

# Correlation Analysis to Quantify Learning Outcomes for Different Teaching Pedagogies

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*Abstract*—A fundamental goal of education includes preparing students to become a part of the global workforce by making beneficial contributions to society. In this paper, we analyze student performance for multiple courses that involve different teaching pedagogies: a cooperative learning technique and an inquiry-based learning strategy. Student performance includes student engagement, grades, and attendance records. We perform this study in the Computer Science department for online and in-person courses for 450 students. We will perform correlation analysis to study the relationship between student scores and other parameters such as gender, mode of learning. We use natural language processing and machine learning to analyze student feedback data and performance data. We assess the learning outcomes of two teaching pedagogies for undergraduate and graduate courses to showcase the impact of pedagogical adoption and learning outcome as determinants of academic achievement. Early findings suggest that when using the specified pedagogies, students become experts on their topics and illustrate enhanced engagement with peers.

*Keywords*—Bag-of-words, cooperative learning, education, inquiry-based learning, in-person learning, Natural Language Processing, online learning, sentiment analysis, teaching pedagogy.

## I. INTRODUCTION

**G**IVEN the recent labor trends and the changing workforce that are driving new pathways of education, it is time to explore advanced teaching styles to prepare the students for the future [2].

Recently, online course enrollment has skyrocketed remarkably however the capability of online learning is obscure [12], [13]. E-learning offers a convenient, accessible and flexible environment, though there are certain limitations which make measuring the efficacy of online learning challenging, such as, high level of proctoring requirement, self-discipline and motivation to self-study [14]. In 2020, the global pandemic compelled educators and students to rapidly adapt to online learning, transforming the future of online education permanently. This necessitates understanding the learning outcomes in an online versus traditional [15] classroom setting. We propose a strategy to quantify student learning for courses taught online, by designing content delivery and surveys incorporating the following teaching techniques. We also integrate student perception and self-assessment to calibrate student performance.

- 1) Jigsaw Technique [3]: Students extensively research their assigned topics, foster self learning by teaching the topic to peers.

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- 2) Inquiry-based Learning: Students develop their own research topic, pitch intelligent questions to peers, collect constructive feedback and present their topic to the peers.

Past research [1], [15] compares online versus in-person learning, however they do not apply specific teaching methods nor incorporate student perspective extensively. The objectives of this research are:

- 1) Assess student learning in online instruction mode.
- 2) Measure the effectiveness of Jigsaw and Inquiry-based teaching pedagogies.
- 3) Identify environmental factors that impact e-learning.
- 4) Quantify student performance based on multiple factors: self-evaluation, participation level, grades.

We collect the data starting from Summer 2020, for six unique undergraduate and graduate courses with thirteen sections, for five semesters for 450 students, through surveys and class grades collected during the semester. The student split is shown in Fig. 3 along with the course number, section number, semester and year in which the course was taught. The naming convention is as follows: Spring20\_332\_02 is for the 332 course, section 02, taught in Spring 2020. The undergraduate courses include the 300 and 400 level courses, whereas the graduate courses are the 500 level courses.

We apply the two teaching techniques and perform detailed analysis for the collected data. We expect that the Jigsaw technique will have challenges impacted by a student's gender; we will analyze the relatable data to confirm the findings. The goal of the research is to identify the most significant factors that impact student performance. We use different visualization techniques to compare the student performance for multiple courses with (1) the inquiry-based technique, (2) the Jigsaw technique, and (3) using both these techniques. We also compare the student performance for online courses and in-person courses during the pandemic and study the impact on student performance.

The broader impact of the project includes contributing towards the growing demand of e-learning, by enhancing student performance and enriching student experience by using multiple teaching pedagogies. The project will demonstrate the use of different teaching techniques, urging the instructor community to consider enriching the student experience and enhancing student performance to maximize learning in online classes. Illustrating an improvement in student performance for multiple courses, and restructuring the curriculum design, is a step towards participating in improving graduation rates and attempts towards changing the perspective of the society and

TABLE I  
 EXAMPLE STUDENT DATA FOR CPSC 332-02 FOR SPRING 2020

Sid	Project (Part 1+ Part 2) total	Quiz 1	Quiz 2	Assignments total	Mid Term Exam	Final Exam	Course total
555	10.78	5	1.5	19.35	34.65	25.55	94.67
556	10.46	5	1	17.15	30.45	29.4	91.04
557	10.56	4	1.5	18.45	26.95	17.85	77.58
558	10.78	4.5	2	19.25	34.3	24.5	92.49
559	10.35	4	1.5	17.5	29.23	18.55	79.42

potential students to consider online learning as a successful platform for knowledge delivery, with a potential to improve retention and graduation rates.

We analyse the online and traditional classroom data to compare students' achievements for the same courses. The research measures student learning by various forms— prior knowledge versus the knowledge gained from the course, thereby quantifying the effectiveness of the applied teaching techniques. If there are nuances to the teaching techniques that can lead to challenges, we anticipate measuring them as well. The ultimate goal of the project is to enhance student performance and decrease student failure rates in chosen courses with a potential to be adaptable to courses within the department and outside.

The rest of the paper is organized as follows. The next section presents the background work, followed by the research questions that we answer in this research. Section IV presents the data used in this work. In Section V, we discuss the teaching pedagogies used in this work. The next section focuses on evaluating the learning outcomes and student performance. Finally we present the findings and challenges in Section VI. In the final section we present the conclusion and future work.

## II. BACKGROUND WORK

Nowadays, the factors of students' performance have been researched by different researchers. Reference [7] believed that different classroom layout has a relationship to student performance. They use a traditional classroom and retrofitted Innovative Learning Environments (ILEs) in a secondary school in Australia as the teaching environments with students divided into three groups: ILE Intervention, ILE Control, and Traditional Control. The method they use is the single subject research design (SSRD). They compare students' attitudes on learning and their academic outcomes. They observe that students have a significant change in attitude, but none has a statistically significant difference. Their findings indicate that different layout of the classroom has a greater influence on different classroom teachers or class groupings.

