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A Comprehensive Study on The Effectiveness of Active Learning Techniques in Remote Learning Classes

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Abstract

Since COVID-19 was declared as a pandemic in March 2020, the world as we know it has changed. Most academic institutions in the U.S. have switch to fully online or remote classes. This abrupt change has left both the instructors and students with a lot of challenges to face, with the most concerning of them all is being able to fully focus and actively engage in a remote classroom. One of the ways to help students in a remote online classroom is incorporating active learning techniques. This paper will study the effect of using different active learning techniques, in a remote classroom, on improving the students' level of engagement and ability to focus. The study will be divided in two different aspects, first: the authors will analyze the students' perspectives on the use of active learning techniques, through a survey-based study. Second, we will investigate the students' scores before and after using active learning techniques in different course modules. The study took place over Summer 2020 and 2021 and covered three different courses, with more than 80 students participating in it. The results obtained are very promising and the authors will be recommending the best active learning techniques to be used in an online environment.

1. Introduction

During the 2020/2021 academic year, most of the U.S. universities switched fully to remote learning, because of the world's battle against COVID-19 [1]. The sudden switch in the remote classrooms has left both the instructors [2] and the students [3, 4] with a lot of challenges to face. It was not until Fall 2021, and with most of the faculty and student body being vaccinated, when life started to get back to normal and most universities opened their doors back to in-person classrooms. Still, some universities had to partially switch back to remote classrooms when their on-campus COVID-19 cases spiked. It seems like the remote classroom is not vanishing anytime soon [5], and it's essential to make sure that students get the best experience that a remote learning classroom can offer.

Previous research, that was conducted during the first year of the pandemic, showed that one of the main points that students suffer from in an online environment is maintaining their engagement levels [3, 4]. It's hard for them to keep high levels of focus and engagement when they are just behind a computer screen and not physically present with their professor and classmates. Another problem that badly affects them is all the sources of distraction that they are surrounded with, wherever students attend their remote classrooms from. One of the methods to help in maintaining the students' engagement in a classroom is using active learning techniques [6].

Active learning is described as any act or work done by the students in a classroom that is extended beyond listening passively to the instructor and taking notes [7]. It can take many forms and can be as simple as answering questions during the lecture or as more involving as asking the students to reflect on the presented material and their learning experience [8]. The effectiveness of active learning had been extensively investigated in the literature and was proven to increase students'

learning, engagement, and interest in the topics discussed [8-11]. Despite these facts, the traditional lecture-based learning is still the dominant approach in STEM fields [12, 13]. According to the study presented in [14], only 30% of faculty in Electrical and Computer Engineering (ECE) departments incorporated the widely available think-pair-share active learning technique. Moreover, 54% of them had discarded using that method later, because of their doubts in the method's effectiveness in ECE classes and how would the students perceive it [14]. In contrast, recent work shows that the use of active learning techniques is growing faster among young ECE faculty and students, and especially during the pandemic and remote learning [2, 15]. The usage of active learning techniques was essential in order to maintain students' level of engagement and focus in the isolated learning environment that was forced on all of us [15]. Unlike traditional in-person classroom, the effectiveness of active learning techniques in an online remote classroom has not been investigated enough. The authors feel that is an urgent topic that needs to be addressed, especially nowadays, when remote learning classes are becoming more popular because of the pandemic.

In this work, we present a comprehensive study on the effectiveness of different active learning practices that can be applied in remote classrooms. The main contributions of this work are:

1) providing methods of effectively applying different active learning techniques in a remote classroom, using different Zoom® features,
2) presenting quantitative results of the effectiveness of using these methods, by analyzing the students' performance in exams and assignments before and after using active learning techniques in the remote classroom,
3) presenting a qualitative study based on the analysis of students' surveys and their opinions about these active learning methods, and finally
4) recommending the best active learning practices that can be effectively applied in a remote classroom.

The rest of the paper is organized as follows: section 2 illustrates the active learning techniques used, along with details about the courses under investigation. The survey questions and method of data collection will be discussed in this section too. Section 3 analyzes the quantitative and qualitative results obtained and recommends the best practices accordingly. Finally, section 4 concludes the paper.

