Teaching Dynamics Using a Flipped Classroom Blended Approach

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Abstract

This paper presents the results of a pilot study performed on flipping an undergraduate foundation course in engineering into a blended or mixed-mode format. A blended instructional model integrates face-to-face instruction with online instruction. Enhanced student satisfaction and greater student success rates are some of the key benefits of a blended model over a traditional face-to-face model. The effectiveness of the blended instructional model is evaluated through comparative data analysis across two semesters for the course Engineering Analysis: Dynamics taught using a traditional face-to-face format in the first semester and a redesigned blended format in the subsequent semester. Student performance, student engagement and student satisfaction are the three primary criterion used in evaluating the effectiveness of the blended delivery model. Results of this study are very positive, with, 85% of the students reporting being satisfied with the redesigned course structure and delivery. Overall student performance in major assignments shows improvement in the blended class as compared to the regular class, thus indicating better knowledge retention in the redesigned course. Finally, the redesigned course shows active class engagement as obtained from video analytics data.

1. Introduction

In recent years, education in the STEM field has transitioned from traditional face-to-face instructional models to newer learner-centered approaches. An important aspect in these newer pedagogical models is integration of technological tools with traditional methods. As reported in literature, the positive outcomes of technology-reinforced learning in STEM education include positive attitudes toward content learning, greater retention of direct content and greater transfer to other areas [1]-[4]. “Blended-learning,” “flipped-classroom,” “hybrid-learning,” and “mixed-mode” are some examples of the newer pedagogical models implemented in recent years by educational researchers [5]-[8]. Although each of these pedagogical approaches have multiple definitions and have been implemented in diverse ways by researchers, the overarching theme in all these models is incorporation of online or electronic instruction beyond simple in-class lectures.

This paper focuses on a *blended* (termed as *mixed-mode* at the authors’ institution) instructional model of content delivery. As identified by Graham, a blended learning model generally falls under the following three categories: 1) blending online and face-to-face instruction; 2) blending instructional delivery media or 3) blending instructional methods [9]. Of these, the first definition is the most common one in literature [9]. Research indicates that blended learning is preferred by educators for improved pedagogy, increased access, and increased cost-effectiveness [7], [9], [10]. A growing trend in the approaches used in the implementation of blended learning is the *blended* approach that combines face-to-face and online instruction while reducing in-class lecture time [11]. In this model, online instruction is mediated through lecture videos while lecture time is devoted to additional classroom-based instructional activities [8]. *Blended* approach also encompasses the flipped-classroom pedagogy, an approach that inverts events traditionally occurring inside the classroom to outside of the classroom and vice-versa [12], [13].

In the *blended* approach (Figure 1), delivering learning content through lecture videos fosters active engagement amongst learners which is deficient in a traditional face-to-face environment where students are passive listeners. Supplementing class time with lecture videos has been shown to be beneficial for student learning as lecture videos in general enhance the learning process and strengthen comprehension of course content [14], [15]. The online lectures in the blended approach encourage self-regulated learning to an extent. An additional advantage of the reduced seat time component in the blended approach is the reduction in excessive course load often observed in traditional flipped classroom settings [16]. However, traditional face-to-face instruction still remains the major mode of content delivery in STEM fields. While it is simpler in terms of content delivery, the face-to-face instructional mode becomes challenging with large class sizes, especially in regards to student engagement and retention of student attention, which may result in greater withdrawal and greater failure rates amongst students. Extensive research and meta-data analysis over several years at the University of Central Florida has shown that adopting a blended approach results in greater student success rates and enhanced student satisfaction when compared to face-to-face instruction [11], [17].

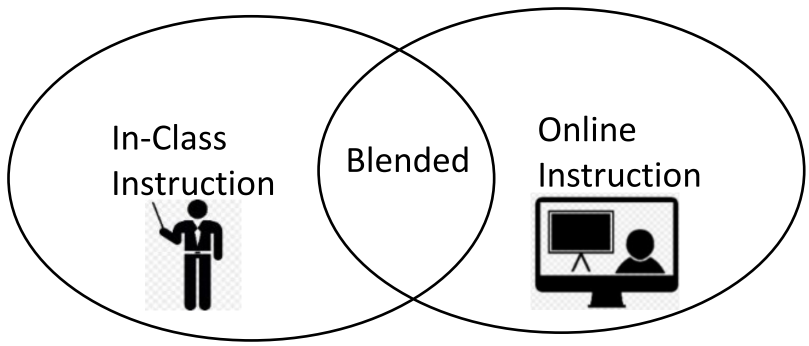


Figure1: Blended Learning Approach

To date, research studies examining the effectiveness of the blended approach have been mostly conducted in the humanities and art disciplines. Implementation and evaluation of the blended teaching model in the STEM fields is scarce. In an effort to address this void, a pilot study was conducted on a foundation course (*EGN3321: Engineering Analysis-Dynamics*) with high enrollment in the undergraduate engineering curriculum that was flipped from traditional to the mixed-mode format. The university uses the term “mixed-mode” to refer to a blended course with required reduced seat-time. Therefore, the two terms are used interchangeably in this study. The broader goal of this study was to evaluate the effectiveness of the mixed-mode delivery method in teaching engineering courses. The research study was a collaborative effort between the course instructor, an instructional designer from the Center for Distributed Learning, and researchers from the university’s Research Initiative for Teaching Effectiveness. The Dynamics course was taught across two successive semesters by the same instructor using a traditional face-to-face model in the first semester and a redesigned, flipped mixed-mode format in the subsequent semester. Comparative data for the two sections was used for this evaluation. The research questions investigated were the following:

- Do students perform better when the course is taught using a flipped, blended model in comparison to a face-to-face model?

- Does student satisfaction change for the course when it is transitioned from face-to-face to a flipped, blended model?
- Are students more engaged in the flipped, blended instructional model?

2. Methods

2a. Course Description

The Engineering Analysis-Dynamics course investigated in this study is a foundation course in Engineering at the University of Central Florida. The course is an interdisciplinary engineering course and is required for all engineering majors. Typically, the students are in their junior year when taking this course and have completed the preceding Engineering Mechanics course, Engineering Analysis-Statics. At the university, the course is offered in a total of four to five sections throughout all three semesters of the year. Typical enrollment in a single section in any semester is between 275 and 300 students. Learning topics in this course include: particle kinematics, particle kinetics, energy and momentum approach, planar rigid-body kinematics, planar rigid-body kinetics and three dimensional rigid body motion. Upon course completion, the students are expected to develop an ability to visualize and model physical configurations of moving machines and structures, an ability to analyze the motions of machines and structures using multiple approaches and to apply course concepts in solving practical engineering problems.

2b. Study Design: Course Transformation

The course transformation was a collaborative effort and took place over an approximate eight month period. In the first semester (Spring 2018), all course content was delivered using the traditional face-to-face model. In this format, the class meetings consisted of 3 weekly, 50 minute sessions. In each 50 minute face-to-face session, the first 20 minutes was spent on explaining concepts, mostly through PowerPoint presentations and demo videos, and the remaining time was spent on problem solving and active learning sessions, facilitated by the instructor's use of document cameras. Pre-class lecture PowerPoints were uploaded the day before and post-class lectures were uploaded after class. Both were made available usingthe learning management system, Instructure Canvas, throughout the semester

In the subsequent semester offering (Spring 2019), the course was taught in a flipped-classroom 50:50 mixed-mode format. The course material delivered remained exactly the same as that of the face-to-face semester, except roughly 50% was delivered online. The students attended 1 weekly 75 minute session in the mixed-mode model, as opposed to 150 minute (three 50 min), weekly sessions in the face-to-face format. The course was structured into weekly modules (Figure 2). For the online content, instructional videos were created by the instructor for weekly topics. Three different types of videos were created by the instructor for the online content: Lightboard videos; voiceover PowerPoints and voiceover PowerPoints with annotations. The length of the instructional videos ranged from roughly 10 to 45 minutes. The videos were made available to the students through YouTube links in each weekly module in Canvas at the beginning of the week. The face-to-face sessions consisted of a 15 minute overview of the weekly concept followed by 60 minutes of problem solving and active learning sessions.