The research presented in [9] analyzes the culturally responsive pedagogies (CRP) and the students' performance. The interview data are collected for grades 9-12 students from four different schools. All students self-identify themselves as Aboriginal. They use an instrument that contains 7 categories and generated 83 items. They use the Rasch model to construct the survey instruments and retained 62 items of the original 83 items. They find out the teachers may emphasize specific subscales based on their teaching environments. Compared to

elementary teachers, secondary teachers have a lower level of commitment to some teaching competencies and standards.

The study [8] investigates the student performance with their motivation for online courses. In this research, the data are collected for 109 undergraduate students who majored in business at a medium size university. There are three main factors in their analysis, which are 'convenience', 'enjoyment & independence', and 'no other option available'. 78.9% variation is explained by the first three factors. They determine that the students take online courses when they have no other options, then their motivation, self-efficacy, satisfaction, learning experience and satisfaction will be negative. If they take online courses because they think online courses are convenient or for their enjoyment and independence, their feedback will be positive.

Researchers [4], [5], [11] have also explored using machine learning to predict student performance such as the class grades. In the future work, we plan to extend this work to apply machine learning to predict the student grades for different courses.

## III. RESEARCH QUESTIONS

Here we present the research questions answered in this work. These questions will be answered throughout the rest of this paper.

- 1) Research question 1: How does the teaching modality: impact the application of the teaching pedagogies in class?
- 2) Research Question 2: Based on the surveys, what are the students' top concerns? And what are the students' perspective for the online courses and in-person courses?
- 3) Research Question 3: What is the correlation between the use of jigsaw technique, inquiry-based learning and student participation in class?
- 4) Research Question 4: What is the relationship between the use of jigsaw technique, inquiry-based learning and student performance in class?
- 5) Research question 5: Does the jigsaw technique work better in conjunction with inquiry-based learning?
- 6) Research question 6: Is the student performance dependant on the teaching modality: online versus in-person?
- 7) Research question 7: What are the challenges involved in using the aforementioned techniques in teaching?

## IV. DATA

The data for this research are collected by the first author, an Assistant Professor in the Computer Science department. The

data analyzed in this work are for a variety of undergraduate and graduate courses taught by the instructor which include: (1) Introduction to Machine Learning (CPSC 483, 2 sections), (2) Advanced Database Management System (CPSC 531, 1 section), (3) Graduate Project (CPSC 597, 1 section), (4) File Structures and Database Systems (CPSC 332, 4 sections), (5) Professional Ethics in Computing (CPSC 315, 4 sections) and (6) The Computer Impact (CPSC 313, 1 section). The data are collected in two ways: (1) Student performance and participation data are anonymized and collected using grades released by the instructor each semester. (2) Student self-evaluation data and satisfaction data are collected through anonymous class surveys.

### A. Student Performance Data

We use the student performance data gathered throughout the semester for all the student submissions (assignments), and exams (quizzes, midterm, and final exam) to analyze the student grade distribution for all the 13 sections. The number of students in each course is shown in Table III. We also include self-assessment using the anonymous student surveys collected in class during the first and last week of classes. The surveys gather information from students which include techniques that worked well for them in the past classes, and their experience with online and in-person classes among other related information.

1) *Student Grade Distribution*: The student grade data include student scores for all the quizzes, assignments, projects, participation activities, and exams. Table VIII showcases the data for 5 students with a randomly generated unique student id (Sid) to mask the student identity. Each submission has a different weightage, and the final score is calculated based on the score of each individual submission multiplied by their weightage towards the final class grade. This final score is represented as the **Course total** column shown in Table VIII which reflects the actual grades of students for the CPSC 332: Files Structures and Databases Course, Section 02 taught in Spring 2020. The final scores of the courses are from 0 to 100. Table II [10] shows the grading scheme used in the classes.

Sid	Project (Part 1+ Part 2) total	Assignment :Phase 1 Submission	Assignment :Phase 2 Submission	Assignment: Project Extra Credit	Quizzes total	Quiz 1	Quiz 2	Assignments total	Assignment 1
552	10.46	1.5	8	1	1.5	0	1	18	4.55
553	10.67	1.8	7.9	1	5.25	4	1.5	18.3	4.7
554	1.6	0	1.6	-	5.63	4.5	1.5	13.7	4.45
555	10.78	1.9	7.9	1	6	5	1.5	19.35	4.85
556	10.46	1.6	7.9	1	5.25	5	1	17.15	3.75

Fig. 1 Student grades consisting of assignments, quizzes, and exams

### B. Student Surveys

In this section we provide detailed description about the surveys that are collected from the students. The feedback is collected in a series of 2 surveys: (1) In the first week of classes and (2) in the last week of classes. These surveys are optional and anonymous. Students are encouraged to give detailed feedback and are informed about the details about the teaching pedagogies and the anonymity of the survey.

Assignment 2	Assignment 3	Assignment 4	Exams total	Mid Term Exam	Final Exam	Course total
4.25	4.95	4.25	56.02	31.33	24.5	85.45
4.45	4.65	4.5	61.6	33.6	27.83	94.12
4.3	4.95	0	42.21	21.35	20.83	61.29
4.8	4.95	4.75	60.46	34.65	25.55	94.67
4.1	4.7	4.6	59.91	30.45	29.4	91.04

Fig. 2 Student grades 2

TABLE II  
GRADING SCHEME USED IN CLASSES

Grade	% of Total Points
A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	Below 59%

1) *Week 1 Survey*: The survey is collected in the first week of classes. The survey asks about students' previous experience of the online class and their preferences for the online settings. Below is a list of some of the questions from the survey:

- In the past, one thing that worked well in any online class setting for you.
- In the past, one thing that did not work well for you in any online class setting/you wished was done differently.
- Do you think online classes tend to decrease student attention. Why or why not? [Examples of decreased student attention: checking phone messages, getting up to eat food, using the restroom more frequently]
- Do you think online classes tend to increase student attention. Why or why not?