2. Assessment of Different Active Learning Techniques in Remote Classrooms

2.1 Classes Under Investigation

This study considers three different courses offered during the Summer semesters of 2020 and 2021, all of which were delivered remotely in a synchronous fashion, with video recording of the lecture meeting made available to the students. Table 1 summarizes the details of these courses, which were under the ECE Department of the school hosting this study. The term regular-book course refers to traditional single textbook course that has no lab components. For the "Data Structure and Algorithms", the students learned about different data structures used in C++ programming, such as linked-lists, stacks, queues, trees, and different sorting and graph algorithms. The assignments considered were ten In-Class Exercises (ICEs), and nine homework.

Students used software development environment of their own choice to develop the code needed for the assignments.

Table 1. Summary of the courses under investigation

Course	Type	Year	Credits	Assessed Over
Data Structure and Algorithms	Regular-Book course	Sophomore	3	Summer 2020 and 2021
Microelectronics Circuits	Lab-based course	Sophomore	3 + 1 lab	First and second halves of 2021
Feedback Control	Lab-based course	Junior	3 + 1 lab	First and second halves of 2021

The "Microelectronics Circuits" covered different electronic circuits analysis, including theory and applications of MOSFET and BJT transistors, and design and analysis of op-amps, amplifiers, and filter circuits. While these topics were covered during the lecture time of the course, students used the lab-time to implement and analyze the circuits presented during the lecture using off-the-shelf discrete components. Since the course was fully remote, the instructors put together lab kits and mailed them to students' homes to allow for the remote labs to take place. For the "Feedback Control" course, students learned about the control theory during the lectures time. Topics like control system analysis and characteristics, controller types and design, and mathematical definitions and theories were discussed during this time. When it comes to lab time for this course, students had the chance of applying the theories they have learnt about by simulating different control systems and seeing their behavior. The instructor used MATLAB® Simulink® as the tool for implementing these labs.

It's worth mentioning here that, for the regular-book course, the effectiveness of the active learning techniques was measured by comparing results from Summer 2020, where no active learning techniques were applied, and Summer 2021, where these techniques were used. On the other hand, for both lab-based courses, the comparison was between the first half of Summer 2021, where minimal active learning practices were applied, and the second half of the semester, where more involving active learning techniques were used. All the classes were taught through Zoom® meeting rooms.

2.2 Active Learning Techniques Under Investigation

Various active learning techniques were incorporated into the three courses, depending on their nature and number of students enrolled. Without loss of generality, all the activities used can be grouped under two main categories: 1) Student-to-Student (StS) activities; and 2) Instructor-to-Student (ItS) activities. For the regular-book course, the StS activities were applied by randomly assigning students into breakout rooms of two or three, where they would discuss a given problem. Students spend some time interacting together and sharing ideas on how to solve this problem. When returned to the main meeting room, all the students would provide an answer via the poll feature of the Zoom meeting, and students with correct answers would receive bonus points. The ItS activities were very similar, except that the instructor is interacting with the students directly in the main meeting room, by randomly calling upon them and having a discussion on how to solve a certain problem. After couple discussions and useful hints, students are left to solve the problem

and provide an answer, via a poll as well, with bonus points for correct ones. Awarding bonus points for both sets of activities incentivized the students to actively participate.

On the other hand, the two lab-based courses had a slightly different set of activities. During the first half of the semester, the instructors used think-share activities minimally, while the second half of the semester included a more involving think-pair-share techniques, as described in [16]. All the discussion and interactions were held in Zoom breakout rooms, with the students been asked to reflect on their learning experience, using polls and minute-paper activities, during the last five minutes of every lecture.

2.3 Methodology and Survey Structure

Over Summer 2020 and 2021, 125 students were invited to participate across the sophomore and junior years in the ECE department of the school hosting this study. Eight three (~66.4%) of the invited students filled in the surveys. The authors helped in teaching these courses over the period of this study.

Towards the end of each semester, and before the final examination period, students were asked to voluntarily take a Qualtrics-based survey. Human subjects' approval (PRO18060710) was secured for these various forms of assessment. Table 2 shows some of the survey questions that are directly related to the study presented here and the active learning techniques used. It's worth mentioning here that both semesters were fully remote in the school hosting this study. As such, the students were presented with the last question in the survey to generally capture their experience regarding remote classes versus traditional in-person ones.