Learning materials for the face-to-face session were made available as pre and post lectures in the weekly modules. In addition to the instructor tailored content in both semesters, students were also encouraged to learn the material through online reading assignments (McGraw-Hill LearnSmart) and online homework assignments administered through the Connect platform associated with the McGraw Hill course textbook. Table 1 summarizes the key elements of the face-to-face course and the blended course.

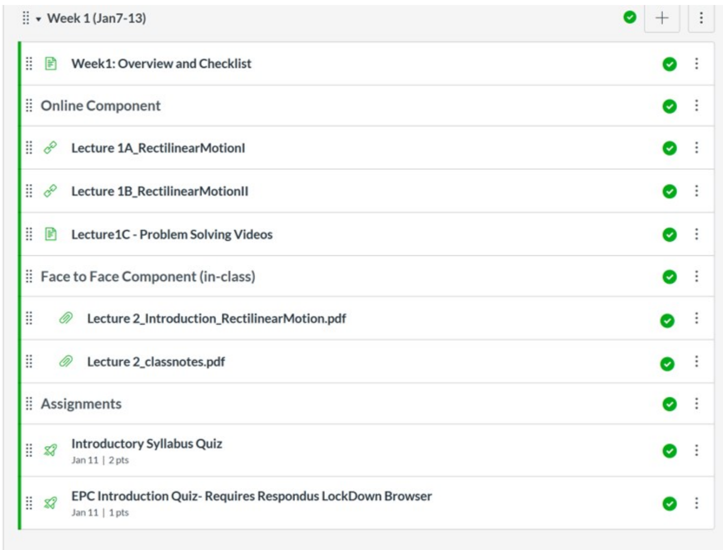


Figure 2: Example structure of a weekly module in the mixed-mode class

Table 1: Comparison of key elements of the face-to-face course versus the mixed-mode course

	Face-to-Face (n= 275)	Mixed-Mode (n= 273)
Structure	Not Modular	Module Based
Pre-class (Weekly)	Text Reading Lecture PowerPoint	Lecture videos (10-40 min),(1-3) Lecture PowerPoint Text Reading
In-class (Weekly)	Lecture (150 min) Class Participation	Lecture (75 min) Class Participation
Post-class (Weekly)	Reading Assignment HW Assignment	Reading Assignment HW Assignment
Assessments	3 Quizzes (10%) 2 Midterms and 1 Final (65%) Homework (20%) (7) LearnSmart (5%) (7)	3 Quizzes (10%) 2 Midterms and 1 Final (65%) Homework (20%) (7) LearnSmart (5%) (7)
Technology	McGraw-Hill Connect Instructure Canvas Lockdown Browser	McGraw-Hill Connect Instructure Canvas Lockdown Browser YouTube Lightboard Voiceover PowerPoint
Classroom	Auditorium	Auditorium

2c. Study Design: Student Satisfaction and Engagement Assessment

Student satisfaction is an important assessment criterion for instructors transitioning a large classroom into a new instructional modality. Both qualitative and quantitative assessment techniques were used to assess student satisfaction and engagement. For qualitative purposes, two forms of online surveys were used by the research team in this study. The first survey was designed by the research team to gauge student satisfaction on the different aspects of the online and face-to-face instruction of the redesigned mixed-mode class. The survey had 25 questions that collected student feedback on instructor created lecture videos, on the mixed-mode class in general, on open-ended questions and on student demographics. The survey was approved through the Institutional Review Board (IRB) at the university and was administered to the students through the experience management software, Qualtrics. The second survey was the standard university-administered student perception of instruction survey, a blanket survey used to assess all types of courses offered by the university and administered automatically each semester through the campus portal for 2 weeks, immediately prior to final exams.

Similarly, student engagement data for the mixed-mode class was collected using a two-fold approach. Quantitative data on student engagement in the online component of the class was collected from YouTube as the majority of the lecture videos were made accessible through YouTube links. As a result, data such as number of video views, student watch time, average click through ratee, and device usage could be easily extracted from YouTube. Qualitatively, student engagement was gauged from student self-reported data on specific questions on frequency of video use and timing of video use embedded in the online survey.

2d. Study Design: Student Performance Assessment

The research team used multiple methods to compare the face-to-face course with the blended course to investigate the research questions. To compare student performance in both courses, different course assessment components were used. Both courses were assessed through a diverse set of assignments that included online reading, online HW, proctored online quizzes, proctored online exams and class participation assignments. These assessments were kept the same across both semesters of face-to-face instruction and blended instruction. This was to ensure that the face-to-face course served as the control group against which the blended course was compared. The online HW, proctored online quizzes and proctored online exams accounted for 20%, 10% and 65% of the course grade, respectively. The online quizzes and online exams were administered through a proctored testing facility, the Evaluation and Proficiency Testing Center (EPC), maintained by the College of Engineering and Computer Science at the university. In addition to student performance, student withdrawal rates and student failure rates were compared across both semesters using data from the Institutional Knowledge Management (IKM) database maintained by the university.

3. Results

3a. Students' Reactions to Course Videos

Students' reactions to the course videos created for the blended course were collected from specific questions embedded in the survey. Students were asked their perceptions regarding the effectiveness of the videos in improving topic comprehension and problem-solving, as well as their perceptions regarding the appropriate video length and pace. Responses were measured using a 5-point Likert scale ranging from "Strongly agree" to "Strongly disagree." Table 2 summarizes the quantitative results on students' reactions to course videos based on content comprehension and content quality.

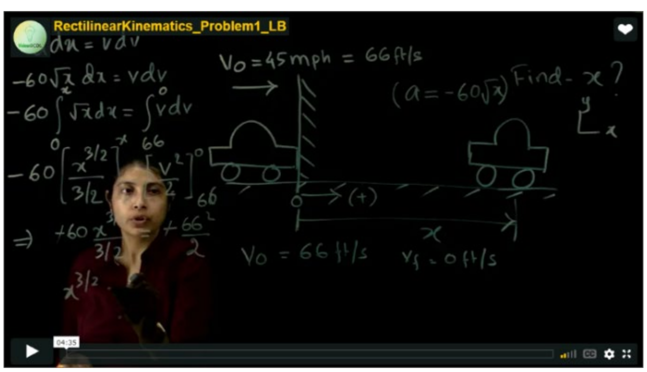
Table 2: Qualitative analysis – students' reactions to course videos