2) *End of class Survey*: The end of class survey is conducted in the last week of classes. It focuses on the students feedback and below are some of the questions from the survey:

- On a scale of 0-10 rate your knowledge about Machine Learning now ( 0- no knowledge, 10 – Expert).
- On a scale of 0-10 rate your experience in this course.
- One thing that worked well in this class.
- One thing that would have worked better if this class was an in-person class.

TABLE III  
NUMBER OF STUDENTS IN EACH OF THE 13 SECTIONS

Course	Number of students
Spring 20_332_02	26
Spring 20_332_04	46
Spring 20_332_05	38
Summer 20_315_01	33
Fall 20_531_01	25
Fall 20_597_01	12
Spring 21_313_52	39
Fall 21_315_03	38
Fall 21_332_05	38
Spring 22_315_01	37
Spring 22_315_04	42
Spring 22_483_01	37
Spring 22_483_02	39

3) *Student Self-Evaluation:* One of the essential steps this work includes the student self-evaluation of their learning and performance in class. We collect and analyze the self-evaluation data in the last week of classes, when the students have completed the course and are getting ready for the final exam. Figs. 3-12 show the self-assessment results for all the six unique classes taught using the teaching pedagogies described in this work.

On a scale of 0-10 rate your knowledge about Computer Ethics after CPSC 315-01 Summer 2020 (0- no knowledge, 10 – Expert)

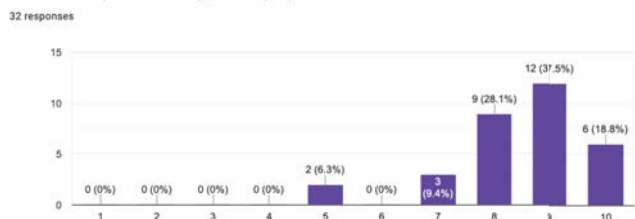
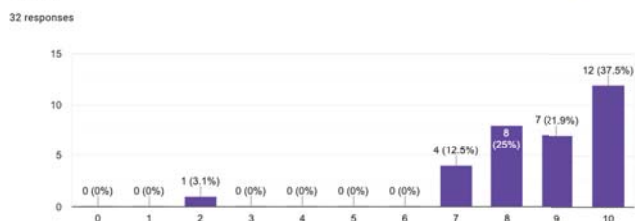


Fig. 3 Last week survey response for CPSC 315 for Summer 2020

On a scale of 0-10 rate your experience in this virtual CPSC315-01 Summer 2020 course.



On a scale of 0-10 how would you rate your class participation in this course (CPSC 315-01)

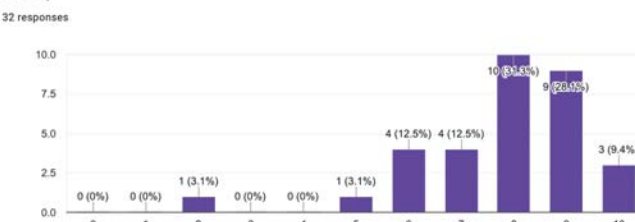


Fig. 4 Last week survey response for CPSC 315 for Summer 2020

On a scale of 0-10 rate your knowledge about File Structures & Database Systems after CPSC 332-05 Fall 2021 (0- no knowledge, 10 – Expert)

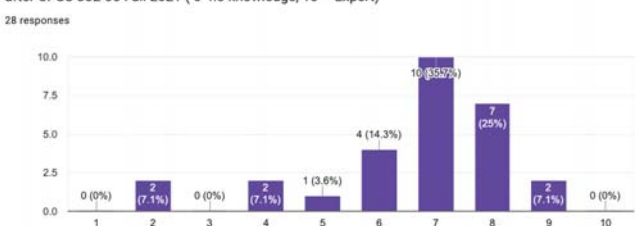


Fig. 5 Last week survey response for CPSC 332 for Fall 2021

On a scale of 0-10 how would you rate your class participation in this course (CPSC 332-05)



Fig. 6 Last week survey response for CPSC 332 for Fall 2021

On a scale of 0-10 rate your knowledge about Computer Impact after CPSC 313-52 Spring 2021 (0- no knowledge, 10 – Expert)

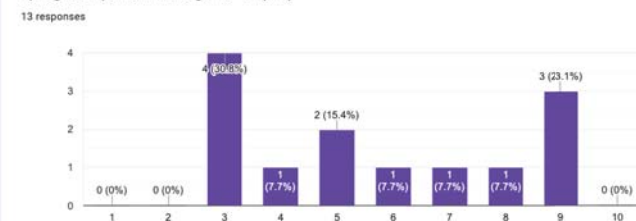
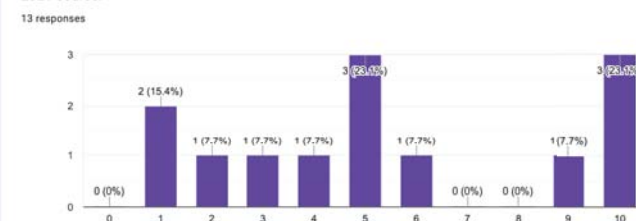


Fig. 7 Last week survey responses for CPSC 313 for Spring 2021

On a scale of 0-10 rate your experience in this asynchronous CPSC 313-52 Spring 2021 course.



