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Effects of Online Versus In-Person Course Modalities on Student Participation in Flipped Classrooms in Engineering

Dr. Crystal Han, San Jose State University

Dr. Crystal Han is an assistant professor of Mechanical Engineering at San José State University. She has a Ph.D. in Mechanical Engineering from Stanford University. She teaches courses in the thermal-fluid area and energy engineering. Her research interests consist of microfluidics, biotechnologies, and engineering education. In particular, in the field of engineering education, she is interested in active learning, collaborative learning, experiential learning, and flipped classrooms.

Effects of online versus in-person course modalities on student participation in engineering flipped classrooms

Abstract

In a flipped classroom, students are responsible for acquiring a basic understanding of the topics before classes by watching pre-recorded videos, reading textbooks, or completing assignments, which prepares them for meaningful engagement during in-class activities. Subsequently, the class time is spent on interactive active learning and reinforcement of knowledge, typically through group problem-solving in engineering courses. The success of flipped classrooms highly depends on student participation in pre-class learning activities. The students who do not fully complete the pre-class activities are usually lost and left out during in-class activities, which can consequently result in loss of interest or even failing the course due to adverse cascade effects of unpreparedness. This paper discusses the impact of course modalities on student participation rates in pre-class and in-class activities and its correlation with student performance. An undergraduate fluid mechanics course was delivered in an in-person and online flipped classroom format during 2021 and 2022 as the campus went through the phased re-opening. The student participation in the pre-class activities was measured through video viewer data and the in-class activity participation was tracked by class attendance. The paper reports that the modality of other courses that students were co-enrolled in at the time of taking the flipped classroom affected student participation more than the modality of the flipped classroom itself. Both pre-class and in-class participation rates decreased as the percentage of in-person courses in the department increased. In addition, a correlation was found between the percentage of students who fully watched videos and the percentage of students who received B or higher grades. Lastly, recommendations are made to increase pre-class participation in an in-person flipped classroom.

1. Introduction

In 2020, students and educators went through an unprecedentedly abrupt and challenging transition from face-to-face to online instruction. And one of the hard-learned lessons was that solely changing the mode of class meetings from face-to-face to virtual did not work effectively for engineering education. As shown in recent studies on student perceptions of online learning during the pandemic, students experienced declines in peer-to-peer and student-instructor interactions in fully online courses [1]. Students also reported difficulties in maintaining motivation and getting support, which has negatively impacted their online learning [2].

During this unusual time, the flipped classroom particularly has drawn attention as an effective way to address the challenges associated with fully remote teaching. In a flipped classroom, students first participate in pre-class activities at home where they learn about basic concepts and foundational knowledge via watching pre-recorded videos, reading materials, or homework assignments. And then students strengthen and solidifies their understanding through in-class

learning activities that encompass group problem-solving, discussion, collaborative learning, and active learning [3]. Primary advantages of the flipped classroom pedagogy have been identified as increased flexibility that allows learning at an individual's own pace through pre-recorded videos, a positive classroom atmosphere, and more opportunities for active learning [4], [5]. On the other hand, the pedagogy involves challenges such as inadequate student preparation prior to class, lack of instant feedback for out-of-class assignments, and substantial instructor commitment requirements on producing videos [5]–[7].

Despite the aforementioned challenges, the flipped classroom approach was well-received by students in the pandemic-driven fully online learning environment [8], [9]. A fully remote flipped classroom typically uses pre-recorded videos for pre-class learning and then holds synchronous online classes intended for in-class active learning, often facilitated by screen share, chat, or Zoom breakout rooms. Regardless of the course delivery method, the same pre-class activities, i.e., pre-recorded videos, can be used in both online and in-person flipped courses. Hence, it was observed that the transition from face-to-face to online modality was significantly smoother and well-received by students in flipped classrooms than in traditional lecture-based classes [8], [10]. Also, there has been a growing number of publications around the successful new implementation of fully remote flipped classrooms in engineering during the pandemic. Hew et al. showed that the online flipped classroom approach was as effective as the in-person flipped classroom through comparative analysis [11]. Han's study demonstrated an increased student engagement and learning outcome in an online flipped classroom approach compared to traditional lecture-based teaching [12]. Azmin et al. reported an overwhelming acceptance of the online flipped classroom format by engineering students with only 2.7% completely rejecting it as a preferred online learning mode [9].