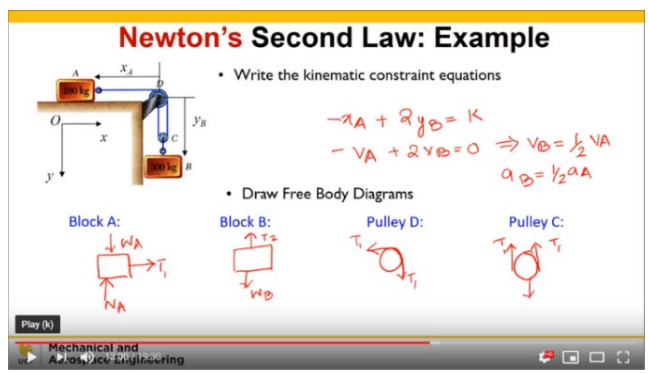
Questions	Did Not Watch	Neutral	Disagree to Strongly Disagree	Agree to Strongly Agree
Content Comprehension				
The videos improved my understanding of course topics.	3%	12%	2%	83%
The videos helped with the key concepts.	3%	8%	4%	85%
The videos helped with the problem solving process.	3%	8%	3%	86%
The videos helped in breakdown aided learning.	3%	8%	3%	86%
The handwritten annotations and equations in the videos helped with learning.	4%	4%	1%	91%
Content Quality				
The figures and animations used in the videos helped me with learning.	3%	15%	4%	78%
The pace of the videos were appropriate for learning.	3%	11%	6%	80%
The videos were of adequate length.	3%	15%	6%	77%
The design and presentation style of the videos were appealing.	3%	17%	5%	74%

As observed in Table 2, student reactions to course videos were very positive in both aspects of content comprehension and content quality. The majority of students (83% to 86%) strongly agreed or agreed that the videos helped them in understanding course content. It is important to note that a large proportion of the students (91%) agreed that handwritten annotations and equations used for explanation of concepts and problems in the videos were beneficial in learning. Additionally, most students (86%) felt the breakdown of topics in the lecture videos were beneficial.

In terms of the quality of the video content, student satisfaction scored slightly lower than the comprehension aspect, but was still high. Student satisfaction remained in between 74% and 80% in areas pertaining to video pace, video length, presentation style and adequate use of figures and animations. Considering this was the first attempt in flipping the class through video lectures, the results were positive. Student feedback will be used to help improve the video quality for future blended learning course sections.

As mentioned in Section 2b, the instructor used three types of videos to deliver the instructional content; Lightboard videos, voiceover PowerPoints and PowerPoints with annotations. Lightboard is one of the newer technologies used in creating videos. Here the instructor faces the camera and writes on a glass board lit by LEDs and the instructor's writing is flipped and projected onto the camera. In the voiceover PowerPoint videos, a PowerPoint presentation of the entire lecture was created that included concepts and problem solving and the instructor's audio explanation of the lecture was embedded in the corresponding slides. In the PowerPoint with annotation videos, the instructor used a tablet and screen casting software (Camtasia) to write directly on the PowerPoints while audio and the screen annotations were recorded and captured. Figure 3 shows examples of each of the created video types.





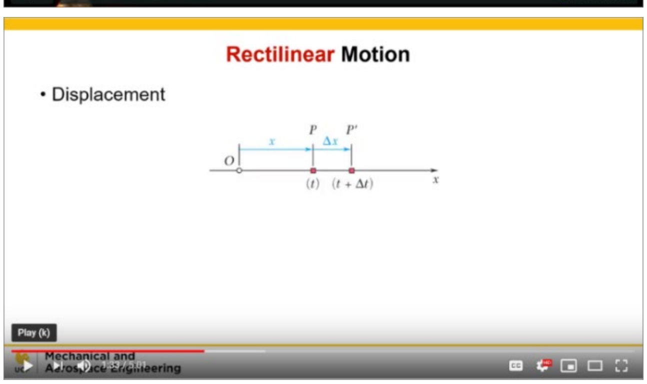


Figure 3: Examples of the different video types created by the instructor for the online content of the mixed-mode class, (a) Lightboard video, (b) Voiceover PowerPoint and (c) Voiceover PowerPoint with annotations

The students were asked about the usefulness of each of the above video type in helping them to learn course content. Figure 4 shows the survey responses of the students. The majority of students (77% to 78%) found the Lightboard videos and the annotated PowerPoint videos to be more useful for learning in comparison to the voiceover PowerPoint videos. In comparison, 57% of the students found the voiceover PowerPoint videos to be useful. The concepts taught in Dynamics are geared to develop object visualization skills, problem formulation skills and application of math, science and engineering skills in students (according to Accreditation Board for Engineering and Technology regulations). In both Lightboard and the annotated PowerPoint videos, the above aspects are facilitated by the instructor's interaction with the students through written explanations of concepts and problem-solving. This is an essential component in teaching engineering courses and hence the videos that have this interaction are more appealing to the students than the narrated videos which do not have explicitly written explanations. Lightboard videos have scored slightly higher in terms of student satisfaction in comparison to annotated PowerPoint videos as the technology is more visually appealing and the presence of the instructor gives a lively aspect to the videos. This is also evident in survey responses elaborated in Table 2, where a large fraction of the students agree that handwritten annotations and equations helped them with learning.

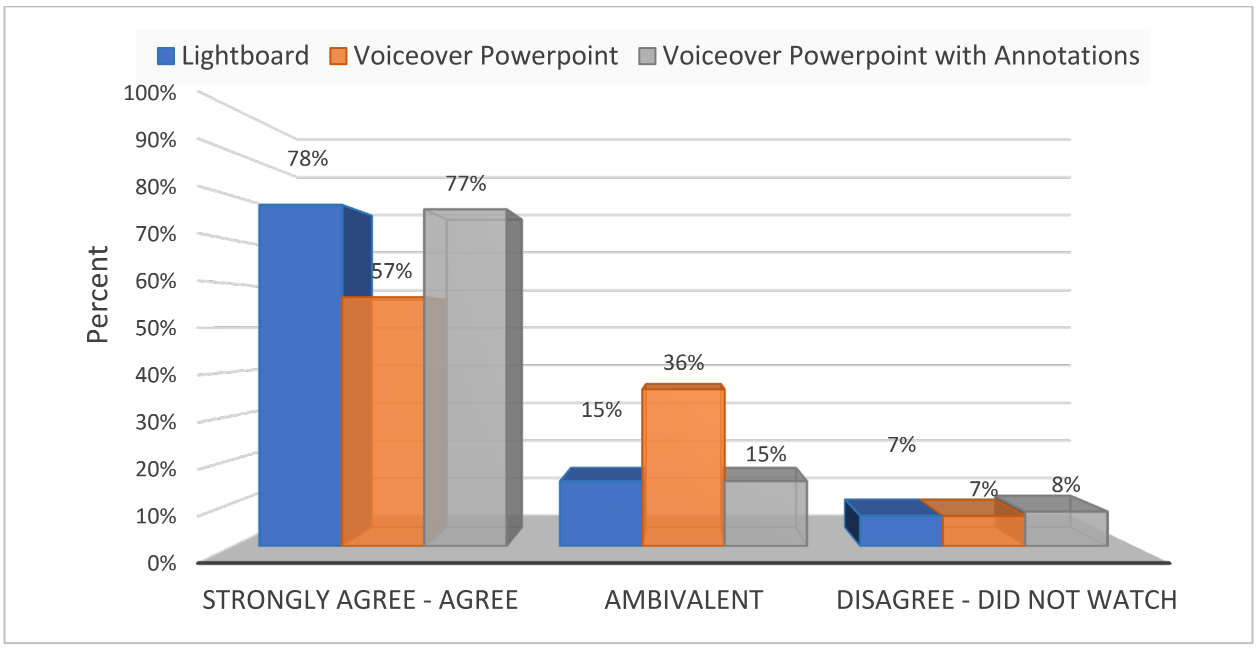


Figure 4: Survey response of students in reporting usefulness of video type in learning.