Table 2. Survey questions

Lecture Delivery		
How would you rate the chosen remote lecturing method?	o Completely satisfied o Somehow satisfied o Neutral	o Somehow unsatisfied o Completely unsatisfied
Why did you give this rating? Please choose all that apply.	□ Multiple choices, removed for conciseness	
Active Learning Techniques in Remote Classrooms		
The instructor asked you to complete activities, discuss items, and in general participate. What is the impact of this instructional style on your learning and development? (Check all that applies)	□ Multiple choices, removed for conciseness	
Overall Satisfaction with Remote Classrooms		
Judging by your overall experience with remote offering of this course during this semester, which of the following statements best describe your experience.	o I prefer remote class to in-person labs o I have found the remote class to be comparable to the in-person classes o I would have preferred an in-person class to remote class o If I went back in time, I would defer my enrollment in this class until in-person classes are resumed	

3. Results and Discussion

3.1. Lecture delivery method

Figure 1 depicts the students' levels of satisfaction from the provided lecture delivery method, which was a fully synchronous method with lecture recording made available after the class meeting. The students' satisfaction with the presented method takes into consideration different factors, including: the method's ability of helping them in achieving the learning objectives and outcomes; its convenience and reliability throughout the semester; and its ability in providing engaging and interactive learning environment. The results show that more than 70% of the students were satisfied with the provided method, about 16% were neutral, and only 12% were "somehow unsatisfied". There were no students at all who were "completely unsatisfied" with this method. The importance of this result is that it makes the original goal of the study presented here, which is the effectiveness of using active learning techniques, fair and unbiased by the students' satisfaction with lecture delivery method itself.

To have more context and in-depth analysis of the reasons for satisfaction and dissatisfaction, we presented question 2 in the survey and Fig. 2 depicts its results. Students were provided with a set of four positive factors and another set of five negative factors. They were allowed to choose all that apply, and the percentages shown in Fig. 2 are the number of students, who chose a certain factor, referenced to the total number of the students who submitted the survey. As can be inferred from Fig. 2, the main reason for students' satisfaction was participation in activities and discussions during the live lecture, with about 58% finding this very useful. Other factors like being in control of this schedule, whether by having later access to video recordings or holding the live lecture meeting during the scheduled lecture time, is another source of satisfaction. On the other hand, the percentages of the set of negative factors were low, with the highest of them being at 28% and was due to internet issues. Only a handful of students (7%) were not satisfied with the activities and discussions during the lecture meeting.

