from the group activity 10 and 13 assignments, as those questions were not auto-graded and were fully manually graded on effort - these scores were instead aggregated in the grade book performance data. We present our data in table II.

Based on table II, we see that overall, the online section had a significantly higher mean score percentage on group activity assignments, based on accuracy defined by the PrairieLearn auto-grader, compared with its in-person section counterpart. However, in-person section students generally started off stronger on group activity questions, as we can see their first and average submission scores were both a lot higher than the online section students - 61.21% vs. 44.25% and 71.30% vs. 56.98%, respectively. On the other hand, online section

Module Name	Section	Mean	Perfect Submission	First Submission	Last Submission	Average Submission	# Attempts	Average Time
Relational Model (SQL)	In-Person	97.90%	96.29%	13.37%	88.97%	29.70%	14.31	322 min
	Online	97.53%	97.48%	18.64%	93.66%	34.80%	12.78	375 min
DB Design	In-Person	99.24%	99.24%	46.62%	79.17%	60.50%	8.91	476 min
	Online	98.18%	98.18%	67.36%	89.26%	73.28%	4.75	260 min
Indexing	In-Person	100%	100%	50.11%	96.31%	68.61%	8.65	101 min
	Online	98.45%	98.45%	63.64%	97.79%	75.83%	6.49	103 min
Transactions	In-Person	98.81%	98.51%	36.66%	71.97%	52.55%	15.07	332 min
	Online	98.44%	98.55%	54.81%	88.64%	64.83%	10.15	244 min
Query Optimization	In-Person	52.14%	48.72%	30.00%	84.52%	48.34%	5.62	174 min
	Online	94.27%	92.62%	45.65%	88.67%	60.92%	4.88	148 min
Document DB (MongoDB)	In-Person	62.92%	62.92%	47.87%	97.47%	56.45%	3.04	87 min
	Online	98.79%	98.79%	23.98%	97.44%	43.17%	6.36	156 min
Overall	In-Person	73.77%	73.72%	61.21%	95.62%	71.30%	3.62	248.67 min
	Online	97.86%	97.77%	44.25%	92.59%	56.98%	8.13	214.33 min

TABLE II: Collaborative Learning Performance Data (from Group Activities) Based on Module. The overall section aggregation is included in the last row. Perfect Submission: % of students having at least one fully correct submission for questions in the module. First Submission: average scores for students' first submissions of questions in the module. Last Submission: average scores for last submissions. Average Submission: an average of all attempts by each student. # Attempts: average number of attempts students submitted for questions in the corresponding module.

students seem to struggle and persist in solving the problems more, as we can see the more than double amount of attempts submitted for a question compared to the in-person section students - 8.13 (online) vs. 3.62 (in-person).

From table II, we observe that the in-person students consistently had a slightly higher average score than its online counterpart, up until the Query Optimization module (online students averaged 94.27% on the group activities vs. 52.14% for the in-person students); then, the online section consistently had a significantly higher average score than the in-person section. For the Document DB module, the online students averaged 98.79% vs. 62.92% (in-person). The in-person students scored almost double the score on their first attempts at MongoDB-related questions than online students (47.87% vs. 23.98%); in-person students utilized less than half the number of attempts on average, compared to online students (3.04 vs. 6.36). Chronologically, both modules were assigned to students weeks before the Thanksgiving break holiday, and the assignments were due right before the break.

In-person students spent less time working on the Document DB module assignments compared with the online students (87 min vs. 156 min). Online students spent less time working on the Query Optimization module - 148 min (online) vs. 174 min (in-person) - but had a significantly higher accuracy score. In-person students devoted significantly more time compared with online students for the DB Design and Transactions modules - 260 minutes (online) vs. 476 minutes (in-person) and 244 minutes (online) vs. 332 minutes (in-person), respectively. For the modules mentioned, there were no significant differences in students' performance based on the course modality; thus, the amount of time spent on the group activities do not seem to be an effective indicator of success (or lack of success).

VI. Interpretations and Conclusion

Overall, although both sections had a similar performance with their final grades in the course, we found that the online flipped-classroom teaching modality is correlated with a higher level of perceived teaching effectiveness, course quality, and course organization; students found online lectures to be more helpful, given that online lectures and recorded pre-lecture videos help students save time, offers more learning flexibility with the ability to pause, rewind, or speed up (pacing), and helps students gain exposure and time to digest challenging topics. Students emphasized the importance of showcasing worked-through examples in pre-lecture videos and in the class meeting time. Students from both modalities indicated a desire for re-watchable lecture videos to review course materials. Furthermore, both modalities indicated the presence of technical difficulties affecting their learning. Although students from both sections indicated that their communication experience with their instructor was highly positive, it was generally associated with (positive) feedback regarding their instructor's attitude towards the course and students. We see a pattern of students' perceptions biasing their responses in the example of in-person students giving higher ratings for the quality of assignments, since both sections received the same assignments. In-person students felt their environment was more conducive to learning, helped them better focus on course materials, and felt less likely to procrastinate, even though both sections' performance were similar; they found homework assignments to be more helpful, but they had also indicated more time dedication towards the homework assignments compared with online students.

In collaborative learning assignments, traditional classroom (in-person) students performed slightly stronger earlier in the semester, but their performance drastically waned later in the semester while online flipped-classroom students maintained a strong performance. The amount of time spent on such assignments was not an effective indicator of performance. Online students displayed a higher level of engagement with collaborative assignments, and more students indicated that their group members fulfilled their role responsibilities most of the time. However, in-person student responses consistently suggested that they were more comfortable with asking questions in class or volunteering their opinions. This is coupled with the finding that they found it easier to meet other peers in the course, or make friends for course material help. Furthermore, in-person students perceived instructors to be more reachable and sensitive to their challenges, although both sections found their instructors equally as caring towards their success. Both sections' students suggested an increased presence of auto-graded problems, and more class time dedicated to showcasing worked-through examples.

VII. Limitations & Future Works

In terms of preferred teaching modality, a majority of students in both sections preferred their status-quo modality; online flipped-classroom students desired smaller discussion or lab sections to promote interactions for group activity assignments. Thus, it is not clear whether students preferred the in-class modality due to it being a smaller gathering (due to COVID-19 restrictions), or if students preferred the online modality due to the availability of pre-lecture videos and worked-through examples. We propose to conduct a similar study where both online flipped-classroom and in-person sections are approximately the same size and provided with the recorded pre-lecture videos. Additionally, it would be interesting if online students were required to turn their video camera on to facilitate interactions for collaborative assignments. Students may also display status-quo bias when preferring their status-quo modality; having students swap teaching modalities mid-semester so they experience both before establishing their preference would be helpful.

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