### C. Teaching Modality

In this work, we analyze different teaching modalities: (1) *in-person and online*, (2) *synchronous and asynchronous*, for the 13 sections taught in the Computer Science department. Majority of these sections are taught online due to the pandemic coming into effect from March 2020 (Spring 2020), when the university switched to synchronous online modality from the in-person modality. The main difference between synchronous and asynchronous modality is synchronous classes are scheduled and occur on their assigned days, at their assigned time and are real-time interactions conducted through Zoom, with the instructor and students present in the Zoom session. Asynchronous mode offers more flexibility as the students can choose time as per their convenience rather than prior scheduled days and time. The instructor releases course material regularly but it is up to the students when they want to access the class material. Generally the course content is disseminated through lecture recordings, slide deck, assignment documents and other material made available on a learning management system (LMS) such as Canvas. Students are informed about deadlines, relevant information through announcements on the LMS. CPSC 313 is the only course which is an asynchronous course in our study. That's why in

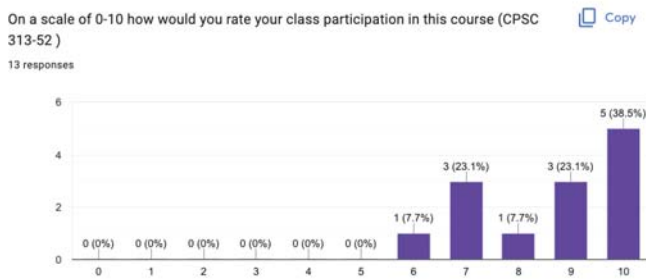


Fig. 8 Last week survey responses for CPSC 313 for Spring 2021

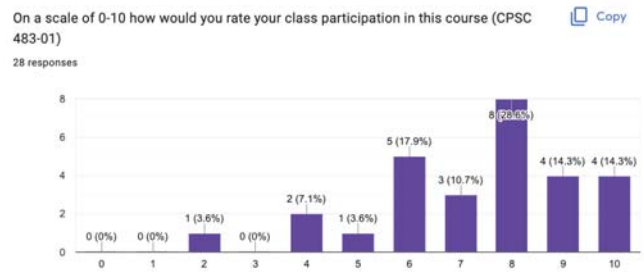


Fig. 10 Last week survey response for CPSC 483 for Spring 2022

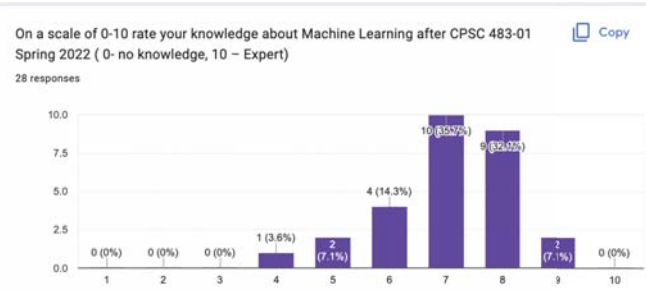


Fig. 9 Last week survey response for CPSC 483 for Spring 2022

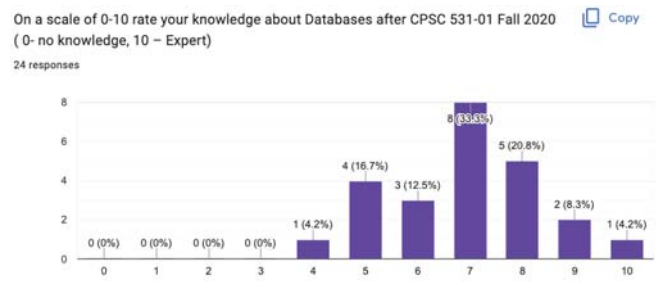


Fig. 11 Last week survey response for CPSC 531 for Fall 2020



Fig. 6, the students' ratings are lower than in other courses.

## V. TEACHING PEDAGOGIES

Traditional teaching styles involve the instructor to be the primary holder of domain knowledge, expertise and experience. Innovative teaching pedagogies guide teaching and transform learning to involve students in the learning process. In this section we present the teaching strategies that are explored in this work to quantify their impact on student performance and learning outcomes with an ultimate goal of enhancing learning experience for students by engaging students more in different classroom settings.

### A. Cooperative Learning

Cooperative learning is a well-established collaborative learning technique where students work with their peers in small groups to complete an assigned structured activity. Each student works individually towards a common goal. Each student is responsible for understanding the content and enhance self-learning by teaching the topic to her/his peers. In this work we use the Jigsaw technique to incorporate cooperative learning in classrooms. The Jigsaw technique was

developed by a graduate professor and social psychologist in Austin, Texas named Elliot Aronson in 1971 [3]. In an online or in-person classroom setting, sections of 30-45 students are divided into groups to research a pre-assigned topic. Students focus on their own topics, conduct their research to gain expertise, hold discussions and present the topic as an instructor.

The way we incorporate the jigsaw technique in classrooms that includes the following steps:

- 1) The students are assigned a list of available topics to the students from which each student needs to select one topic for the assignment. The topic selection is done on first-come first-serve basis and the majority of the students select a topic within the first 24 hours of sharing the topics.
- 2) The deliverable of the assignment are (1) a 1-2 page summary and (2) an oral presentation that includes compelling questions for the audience to engage with the speaker. The summary includes their viewpoint along with research from the recent events associated with the topic. The summary and presentation slides are shared with the class for review 24 hours before the presentation.