3b. Student Engagement

Student engagement in the mixed-mode class was assessed both qualitatively and quantitatively. For qualitative analysis, the survey included questions where students were asked how often and when they watched lecture videos. Figure 5 reveals students' self-reported responses to these questions. As seen in Fig. 5(a), 42% students watched the lecture videos only once, 33% of the students reported watching the videos twice, while 20% of students watched the videos 3 or more times. Similarly, regarding timing of video use, as seen in Fig. 5(b) most students reported watching the videos just before exams (36%) or just before class lectures (26%), while some reported watching them when available (14%) or just before homework assignments were due (11%). The survey data sheds light on student behavior in terms of video usage in a large class where most students watch videos once or twice as opposed to multiple times. It is also common for students to watch lecture videos right before major assignment due dates such as exams and homework assignments.

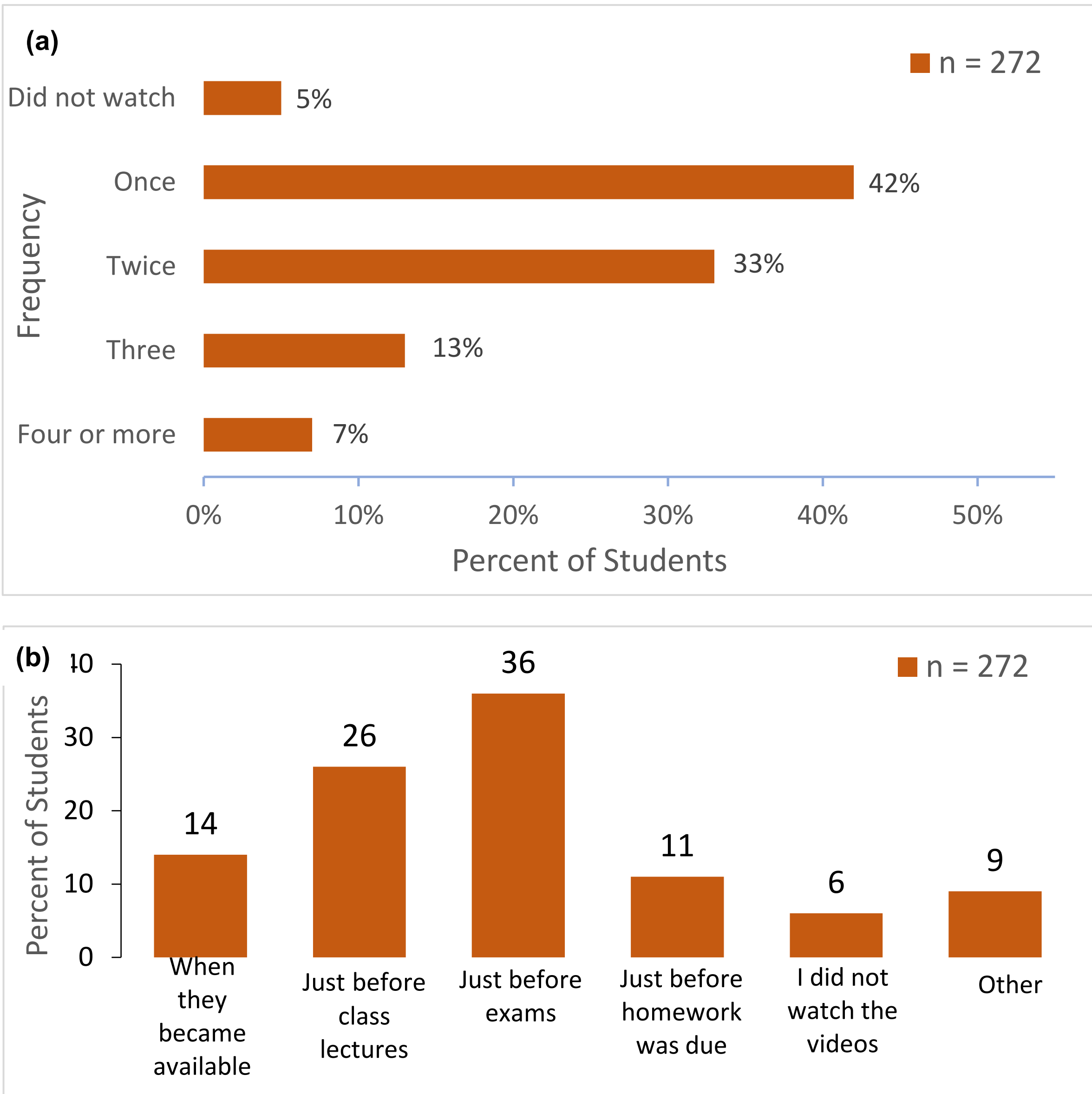


Figure 5: Survey responses of students reporting (a) frequency of video use and (b) timing of video use.

Quantitative data on student engagement was analyzed from YouTube Analytics. Amongst all lecture videos created by the instructor, 25 videos were provided to students through YouTube.

The videos were kept unlisted in YouTube to restrict public distribution. Figure 6 shows the distributed view statistics of these lecture videos. As observed in the figure, 60% of the videos (15 of 25) had between 280 and 450 views, while 28 % videos (7 of 25) had between 451 and 650 views. The remaining videos were viewed 650 or more times. The highest number of video views that was recorded was 780.

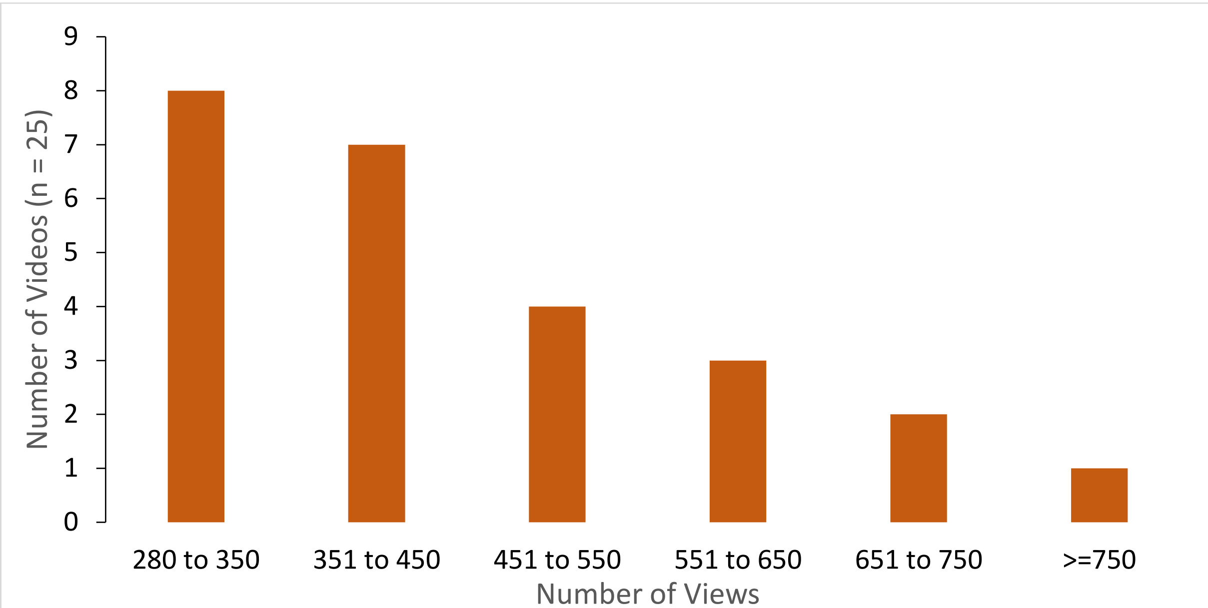


Figure 6: Student video view statistics correlating the number of videos to corresponding number of video views as obtained from YouTube video analytics for the mixed-mode class

Table 3 provides cumulative data on usage of all 25 videos as extracted from the Analytics section of YouTube. Data in the table illustrates the nature of student engagement in this class. The total number of views for all YouTube videos was 11,124. This is twice the number that was calculated from the class size and the number of posted videos, assuming all students in the class watched each video at least once. Students' self-reported data on video use frequency (Fig. 4a) was validated by the total number of views data obtained from YouTube Analytics. Data also shows that the total student watch time for the videos was 1,112 hours with an average view duration of 5.59 minutes. Although the average view duration per video is only about 6 minutes, it should be noted that a common trend amongst students is to increase the video pace to a faster rate while watching.