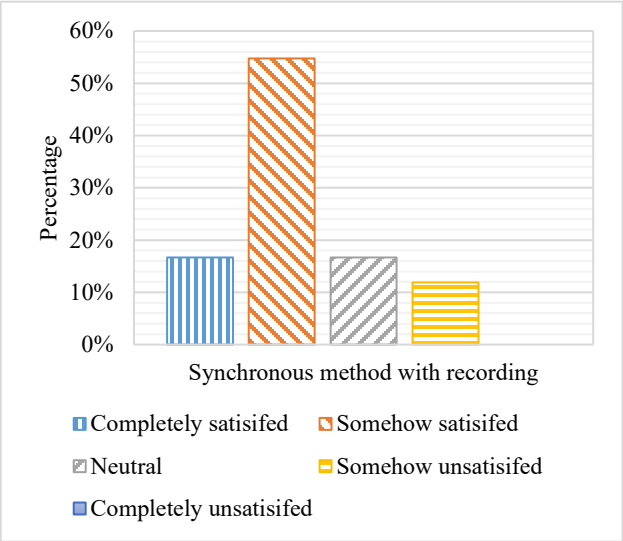

Figure 1: Students' perspective on the lecture delivery method

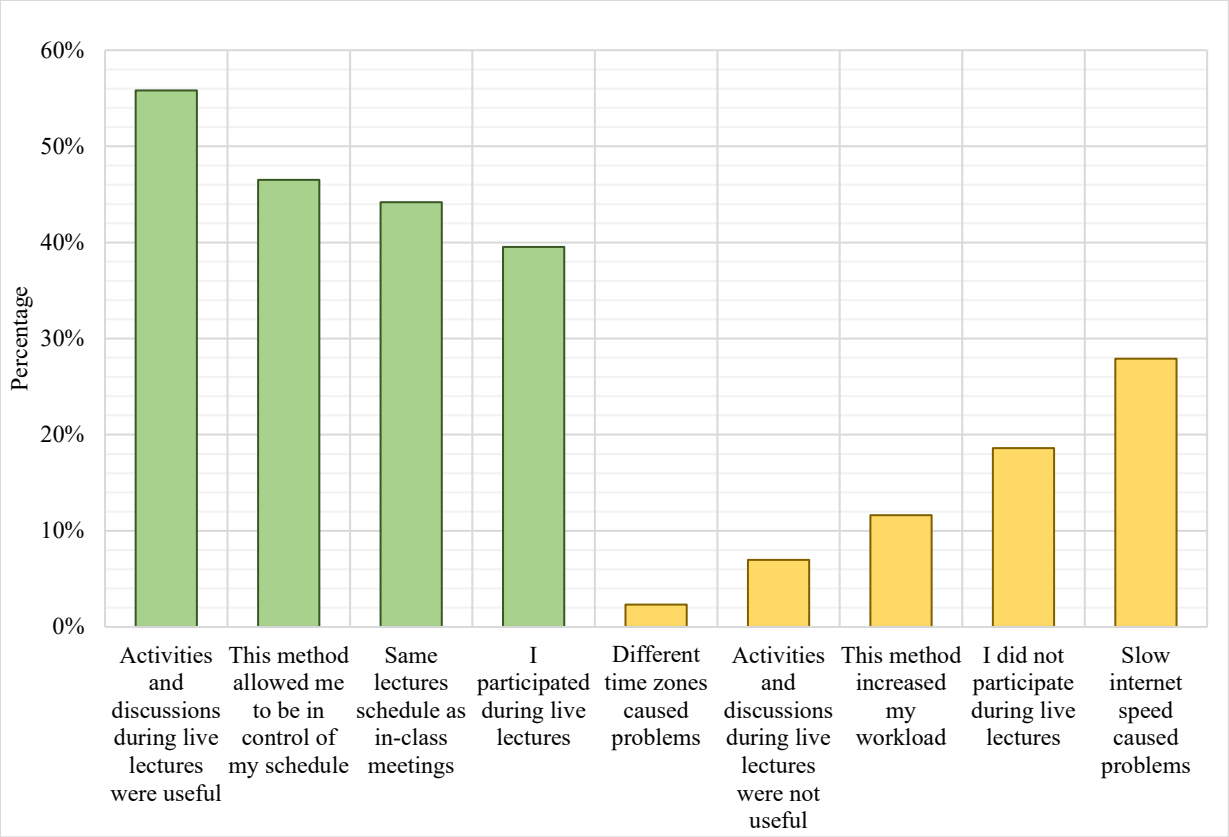

Figure 2: The positive and negative factors correlated with the student satisfaction and dissatisfaction with the lecturing method, respectively.

3.2. Qualitative analysis of the active learning techniques used

The third question in the survey asked the students about their experience in having active learning techniques in a remote classroom, where the students were presented with a set of positive and negative experiences, and they were allowed to choose all that apply. The results of positive (negative) experiences are shown in Fig. 3 (Fig. 4), respectively, with the percentages representing the students who chose a specific experience, referenced to the total number of students surveyed.

The results obtained are very promising with about 62.8% (4.65%) of the students had an overall positive (negative) experience with the active learning techniques used, which leaves about 32.5% of the students with a neutral experience. Students appreciated the active learning techniques in a remote classroom because it helped clarifying and reinforcing difficult materials; kept the students engaged; allowed them to efficiently communicate with their colleagues and instructors; and promoted liveliness and attentiveness. On the other hand, the few students who had a negative experience with these techniques indicated that the main reason behind it was not participating in it because of social fear. Only few students didn't participate because they didn't like to or due to some logistic issues (internet problems, being in a room with noise in the background so they can't speak freely, etc...)