On a scale of 0-10 how would you rate your class participation in this course . ( 0 - no participation, 10 - active participant) Copy  
24 responses

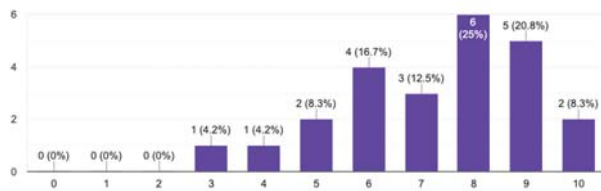


Fig. 12 Last week survey response for CPSC 531 for Fall 2020

- 3) Each week students work towards gathering information about their topic and are encouraged to collaborate with other students who have chosen a related topic.
- 4) Every week 2-4 students present their topic to the class while others review the material to be presented before coming to class. Presenters gather resources, read articles, connect related events and finally thoroughly research their topic to gather as much information they can. The students attending the presentations come prepared with relevant questions for the speaker.
- 5) A sample assignment includes summarizing the assigned topic by raising relevant ethical questions and connecting the topic to current events by exploring the textbook as well as from sources outside of the textbook.
- 6) The students receive detailed feedback, comments from the instructor and the peers. Followed by the presentation is the question & answer (Q&A) session where the audience gets a chance to interact with the presenter.

### B. Collaborative Learning

We adapt the inquiry-based learning [5] technique for this work. The technique is introduced to us early-on in lives; as toddlers we ask questions and try to make sense of the world. With this teaching pedagogy, each student learns through inquiry and discovery, promoting learning by focusing on critical thinking. For students the technique initiates with a question: what will I learn today? Unlike traditional approaches, with this teaching pedagogy, rather than having the knowledge being delivered just by the instructors, the students are involved in their own learning. As compared to conventional teaching strategies, where student learning relies on the instructor's directed activities, research shows that students learn best when they ask questions and investigate solutions by interpreting new information and working towards discovering the solutions.

The way we incorporate the inquiry-based learning technique in classrooms includes the following steps:

- 1) The students are permitted to select a relevant topic of their choice. The selected topic along with an abstract is sent to the instructor for approval.
- 2) Once the topic is approved, the students can start gathering the resources. The students are provided additional resources to prepare the topic.
- 3) The deliverable of the assignment are a (1) 7-8 page paper and (2) an oral presentation. The summary and

presentation slides are shared with the class for review 48 hours before the presentation.

- 4) The students collectively work towards a common goal in a group of 3 students.
- 5) Every week 2-4 groups present their topic to the class while other students go over the material before coming to class. They gather resources, read articles, connect related events, shortlist other sources to use for the work and finally thoroughly research their topic to gather as much information they can. The students who are attending the oral presentations come prepared with relevant questions for the speaker.
- 6) A sample assignment includes summarizing the assigned topic by raising relevant ethical questions and connecting the topic to current events by exploring the textbook as well as from sources outside of the textbook.
- 7) The students receive detailed feedback, comments from the instructor and the peers. Followed by the presentation is the question & answer (Q&A) session where the audience gets a chance to interact with the presenter.

### C. Comparison with Conventional Teaching Techniques

In contrast to the traditional teaching techniques, where the instructor alone delivers the information, collaborative and inquiry-based learning enables an instructor to act as a facilitator. Below are the key responsibilities of an instructor implementing these techniques:

- 1) Be the content expert in the classroom.
- 2) Proactively design the course and class activities.
- 3) Implement the class activities to execute them in a pre-assigned time frame.
- 4) Design the class activities such that they are easy to follow, and engage students, and intrigue student interest
- 5) Encourage group work and discussions.

These teaching pedagogies involve open-ended questions for students to think, discover, inquire and discuss. The students are encouraged to discuss the questions, gather resources, perform research, process the information and investigate the answers. Finally they present and share their findings with the class acting as the expert for the assigned topic. The other students comprehend the information disseminated by their peers, provide feedback and participate by asking questions to the presenters. In the analysis presented in this work, we have the following scenarios: (1) Only the Jigsaw technique implemented in classrooms. (2) Only the Inquiry-based learning implemented in classrooms. (3) Both the Jigsaw technique and the Inquiry-based learning implemented in classrooms. Based on these scenarios we perform a comparative analysis in classes where the individual teaching pedagogies are applied as a standalone as well as in conjunction with other teaching pedagogies. Additionally we can compare the impact of the presence and absence of a teaching pedagogy.

## VI. LEARNING OUTCOMES EVALUATION

In this section, we present the evaluation of the learning outcomes for students based on multiple factors (1) student









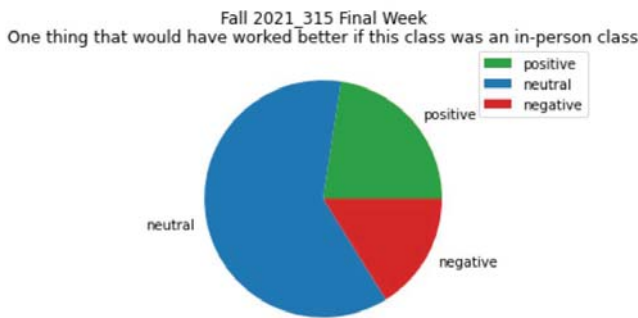
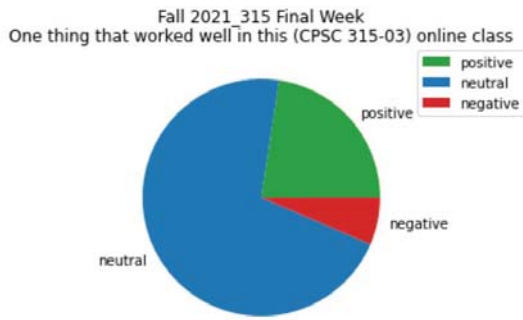