Similarly from Table 3, the average click through rate recorded for the uploaded videos was 7% which is within the average range of click through rates for YouTube videos. Data was also collected on the types of devices that the students used for watching videos. As evident in Table 3, the majority of the students (79.4%) viewed the videos using a computer, while some (2.3%) viewed using phones and only a small fraction of the students used tablets (2.3%) or TV (0.2%) for viewing.

Table 3: Cumulative analysis for all 25 videos – student engagement in course videos

Video Aspects	Usage Data
Total number of views for 25 videos	11,124
Total view time	1112 hours
Average view duration per view	5.59 min
Average click through rate	7.0%
Device type	Computer – 79.4%; Phone – 18.1%; Tablet – 2.3%; TV – 0.2%

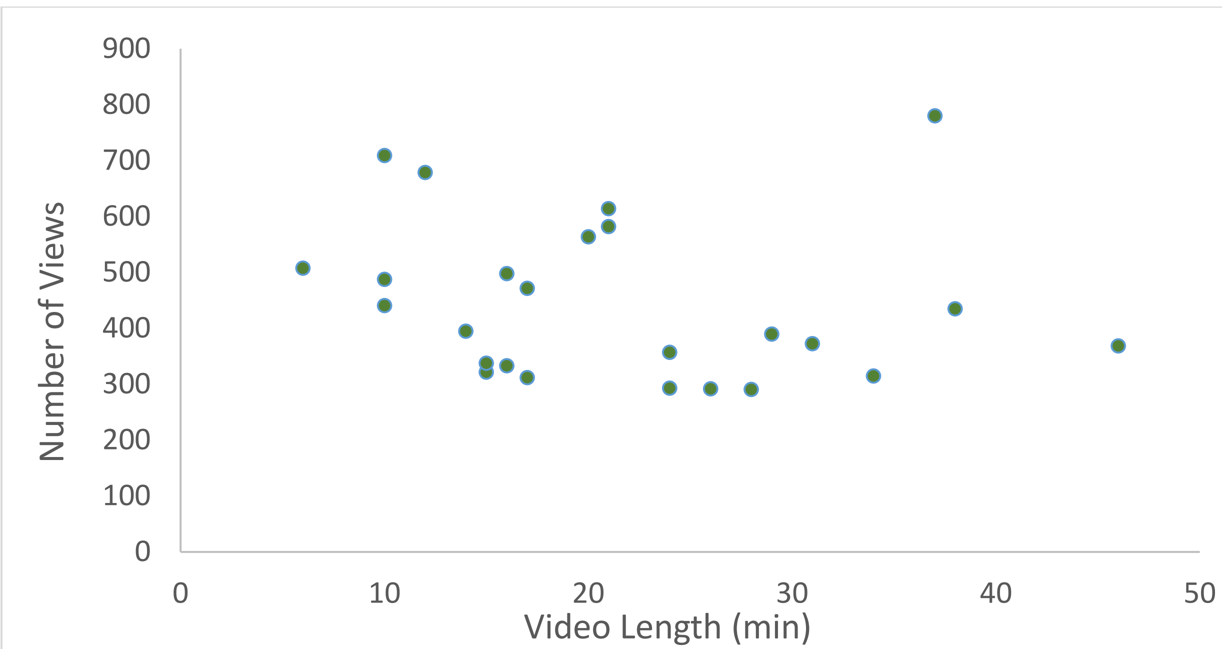


Figure 7: Student video view statistics correlating the number to views to the length of videos obtained from YouTube video analytics for the mixed-mode class

Pedagogical research on video-based student learning suggests that shorter videos lead to increased student engagement as documented through number of video views [15], [18]. In the mixed-mode class, to study the effect of video length on video viewing frequency, data on individual videos was extracted from YouTube Analytics. Figure 7 shows the relationship of video length and number of video views. The data in Figure 7 is too scattered to draw a strong correlation between these two variables. The correlation coefficient for a trend line that indicates a linear decrease in views with increase in video length is 0.032 which is very low. Although as evident in Figure 7, the average number of views for videos lasting from 10 to 25 minutes was slightly higher than number of views for videos between 25 and 45 minutes, it should be noted that the number of videos developed in the 10-25 minute range was higher. Interestingly, the highest number of video views was recorded for a video longer than 40 minutes. Additional data on longer length videos would be necessary to validate the literature claims.

3c. Student Satisfaction

As mentioned in the methodology section, student satisfaction for the mixed-mode class was gauged through questions embedded in the IRB-approved survey. Figure 8(a) shows students' self-reported preferences for the mixed-mode format over the regular face-to-face format. Amongst the reasons reported by the students, flexibility and accordance to schedule ranked the highest while instructor and convenience ranked second and technology and other reasons ranked the lowest. The data suggest that making the class partially online as was done in this study, makes it more accessible to the different needs of the student population in a large class.

Students were also asked to comment on the proportion of online content they would prefer for future mixed-mode classes. Figure 8(b) shows the student responses. In the current study, 50% of the course content was flipped from face-to-face to online. Many students (36%) favored the current breakdown of the flipped mixed-mode class. An equivalent number of students (37%) also favored a structure which would have a higher face-to-face content (80% as opposed to 50% face-to-face). A small fraction of the student population (13%) preferred the class be either fully online or fully face-to-face. From the survey data, it is evident that students, in general, appreciate the partial online nature of the class due to the flexibility in learning it provides. However, to determine the right balance of online and face-to-face instruction necessary for learning in engineering courses, further research studies are necessary. A relatively small student population was not supportive of the new class modality due to its associated learning challenges which will be elaborated in later sections.

The pie chart in Figure 9 shows overall student satisfaction for the mixed-mode class. Of all students taking the survey, 85% of the 272 students in the class reported being very satisfied or satisfied with the current structure and delivery of the flipped, mixed-mode class for Dynamics. Only 12% of student remained neutral about the mixed-mode modality while 0% reported being very unsatisfied. The response of the students to the new teaching modality was very positive considering that this was the first attempt at flipping and delivering a complete core course in engineering in the mixed-mode modality.