During 2021 and 2022, as the world put its best efforts to bring back normalcy in life and in engineering education, many faculty were faced yet another transition from online to in-person instruction. In particular, for those courses flipped during the pandemic, it is important to identify critical elements for successful adaptation to in-person teaching. This paper investigates changes in student participation in flipped classrooms as the university went through the phased re-opening over the course of 2 years. The impact of the course modality change was analyzed for both pre-class and in-class student participation in a Fluid Mechanics course offered as a flipped classroom. The paper also considers the effect of substantial shifts in the modality of other courses in which students were concurrently enrolled along with the flipped classroom. Student preparation prior to classes is the critical element in the success of the flipped classroom. Therefore this paper focuses on identifying the factors that affect pre-class participation and discuss the best practices for promoting higher student participation in flipped classrooms.

2. Methods

2a. Course information

The course used in this study was a 3-unit Fluid Mechanics, which is a junior-level requirement in both Mechanical Engineering (ME) and Civil and Environmental Engineering (CEE) at the author's institution. The course was taught in a flipped classroom format in Spring 2021, Fall 2021, and Fall 2022 by the author using the same syllabus, course materials, assignments, and grade weighting, which is detailed in Table 1. In this course, students were expected to watch 2-5 videos and then submit their homework assignments prior to weekly class meetings. The videos were 27 min long on average, with a total run time of fewer than 2 hours per week. Videos were assigned as 'video-embedded quizzes' where students were asked 2-3 simple questions at hidden time marks while watching each video on Canvas LMS. Videos covered the introduction of new concepts, derivation of key equations, and example problems. Videos also served as guidance to pre-class homework assignments, which consisted of problems highly similar to the example problems covered in the assigned videos. In this paper, pre-class activities specifically refer to watching the weekly assigned videos. For in-class activities, students solved problems in worksheet assignments in a group of 3-4 students and submitted their worksheet write-ups as a group and as an individual (50% weight each toward worksheet score). The pre-class and in-class activities ran in the same way described in the author's previous publication [12].

Table 1
Grade weighting used in the flipped Fluid Mechanics course used in the study

Component	Frequency	Weighting
Video-embedded quiz	2-5 videos weekly (a total runtime of 2 hours or less per week)	5%
Homework	One weekly except exam weeks (a total of 11/semester)	8%
Worksheet	One weekly except exam weeks (a total of 11/semester)	8%
Practice problems	3/semester	4%
Quizzes	4/semester	20%
Midterms	2/semester	30%
Final Exam	1/semester	25%

Differences among the three offering semesters are summarized in Table 2. For online offerings (Spring 2021 and Fall 2021), both the pre-class and in-class activities were online. In contrast, when the course was offered in person in Fall 2022, weekly in-class activities were in-person while the pre-class activities were still online. The percentage of in-person classes in the department drastically increased over the three offering semesters; from 10.4% in Spring 2021 to 32.9% in Fall 2021, and then to 82.5% in Fall 2022. This data was obtained by counting all in-person sections of undergraduate mechanical engineering courses divided by the total number of

sections offered by the department, which ranged from 67 to 80. The author taught two identical online sections of Fluid Mechanics each in Spring 2021 and Fall 2021, and one in-person section in Fall 2021.

Table 2

Comparison of course information of Fluid Mechanics for the three offering semesters

Course Information	Spring 2021	Fall 2021	Fall 2022
Number of students	40 and 39 (a total of 79)	41 and 42 (a total of 83)	37
Modality of pre-class activity	Online	Online	Online
Modality of in-class activity	Online	Online	In-person
Percentage of in-person undergraduate ME course sections	10.4%	32.9%	82.5%

2b. Method of assessment

In-class participation was measured via attendance at the weekly class meetings where the group problem-solving sessions took place. Students who were absent in the in-class activity received zero on the group worksheet assignment. The number of students who received zero was counted and averaged over the semester, and then divided by the total number of students in each section to calculate the average percentage of absences throughout the semester. Pre-class participation was analyzed using the video viewer data under the Insight tab on Canvas. The completion rate of each video by individuals was downloaded from 40 assigned video-embedded quizzes each from the three offering semesters. The numbers of students who did not watch, partially watched, and fully watched the videos were counted for each video, and then averaged throughout all videos. The average number of students in each video-completion level was divided by the number of students in each semester to obtain the percentage of students in each category, which was used to generate the pre-class participation distribution. The sum of student percentages in the three groups, namely unwatched, partially watched, and fully watched, always adds up to 100%.