Fig. 24 Pie chart of course CPSC 315 last week survey in Fall 2021

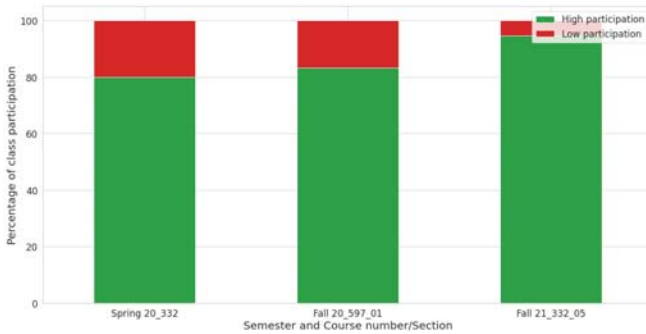


Fig. 25 Students participation in courses with one teaching pedagogy

is considered as high participation and below 70% is low participation. The average score is calculated from the final grade. Both plots show that for all courses with one and two teaching pedagogies, students with high participation have higher grades. Students with low participation for the courses CPSC 597 in Fall 2020 and CPSC 332 in Fall 2021 have the lowest average score. However, CPSC 597 has only two low participate students with grades of 3.38 and 0, thereby reducing the average score of the class. CPSC 597 and CPSC 332 both use a single teaching pedagogy, hence indicating that the two teaching pedagogies as a standalone require students to participate more to improve their grades.

*Research Question 4: What is the relationship between the use of jigsaw technique, inquiry-based learning and student performance in class?*

*Answer:* For the courses CPSC 313, CPSC 315, CPSC

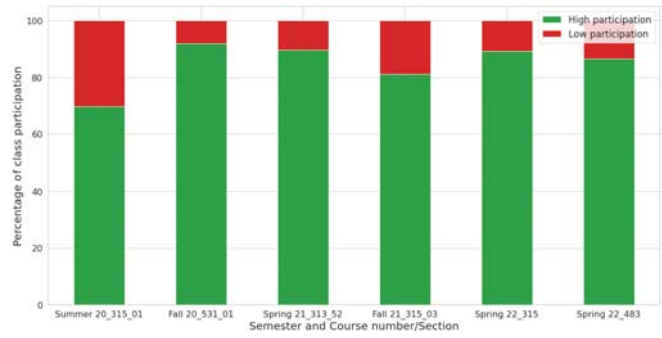


Fig. 26 Students participation in courses with two teaching pedagogies

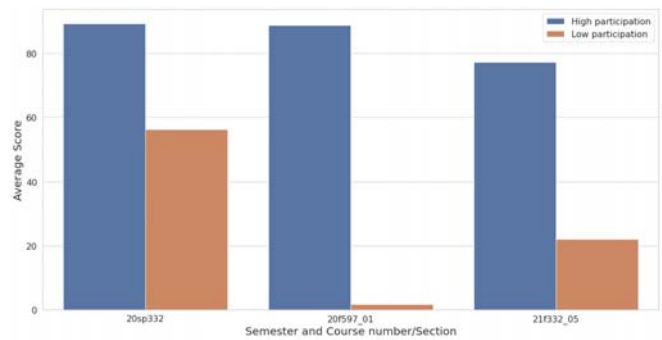


Fig. 27 Correlation between student participation and average grades of the course with one teaching pedagogy

531, and CPSC 483 use both the Jigsaw technique and the inquiry-based technique. Students in CPSC 332 experience the Jigsaw technique as a standalone and students in CPSC 597 only have the inquiry-based technique. We want to know how different teaching techniques affect students' performance. Hence we divided the courses into two groups: courses with 2 techniques and courses with only 1 technique. The first two plots in Fig. 29 show students' performances for each group. Analyzing the grades for courses with one teaching pedagogy that is shown in Table VI, CPSC 332 in Spring 2020 has 42% of students who got an 'A', 29% students have a 'B', 16% of the students have a 'C', 4% of the students got a 'D' grade, and 9% students have an 'F' grade. In Fall semester of the same year, CPSC 597 has 42% students who got an 'A' grade and 33% of students got a 'B'. And there are 8% 'C'. There

TABLE IV  
 GRADE DISTRIBUTION FOR ALL CLASSES AND SECTIONS

Grades	A	B	C	D	F
Spring 20-332-02	12	7	4	2	1
Spring 20-332-04	22	11	9	0	4
Spring 20-332-05	12	14	5	2	5
Summer 20-315-01	24	9	0	0	0
Fall 20-531-01	7	12	5	0	1
Fall 20-597-01	5	4	1	0	2
Spring 21-313-52	18	10	5	1	5
Fall 21-315-03	13	14	6	2	2
Fall 21-332-05	3	14	12	6	3
Spring 22-315-01	3	21	10	2	1
Spring 22-315-04	3	21	10	2	1
Spring 22-483-01	12	15	5	0	5
Spring 22-483-02	9	22	5	0	3

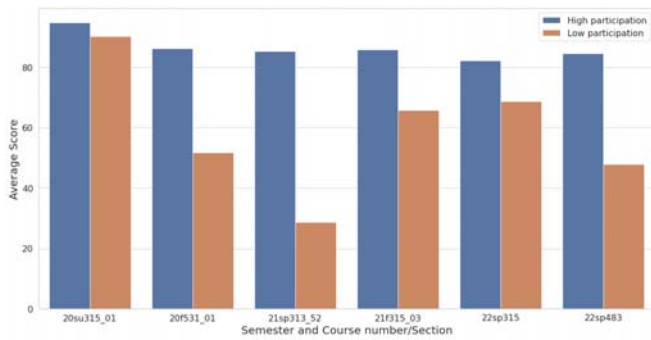


Fig. 28 Correlation between student participation and average grades of the course with 2 teaching pedagogies