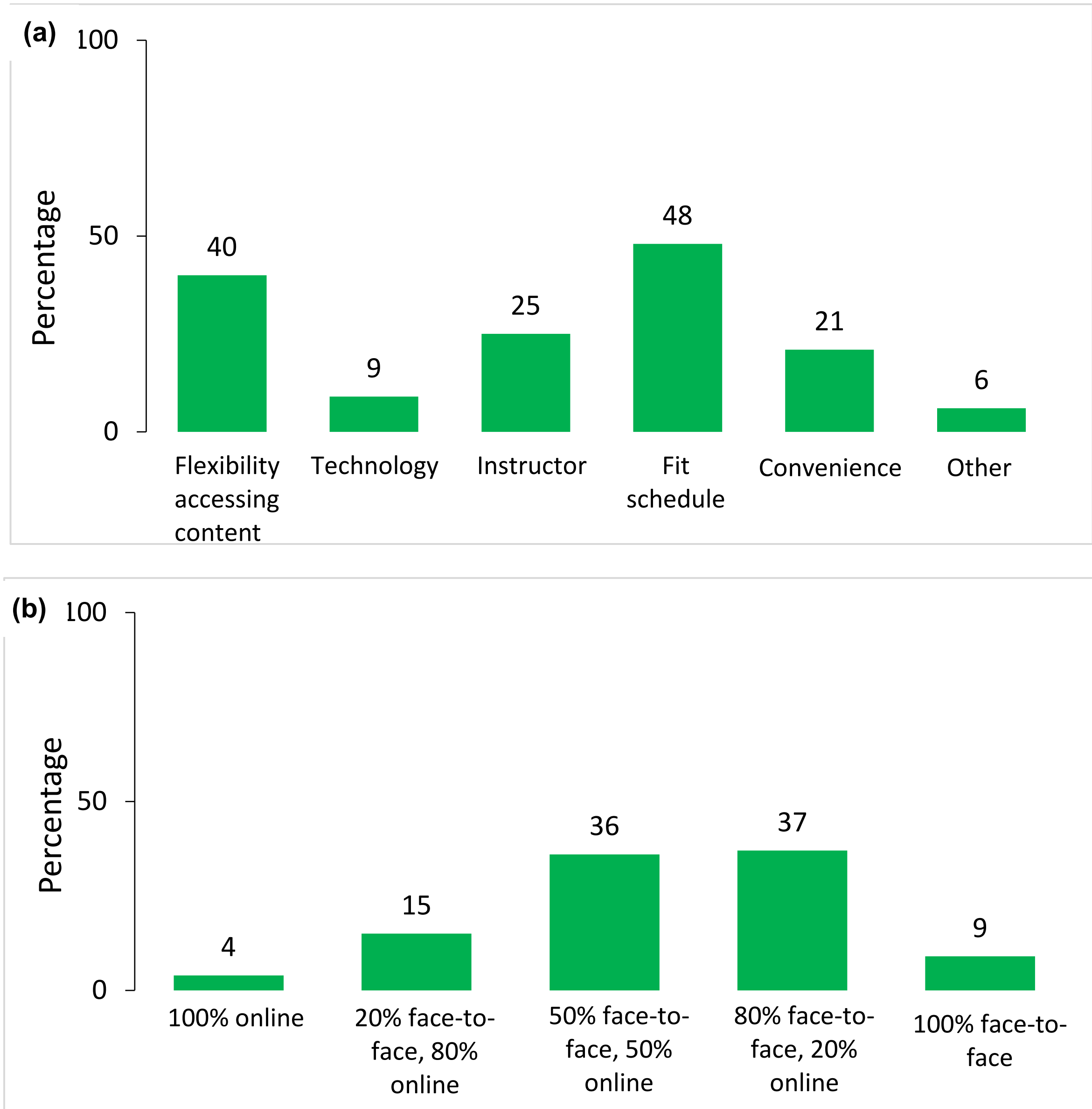


Figure 8: Student survey response on (a) primary reason for choosing a mixed-mode class and (b) future preference on the online portion of the class.

Data from student perception of instruction (SPI), a standardized survey administered by the university each semester was used to compare the mixed-mode class with the regular face-to-face class. The average SPI of the instructor remained the same for the class across both semesters. Small improvements were observed in the effectiveness in communicating ideas, in stimulating course interest and in helping students achieve course objectives in the mixed-mode class as shown in Table 4.

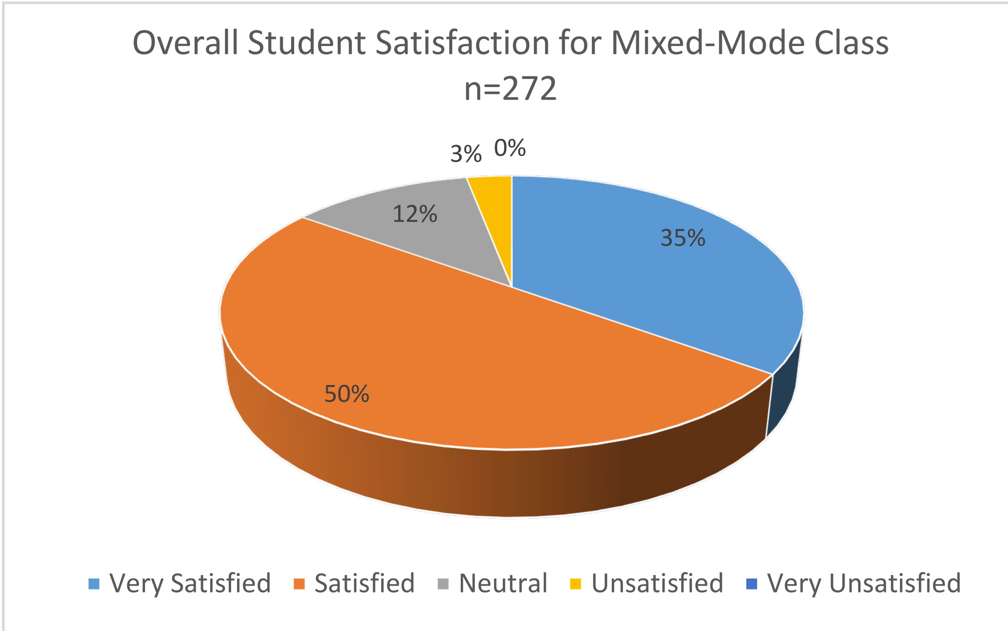


Figure 9: Student survey response on overall satisfaction for the mixed-mode class.

Table 4: Comparison of SPI rating in the face-to-face and mixed-mode class

SPI Criterion	Face-to-Face	Mixed-Mode
Effectiveness communicating ideas or information	4.18	4.22
Effectiveness stimulating interest in the course	3.88	4.02
Effectiveness helping students achieve course objectives	4.16	4.25
Effectiveness organizing the course	4.40	4.29
Effectiveness giving useful course feedback	4.16	4.19

The IRB-approved survey delivered to the students also included two open-ended questions. The students were asked to list the reasons on what they liked most and what they liked least about the flipped, mixed-mode class. Figure 10 shows the student responses themed into similar categories for the above questions. Amongst the most liked aspects as evident in Figure 10(a), convenience and flexibility of the mixed-mode course scored the highest with 62% (169) of the students reporting them as a reason. Fifteen percent of the students (41) liked the fact that they had to commute less since the course was partially online, while 12.5% of the students appreciated the mixed-mode class for better conceptual understanding of topics. Only 6% of the students admired the engagement aspect of the mixed-mode class.