Students who fully watched the video were defined as those showing a video completion rate of higher than 90% because skipping the title and ending slides can easily decrease a few percentages in the completion rate data. The unwatched group was defined as people who had a completion rate of less than 15% including those who did not start the video-embedded quizzes. The threshold of 15% was determined from the histogram of raw video completion rate data where a cluster of students exhibited a completion percentage in the range of 5 – 15%. These students are suspected to be those who figured out the time mark where the embedded quiz questions appear by asking the previous students or peers to receive the assignment scores without watching the videos. Students who showed the rest of the completion rate were considered viewers who partially watched the videos. Finally, the course letter grades were used

to investigate the relationship between participation level and student performance. The grade distribution was generated by counting students associated with three grade groups: A or B grade, C grade, and DFW grade. For the semesters with two sections, the combined data from both sections were used to represent the semester.

3. Results

Based on the student attendance data, the course modality of a flipped classroom did not affect student participation in in-class learning. As shown in Figure 1, there was a negligible difference in the average percentage of absence between the online offering in Fall 2021 (5.0%) and the in-person offering in Fall 2022 (5.2%). However, the percentage was far lower in Spring 2021 (1.3%) than in Fall 2021. The noticeable difference between the two online-offering semesters can be attributed to the increase in the percentage of in-person teaching in the department starting in Fall 2021. The 10% of in-person courses in Spring 2021 were entirely the sections of a senior-level course, ME 120, experimental method, which juniors were unlikely to register due to the lacking prerequisites. Essentially, it is safe to assume that junior-level students in this study were taking all of their other classes online in Spring 2021. But in Fall 2021, 32.9% of undergraduate courses were offered in-person (with a higher percentage if hybrid courses are included), so students had mixed in-person and online courses in their course schedule. The attendance result shows that concurrently taking other in-person courses while taking an online course can decrease the attendance rate in online courses. Potential reasons for this trend could be the reduced availability of students due to commuting and their tendency on perceiving in-person classes as more important than online courses. In sum, the data suggests that attendance in in-class activity barely depends on the flipped classroom's own modality, but it was largely affected by the modalities of other courses concurrently taken by the student.

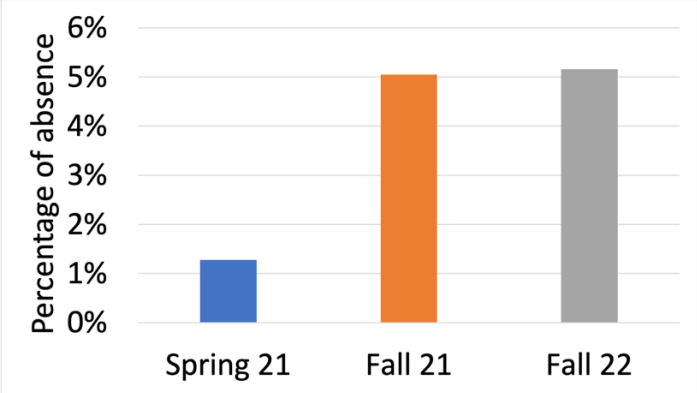

Figure 1. The average percentage of students absent from the weekly class meetings during the three offering semesters.

In Figure 2, the percentage of students who fully watched the video is plotted against the sequential module numbers, which correspond to semester weeks excluding the exam weeks. All offering semesters commonly exhibited the highest percentage in the first module and the lowest percentage in the last module. Also, there was a shared trend of monotonic decrease during the

first three weeks and the last three weeks. The cause of the decrease in participation in this time period may be tied to the decrease in students' time affordability during the first and last weeks of the semester when the academic load from other courses drastically increases. When three semesters were compared, the participation levels were similar at the beginning of the semesters, but they showed significant differences after the first couple of modules. Overall, student participation in pre-class learning decreased over the three offering semesters. Fall 2021 had a lower percentage of participation than Spring 2021 in all modules after module 2. Fall 2022 participation was even lower than that of Fall 2021 in all modules after module 5.