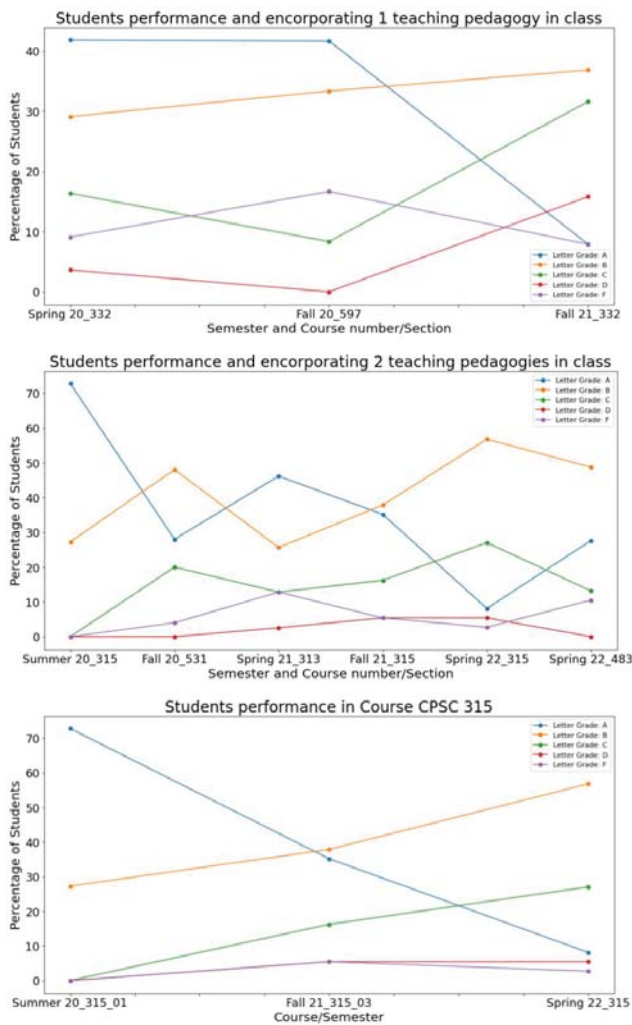


Fig. 29 Student performance with respect to teaching pedagogies

isn't any student get a 'D', but the failure rate of this course is 17%.

In Fall 2021, CPSC 332 has 8% of students who receive an 'A', 37% of students receive a 'B', 32% of students got a 'C', 15% got a 'D', and 8% fail the course. CPSC 332 in Spring 2020 and CPSC 597 in Fall 2020 have more students with an 'A' grade than with a 'B' grade. CPSC 332 in Fall 2021

TABLE V  
 PERCENTAGE OF STUDENTS GETTING THE LETTER GRADE WITH TWO TEACHING PEDAGOGIES

Grade (percentage of students)	A	B	C	D	F
Summer 20-315	72.73	27.27	0	0	0
Fall 20-531	28	48	20	0	4
Spring 21-313	46.15	25.64	12.82	2.56	12.82
Fall 21-315	35.14	37.84	16.22	5.41	5.41
Spring 22-315	8.11	56.76	27.03	5.41	2.7
Spring 22-483	27.63	48.68	13.16	0	10.53

TABLE VI  
 PERCENTAGE OF STUDENTS GETTING THE LETTER GRADE WITH ONE TEACHING PEDAGOGY

Grade (percentage of students)	A	B	C	D	F
Spring 20-332	41.82	29.09	16.36	3.64	9.09
Fall 20-597	41.67	33.33	8.33	0.00	16.67
Fall 21-332	7.89	36.84	31.58	15.79	7.89

has more students with a 'B' or 'C' than with an 'A'. The percentage of students who get an 'A' in CPSC 332 Fall 2021 is the lowest among all courses with 1 teaching pedagogy. When we analyze courses with 2 teaching pedagogies, which is shown in Table V, course CPSC 313 in Spring 2021 has 46% of 'A', 26% of 'B', 13% of 'C', 3% of 'D', and 13% students fail the course. CPSC 315 in Fall 2021 has 28% of students with an 'A', 48% students with a 'B', 20% of students with a 'C', 0% of 'D', and 4% of students have an 'F' the course. Course CPSC 315 in Summer 2020 with 73% of 'A', 27% of 'B', and no students get a grade below 'B'. Course CPSC 315 in Fall 2021 has an almost equal amount of students who get an 'A' and a 'B', which are 35% and 38% corresponding. And there are 16% of students with a 'C', and 5% with a 'D'. Also, there are 5% students who have an 'F'. CPSC 315 in Spring 2022 has more students who have a 'B' than students who have an 'A', which is 57% and 8% corresponding. Also, CPSC 315 in Spring 2022 have the highest percentage of 'C' among all courses, which is 27%. The percentage of students with a 'D' is 5%, and 3% student has an 'F'. CPSC 483 in Spring 2022 has 28% of students with an 'A', and 49% of students with a 'B'. There are 13% of students with 'C', 0% of students with a 'D', and 11% with an 'F'. Comparing the courses with one teaching pedagogy to two teaching pedagogies, fewer students get an 'F' if there are two teaching pedagogies. On the other hand, all courses with one teaching pedagogies have more than 7% students with an 'F', and the highest failure rate is 17%.

*Research question 5: Does the jigsaw technique work better in conjunction with inquiry-based learning?*

*Answer:* Yes. Based on the Fig. 22-25 and Table 4, the courses with both teaching pedagogies applied to a course are more likely to have a lower failure rate, and have a higher average score.