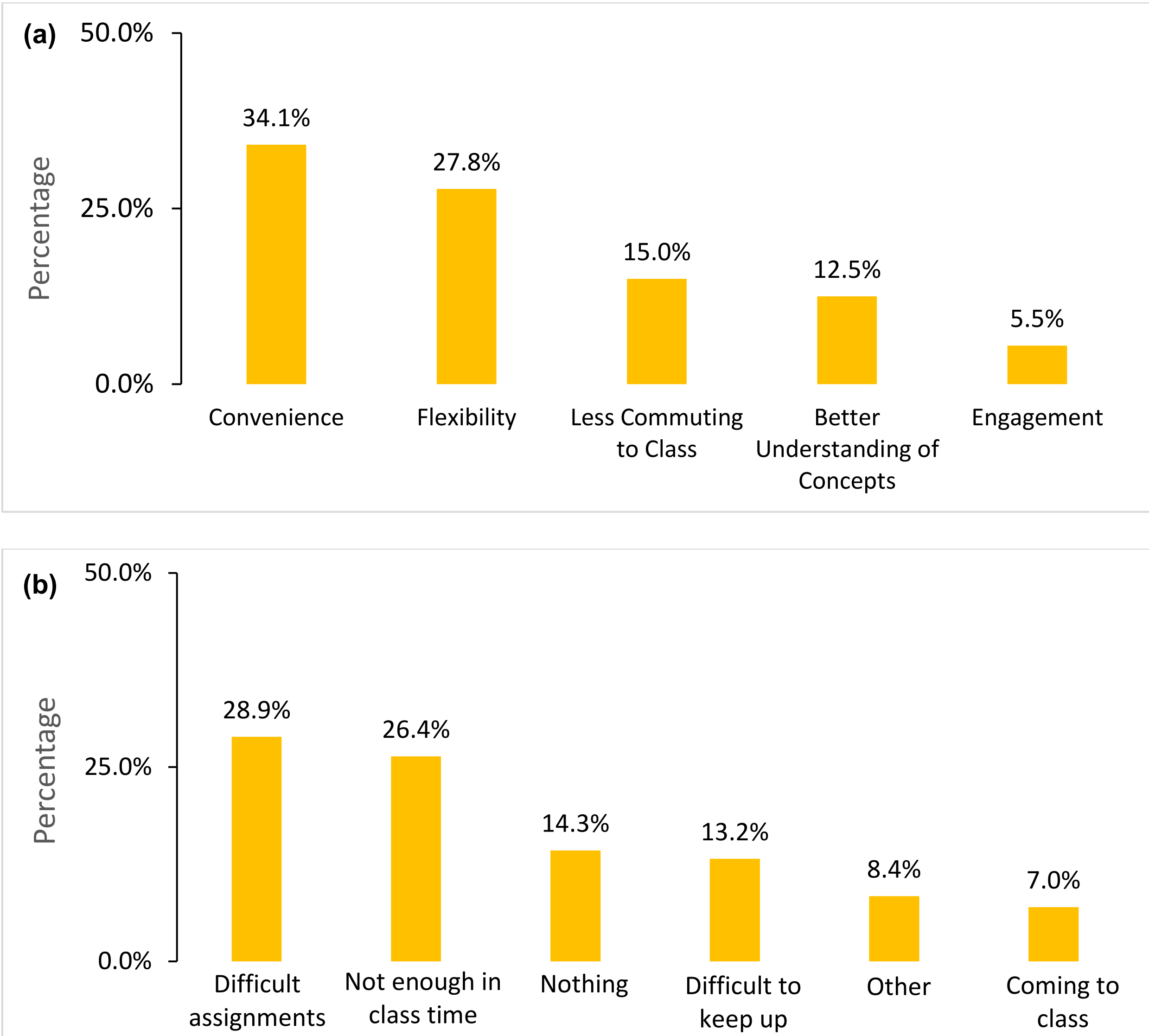


Figure 10: Student survey response on (a) most-liked aspects and (b) least-liked aspects of the mixed-mode class.

Amongst the least liked aspects, as seen in Figure 10(b), difficult assignments (~29%) ranked the highest. Not enough in-class time ranked second (27%) amongst the least-liked aspects reported by students for the mixed-mode class. This resonated with the instructor's own experience in teaching the class where the class time seemed insufficient for certain lectures. This concern can be addressed in the future offerings of the course by adjusting the class length or by supplementing the online content with more videos. In the mixed-mode format, another aspect that some students struggled with was self-regulated learning. In a mixed-mode class, students are responsible for learning the materials presented in the online lecture videos on their own. This aspect was a strain for some students (13%) in the flipped class. For a few students (7%), attending lectures was the least liked aspect of the mixed-mode class.

In the open-ended questions, students were asked to list suggestions for course improvement for future offerings of this course. The top four suggestions were: a) cover more core concepts in class, b) increase class time length, c) more in-class participation assignments and d) reduce difficult assignments. Some of these suggestions concur with the students' previous responses in Figures 8(b) and 10(b) regarding the lecture time length for the mixed-mode class. Student suggestions and satisfaction data and the instructor's experience are indicative of the fact that a longer class length with adjustments in the extent of online content would be valuable if teaching Dynamics in a mixed-mode format.

3d. Student Performance Assessment across Semesters

Student performance in the Dynamics course was compared across semesters to assess the effectiveness of the mixed-mode teaching modality in comparison to the regular face-to-face modality. Figures 11(a) and 11(b) shows the comparative data across two semesters Spring 2018 in the face-to-face mode, and Spring 2019 in the mixed-mode.

As observed in Figure 11(a), the average class performance for both exams and homework assignments improved by approximately 5% in the mixed-mode format as compared to the face-to-face class. For the quiz category, the class performance remained almost the same across both semesters. A possible reason for the marginally lower performance of the students in quizzes is due to the lower weightage assigned for quizzes in the cumulative score in comparison to homework and exams.

Figure 11(b) shows percent increase or decrease in the cumulative final score in the mixed-mode Dynamics class as compared to the face-to-face class. As evident in the figure, 13.2% more students had a final score of at least 90% in the mixed-mode class, compared to the regular class. Additionally, the percentage of students who scored in the range 70–79.99% and in the range of 60–69.99% decreased by 5% and 2.5%, respectively in the mixed-mode class. Student performance comparison across both semesters, as evident in Figure 11, clearly indicates that students performed better in the mixed-mode class. The mixed-mode students had access to lecture videos for all core concepts through the online portion of the class which may have contributed to their better performance. This allows students to review learning materials multiple times at their own pace and also before major assessments such as exams. Additionally, the face-to-face class time in the mixed-mode section was used by the instructor to review the online content and solve more concept problems, but also for active-learning assignments, which further reinforced the topics learned through lecture videos. This pilot study examined student data across two semesters for the course. However, future studies designed to compare data across multiple semesters would further validate the findings of this study.