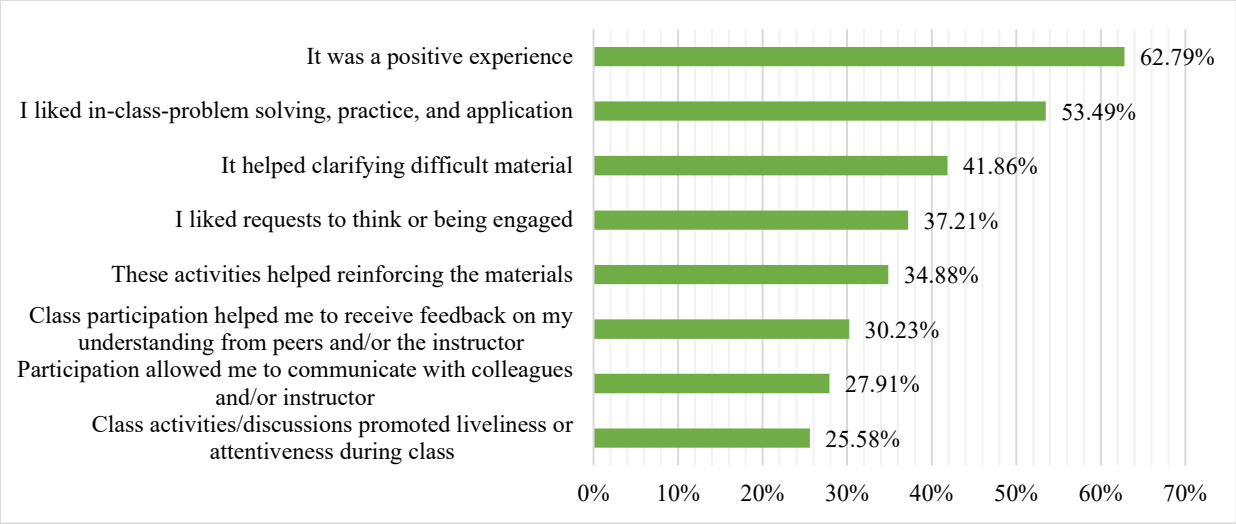

Figure 3: Set of positive experiences associates with active learning techniques.

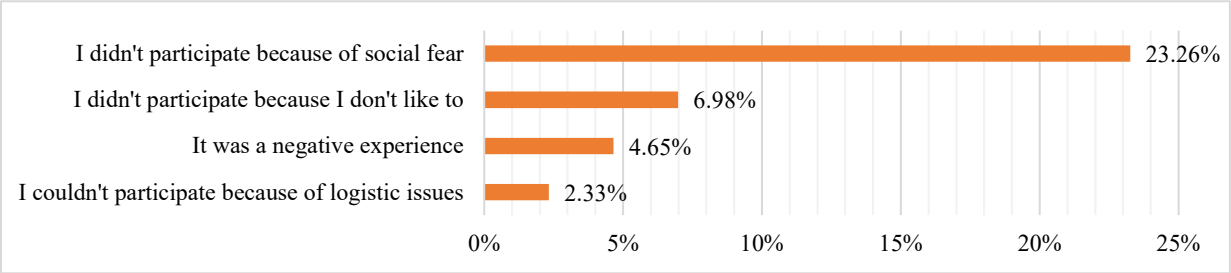

Figure 4: Set of negative experiences associates with active learning techniques.

Judging by the results of this question, it's very clear that the majority of the students enjoyed and benefited from incorporating different active learning techniques in remote classrooms, regardless of the nature of the course itself. This result is in agreement with the recommendations in [6], which suggest changing the teaching method every 15 minutes to maintain the students' focus. Therefore, the authors strongly recommend that active learning techniques be used, especially in a remote classroom, to enrich the overall learning experience.

3.3. Quantitative Analysis of The Students' Performance

To the study the effect of using active learning techniques on the students' performance, the authors compared students' scores of different class assignments for the three courses investigated. In addition, the authors of this paper were the sole instructors of the three courses, and, although the courses were different in nature, we agreed on the same grading scheme and general rubric items for the assignments to be able to combine and compare the scores.

For the two lab-based courses, we compared quizzes, lab experiments, and exams scores for modules with low active learning techniques, (i.e., first half of the semester), and modules with higher active learning techniques (i.e., second half of the semester). The scores from both courses were combined to increase the sample size. Since it is the same population of students, scores from the two semester halves were compared using t-test paired two samples for means, which is often used in case of paired samples to determine the significance of the difference between the two

compared values. The Glass' Delta effect sizes was used to measure the practical significance of the differences, with values below 0.50 considered small and values of 0.80 or above large [17]. The results are shown in Table 3, with sample size of (n = 42).

Table 3: Scores comparison for the two lab-based courses, pre and pose active learning.

	Mean Score (100)		***p***	**Effect Size**
	Few class activities (*n*=42)	More class activities (*n*=42)	Paired Samples *t*-test	Glass' Delta
Quizzes	55.77	59.23	0.26	0.12
Lab Experiments	95.10	95.93	0.23	0.13
Exams	72.29	76.08	**0.05**	0.31

The results show that, on average, the students performed better during the second half of the semester when more active learning techniques were used, even though the modules and topics discussed in the second half were relatively harder. While the exams were not the same, they had the same difficulty level and same duration. The exam scores were used to capture the long-term effect of active learning in retaining information and problem-solving skills. The improvement in the exams' scores is statistically significant, as suggested by the p-value, and shows the importance of active learning in retaining information on the long-term.