*Research question 6: Is the student performance dependent on the teaching modality: online versus in-person?*

*Answer:* Given that 73% of the students received an 'A' in Summer 2020, which is much more than the other two

TABLE VII  
 STUDENT AVERAGE SCORE FOR EACH COURSE AND SECTION

Course	Average Score
Spring 2020 CPSC 332-02	85.64
Spring 2020 CPSC 332-04	83.97
Spring 2020 CPSC 332-05	79.05
Summer 2020 CPSC 315-01	93.38
Fall 2020 CPSC 531-01	83.41
Fall 2020 CPSC 597-01	74.34
Spring 2021 CPSC 313-52	79.56
Fall 2021 CPSC 315-03	82.06
Fall 2021 CPSC 332-05	74.38
Spring 2022 CPSC 315-01	80.66
Spring 2022 CPSC 315-04	75.92
Spring 2022 CPSC 483-01	78.28
Spring 2022 CPSC 483-02	81.93

sections. Comparing Fall 2021 and Spring 2022, we find that the percentage of 'A' dropped from 35% to 8%, and the percentage of 'B' increased from 38% to 57%. Also, the percentage of 'C' increased from 5% to 27%. The percentage of 'D' between the two semesters is the same and the percentage of the students who failed the course decreased from 5% to 3%. Since the pandemic started in 2020, all courses in 2020 and 2021 were online courses. In spring 2022, based on the CSUF's regulation, the courses transitioned from in-person to online courses. We have the students' performance data for CPSC 315 in Summer 2020, Fall 2021, and Spring 2022, so this is the perfect course for us to compare the students' performance in online and in-person settings. The last plot of the Fig. 29 shows the time series plot for CPSC 315.

## VII. FINDINGS AND CHALLENGES

- 1) Finding 1: *Does high participation suggest high grades?*  
 Yes, students with high participation are likely to have higher grades. Based on Research question 3, we know that high participant group of students have a higher average grade than the student group with low participation.
- 2) Finding 2: *Do multiple teaching pedagogies work better than a single pedagogy?*  
 Yes, based on the analysis in Research question 6, fewer students get an 'F' and the average score is more likely to be higher if the course has two teaching pedagogies.
- 3) Finding 3: *Can we compare the student performance based on single pedagogy versus multiple pedagogy?*  
 Yes, incorporating multiple pedagogies reduce the risk of failing the course and increase the average score.
- 4) Finding 4: *Does student happiness and satisfaction reflect their performance?*  
 At first, no obvious relationship is found. For example, CPSC 531's survey has fewer positive comments compared to other courses. The student performance is not worse than student performance in other courses. Course CPSC 315 in Summer 2020 had the best student performance (all students had an 'A' or 'B'). The survey's positive comments are only 28.12%, lower than many other courses. Another finding is there are fewer

negative comments in the final week survey than in the first-week survey which can indicate higher satisfaction in students on finishing these courses.

- 5) Finding 5: *Do students have better performance in online courses than in in-person courses?*

Yes. Students with 'A' grades decreased over time, and students with 'B' or 'C' grades increased over time due to students who failed to get an 'A' received a 'B' or 'C'. The least students got an 'A' and the most student got a 'B' or 'C' in Spring 2022, which is an in-person course. Therefore students seem to perform better in online courses.

- 6) Finding 6: *Do students prefer online courses or in-person courses? Why?*

Students think online courses and in-person courses have their pros and cons. Students find it hard to focus in online courses since there are a lot of distractions. On the other hand, students like online courses because they can have course recordings and it's more flexible.

*Research question 7: What are the challenges involved in using the aforementioned techniques in teaching?*

*Answer:* The main challenges in incorporating the Jigsaw technique and the inquiry-based techniques are:

- 1) Formulating the surveys questions involve time and a few iterations. However changing questions for some of the classes would make the survey analysis inconsistent. Hence to handle the changes and manage the inconsistencies we frame the questions such that the meaning is not altered drastically yet integrate the necessary change.
- 2) Collecting surveys twice a semester from students depends on the student's willingness to participate in the survey. So far, we got more than 90% response for each section, however there is no guarantee that the response rate will remain the same in the future.
- 3) The data collection is a slow process and it takes time and resources. In the future, we would aim for a collaboration with other faculty who are interested in implementing the teaching pedagogies used in this work or other teaching strategies that they would like to incorporate in their teaching. However, given that other faculty may choose a different teaching technique, it may involve further analysis and resources to investigate the effectiveness of all the teaching techniques. To address this issue, we would like to use machine learning to include the teaching technique, instructor as additional features where we can use a variety of teaching pedagogies.

## VIII. CONCLUSION AND FUTURE WORK

The study reveals that by using teaching pedagogies, students want to interact more with their peers and contribute to each other's learning. The students also raise interesting questions that further deepens the understanding of the topic. They also learn to be more acceptable and respectful towards a contrast opinion presented by their peer(s). The question and answer session after the student presentations received active

TABLE VIII  
STUDENT AVERAGE SCORE

Course	Spring 2020	Summer 2020	Fall 2020	Spring 2021	Fall 2021	Spring 2022
CPSC 313	-	-	-	79.56	-	-
CPSC 315	-	93.38	-	-	82.06	78.14
CPSC 332	82.66	-	-	-	74.38	-
CPSC 483	-	-	-	-	-	80.15
CPSC 531	-	-	83.41	-	-	-
CPSC 597	-	-	74.34	-	-	-

participation from their peers and were highly rated by the students in the surveys. Based on the analysis of students' performance and students' surveys, the course with both the Jigsaw technique and inquiry-based learning can lower the risk of failing the course. Also, the student's performance in online courses is better than in in-person courses. And participation can also affect students' performance. On average, students who actively participate in the course have a higher score.

In the future we would like to expand and include other instructors with the Computer Science department, College of Engineering and Computer Science and later reach out to other departments within the University and outside. We would also like to include data from classes that do not implement cooperative learning and collaborative learning to contrast the effectiveness of these teaching pedagogies while comparing them with the traditional teaching styles.

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