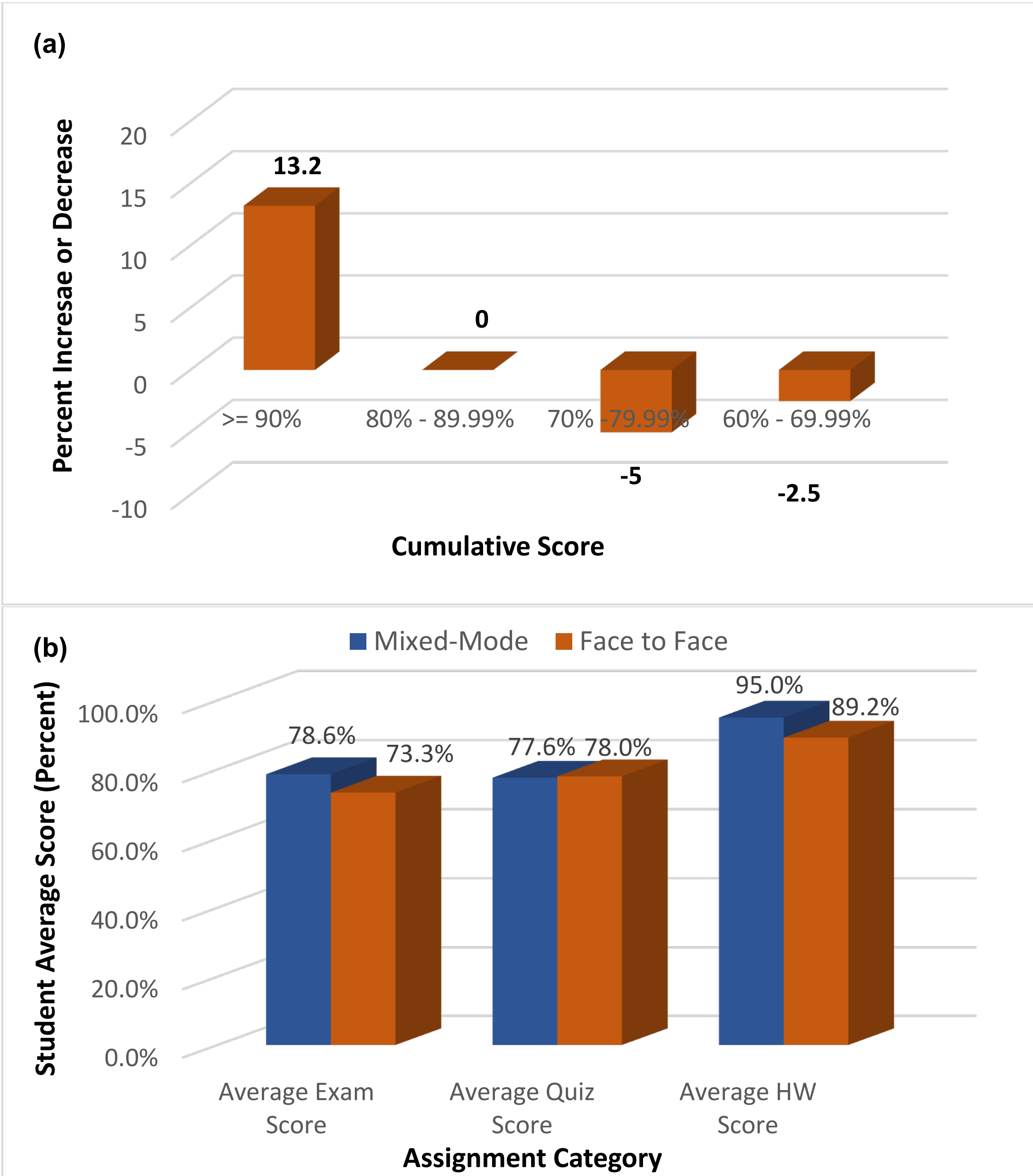


Figure 11: Comparison of class performance across semesters (a) percent increase or decrease in cumulative grades and (b) average class performance in three major assessment categories and

Student failure rates and withdrawal rates were also compared across both semesters to delve more on student retention in mixed-mode classes. As evident in Figure 12(a), student withdrawal rates diminished by 3.2% in the mixed-mode class in Spring 2019 from the regular class. A small decline (0.8%) in student failure rate was also observed (Figure 12b) in the mixed-mode class when compared to the face-to-face class. The data indicates that mixed-mode classes have the potential to increase student retention and student success rate in engineering courses and is in accordance with studies in the literature on flipped, mixed-mode classes across different disciplines [11], [17].

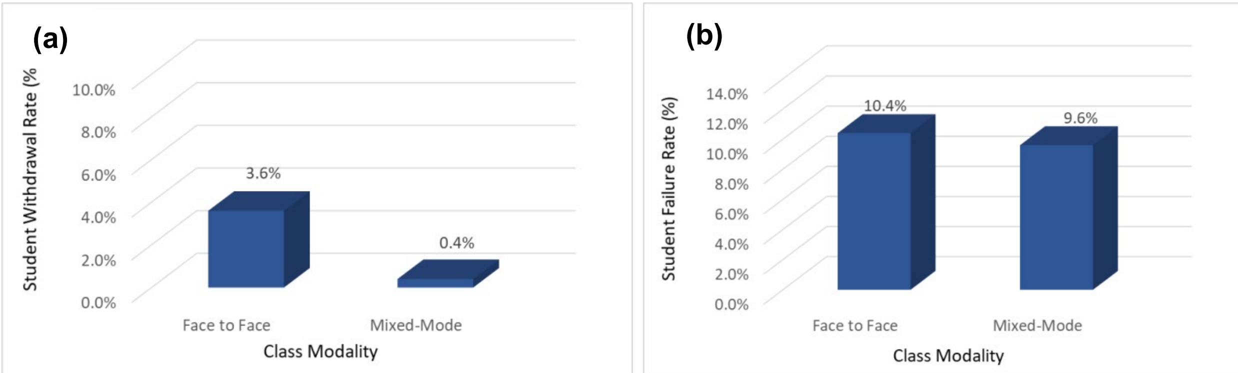


Figure 12: Comparison of (a) student withdrawal rates and (b) student failure rates in the mixed-mode and face-to-face class.

4. Discussion and Conclusion

As the blended or mixed-mode model continues to gain momentum in higher education, its implementation in different disciplines is inevitable. Discipline-specific pilot studies such as the one presented here are imperative to shed light on effective strategies for course redesign and also for evaluating the effectiveness of these newer models as they are implemented in core engineering courses. To determine the efficacy of a newer pedagogical model, a study design should spread across semesters with a thoughtfully created control class for data comparison to minimize variabilities from instructors, course assessments, and course content. In this study, efforts were taken to minimize effects from the above mentioned. Structuring a blended course into weekly modules and planning ahead on the breakdown of videos and class lectures to be presented each week can aid in the smooth delivery of a blended course especially when teaching high enrollment courses. Writing down equations and problem solving steps was essential for developing engaging videos, as it helps in better comprehension of complex concepts. The technology used for writing in videos can have a small but not substantial impact on student engagement as was seen with a slightly higher acceptance rate for Lightboard videos in contrast to Voiceover PowerPoint with annotation videos. If teaching a course such as Dynamics which is heavily based on visualization and analysis of objects and their motion in three-dimensional space, it is beneficial to have ample figures and animations within the videos for student engagement as it allows better explanation and may help students better comprehend complex problems. Regarding video length, literature has traditionally shown positive responses in terms of student engagement for shorter videos. However, video analytics in this study showed no significant correlation between video length and the number of video views. This is indicative of the fact that students in engineering courses are more receptive toward videos of longer length as complex topics require longer explanation time.

Two important criteria in evaluation of a blended class over a face-to-face class are student satisfaction and student performance as both are reported in literature to be high for blended courses in other disciplines. The results of this pilot study were promising in both criteria for the engineering course redesigned. In terms of student satisfaction, 85% of the students in the blended class were satisfied in the new, blended delivery format. Convenience and flexibility in learning the content was the most important factor that played in high student satisfaction. Difficult assignments and insufficient class-time were reported as some of the drawbacks in the blended format. Adjusting the face-to-face lecture time length and increasing the number or content of the videos would leave more time for instructor interaction and active learning sessions in future blended courses. Course assessment data shows marked improvement in student performance in the blended class as compared to the regular class. Withdrawal rates from the blended course were significantly lower than the control lecture-based class. Course data suggests that better learning in foundation courses in engineering is promoted through the redesigned format. This can lead to higher student success rates in advanced engineering courses. Overall, the conversion and delivery of the Dynamics course in the blended format was a success and the course will continue to evolve in future offerings to further enhance student learning and satisfaction.

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