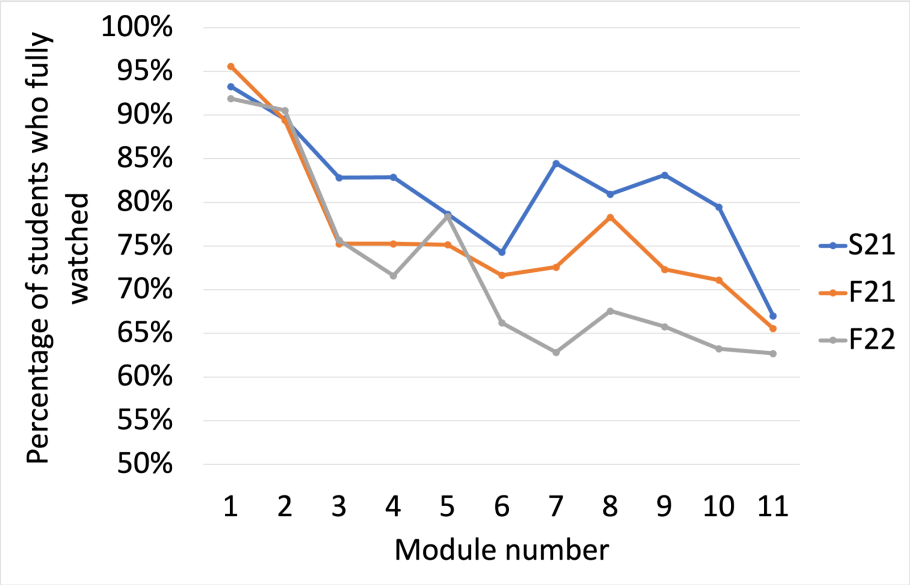

Figure 2. Percentage of students who fully watched the videos over time in Spring 2021, Fall 2021, and Fall 2022. The *x*-axis represents weekly assigned module numbers. There were no modules assigned on the first week of the semester, midterm weeks, and final week.

The effects of course modalities on pre-class participation and its correlation with student performance can be deduced from Figure 3. Figure 3a shows the trends in the distribution of video completion levels over the three semesters. The percentage of the unwatched population did not show a specific trend, but the percentage of students who fully watched videos decreased in Fall 2022 by 9% compared to Spring 2021 and by 4% compared to Fall 2021. The percentage of the population who partially watched the videos also clearly increased in Fall 2022, by 8% and 7% compared to Spring 2021 and Fall 2021 respectively. Previously published papers suggest students tend to watch example-related videos more than theory-heavy parts [13] and have a tendency to skip the parts that are deemed less important [7]. It's likely that the population who partially watched the videos followed a similar pattern.

Results in this paper reveal a higher student resistance to completing online pre-class activities in the in-person offering (Fall 2022) of flipped classrooms compared to its online offering (Fall 2021 and Spring 2021). In addition, considering that the pre-class participation rate already

started decreasing in Fall 2021's online offering, the drop in pre-class participation in the in-person flipped classroom in Fall 2022 was not solely due to switching its modality from online to in-person but was also affected by the significantly more prevalent other in-person classes that students were concurrently enrolled in.