For the regular-book course, homework and ICEs were compared between Summer 2020 (no active learning) and Summer 2021 (with active learning). We didn't not include the exam scores for this class because there was a significant difference between the exams offered for both classes. Since scores are compared between two independent groups of students, we used single-factor ANOVA test to compare the scores [18]. Forty-two (34) students were enrolled during Summer 2020 (2021) and Table 4 summarizes the results. An alpha value of 0.05 is used to obtain the results, which is a typical choice for these kinds of comparisons [18]. The improvement in the mean of the homework scores between the two semesters is large and significant (according to the p-value), which can be related to the use of active learning techniques used. Since homework were assigned on a weekly basis, the different techniques used helped the students retain the information longer in their short-term memory and was directly reflected on the homework scores. In addition, while there is a slight improvement in the ICEs scores, it's not of practical significance according to the p-value.

Table 4: Scores comparison for the regular-book course between Summer of 2020 and 2021.

	Mean Score (100)			
	Summer 2020 (*n*=42)	Summer 2021 (*n*=34)	F (ANOVA test)	*p-value*
In-Class Exercises	85.8	87.65	0.33	0.57
Homework	88.36	93.31	8.5	4.7E-3

3.4. Remote versus Traditional in-person Classrooms

Since all the courses under this study were fully remote classes, it made sense to ask the students the last question in the survey presented in Table 1. At the time of conducting this survey, students at the school hosting this study would have experienced four fully remote semesters and the authors wanted to capture their honest and fair perspective about taking remote classes for regular-book and lab-based courses. Figure 5 depicts this comparison between the four choices presented. Half of the students found that remote classrooms are at least comparable to in-person classrooms, while 42.5% preferred in-person over remote classrooms. Only 7.5% had a really bad experience, that they would have preferred to defer their enrollment until in-person classrooms are back. While these results coincides with previously published results for regular-book courses [4, 19], it is a huge improvement, in terms of students favoring remote classes, from previously published results for lab-based courses [20, 21].

The authors revert this very significant improving to the fact of using active learning techniques in remote classrooms, which helped in bridging the gap between remote and in-person classrooms.

4. Conclusion and Future Work

In this work, the authors presented a detailed study about the effectiveness of using active learning techniques in remote classrooms. The study covered two lab-based courses and one regular-book course, offered during Summer 2020 and 2021. Eighty-three students were surveyed to capture their perspectives on using active learning techniques and its effectiveness. Based on the results obtained, students liked having different active learning techniques in a remote classroom, as it helped them maintain their levels of engagement and focusing in an online setting. This is not only reflected in students' responses in the survey, but also in comparing their different course assignment scores before and after using active learning techniques. As a result, the percentage of students who are at least neutral with remote classes, when compared with traditional in-person classes, has increased when compared to the previously published results, that didn't involve active learning techniques. For future work, the authors plan to expand on this study and explore more innovative ways of using active learning techniques, to improve the quality of learning offered in remote classroom.

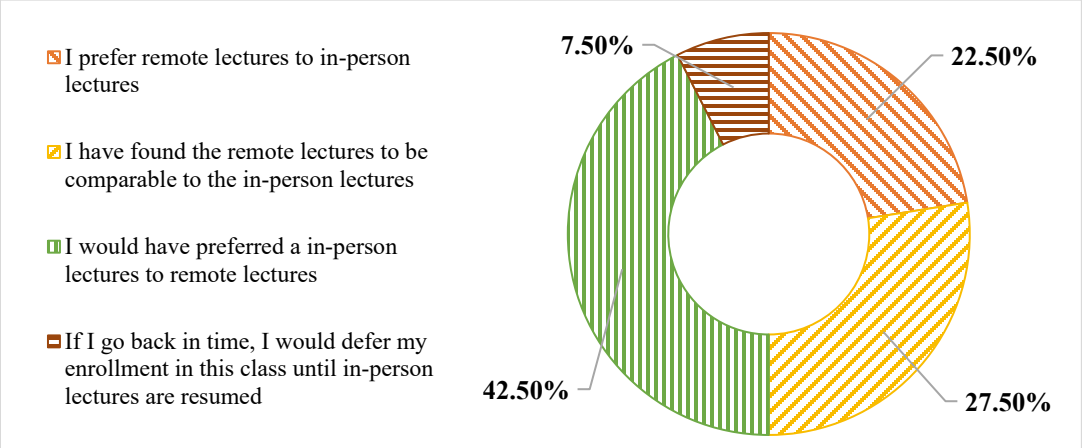

Figure 5: Comparison between remote and in-person learning experience for summer 2021

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