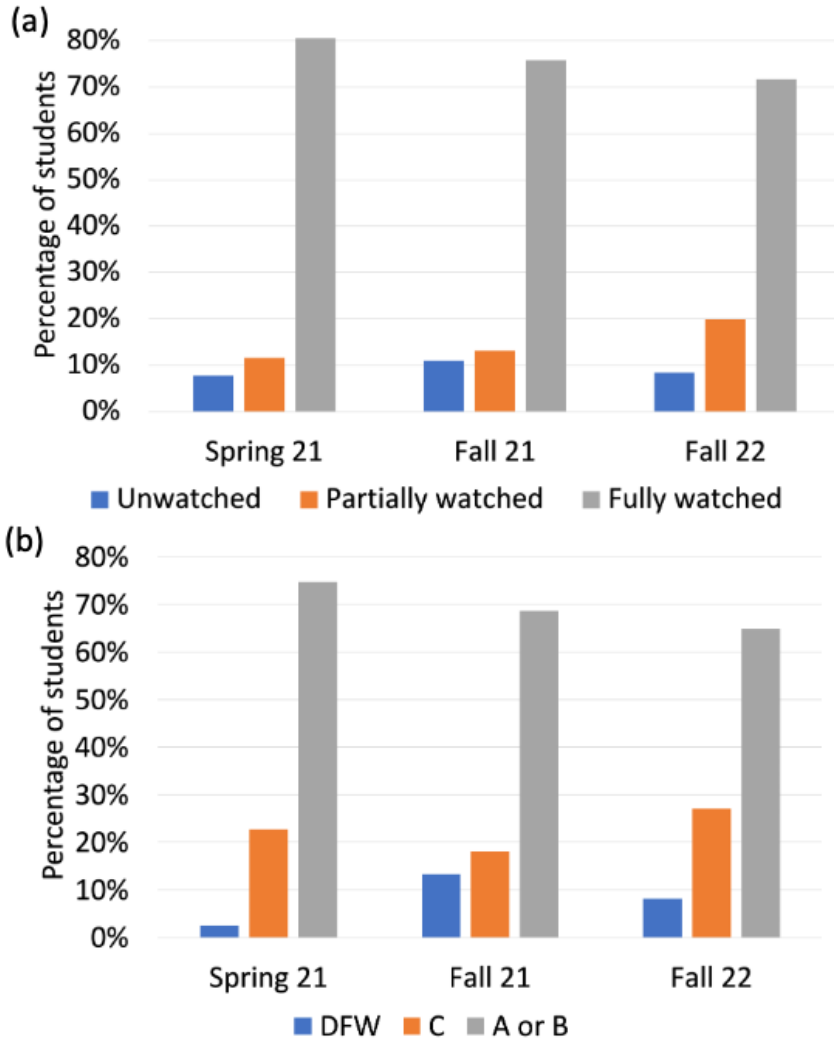

Figure 3. (a) Distribution of video completion levels for the three offering semesters. (b) Grade distribution change over the three offering semesters.

The grade distribution of each offering semester is presented in Figure 3b. There was no obvious relation between the grade and the video completion level for the grade group C and DFW. However, there was a proportional relation between the percentage of students who received grades A or B and the percentage of students who fully watched the videos. The percentage of those who received A or B dropped by 10% and 4.5% compared to Spring 2021 and Fall 2021 respectively, which was very much correlated to the reduction in the percentage of students who fully watched videos.

4. Discussions and Conclusions

The paper tracked changes in student participation in a Fluid Mechanics course offered in flipped classroom format as the university reopens and transitions from online to in-person course modalities. In Spring 2021, the course was offered as an online flipped classroom and students took other classes fully online as well. In Fall 2021, the flipped course was again offered online, and students took about 30% of other courses in an in-person modality. In Fall 2022, the course was offered as an in-person flipped classroom format, and over 80% of other classes were offered in person. The student participation was analyzed in two categories: pre-class activities through video watch history and in-class activities via attendance in class meetings. The in-class participation was not affected by the modality of the flipped classroom, but attendance in the online flipped classroom decreased by 3.7% when students started taking other classes in person. The pre-class participation dropped by 9% in the in-person flipped classroom (Fall 2022) compared to the online flipped classroom offered when all other classes were online as well (Spring 2021). The results unveil that student participation in flipped classrooms was affected not only by the modality of the flipped classroom itself but also by the modality of other classes in which students were concurrently enrolled. The decrease in participation negatively affected the student outcome; the percentage of students who achieved the letter grade of A or B was decreased by 10% as the pre-class participation decreased by 9%.

Student participation in pre-class and in-class activities is critical for successful flipped classroom-based instruction. And this study found that it was more challenging to motivate students to watch the videos when most classes returned back to in-person modalities compared to when it was the online education era. Therefore, careful reconsideration is recommended in developing pre-class activities when transitioning from online to in-person for a flipped classroom. Boiling down a longer video into shorter clips is proven to help students complete the pre-class video-watching [7]. Converting some contents in the videos into fill-in-blank or lecture note annotation assignments could be another useful strategy for an in-person flipped classroom. Although the results show that the pre-class participation quantitatively decreased in an in-person flipped classroom, the quality of peer-to-peer and student-instructor interaction is generally higher in the in-person modality because students engage more easily in the discussion without technical limitations. With a careful course design, flipped classroom pedagogy can provide very effective in-person instruction and a positive student learning experience.

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