Advances in Engineering Education

SPRING 2018

Student Interactions with Online Videos in a Large Hybrid Mechanics of Materials Course

BENJAMIN AHN

AND

DEVAYAN D. BIR
Iowa State University
Ames, IA

ABSTRACT

The hybrid course format has gained popularity in the engineering education community over the past few years. Although studies have examined student outcomes and attitudes toward hybrid courses, a limited number of studies have examined how students interact with online videos in hybrid courses. This study examined the video-viewing behaviors of students and their reasons for deciding to watch or not watch videos in a hybrid sophomore-level Mechanics of Materials course. The findings show that when students played the videos, they watched most of the content; for videos 1 to 22 minutes long, the number of times played and the percentage of videos completed did not vary; the number of times played depended on the difficulty of a video's topic; and the number of times played increased during exam periods. Students' reasons for watching or not watching videos were identified. The findings have implications for the development of online videos for hybrid courses and improving engineering student utilization of videos.

Key words: Flipped classroom, instructional design, Mechanics of Materials, streaming video, student video-viewing behaviors

INTRODUCTION

The last decade has seen increased implementation of hybrid pedagogy in undergraduate engineering courses. Hybrid pedagogy, also termed flipped classroom, blended learning, and inverted instruction, teaches students through a combination of online materials and face-to-face instruction [1, 2]. Typically, students watch online lecture videos prior to classes, and during class periods faculty answer students' questions and assist them to perform in-class activities that require the application of information obtained from watching the videos. Because most of the lecture content is provided outside the classroom, faculty can use class time for student-centered learning activities. Hybrid pedagogy has been used in a wide variety of engineering subjects and disciplines (e.g., a construction equipment and heavy construction methods course for junior construction engineering students [3], a heat transfer course for junior and senior mechanical engineering students [4], and an introduction to work design for junior industrial engineering students [5]). The number of hybrid engineering courses will increase over the next few years given this pedagogy's usefulness in meeting the training needs of a changing workforce [6] and the plans of many universities in the United States to transform required undergraduate courses from the traditional lecture format to the hybrid format [6–8].

Empirical studies on the effect of hybrid pedagogy on engineering students have been performed. Studies comparing the outcomes for engineering students in classes with an instructor-led lecture format and classes with a hybrid format show mixed findings: Some showed significant higher student outcomes for the hybrid format [9-13], and others showed no differences in student outcomes between the two formats [12, 14]. Studies of student engagement in and attitudes about hybrid classes have overwhelmingly found increased student engagement [10, 13] and positive student attitudes toward hybrid classes [5], mainly because the hybrid format encourages students to work with peers and instructors and gives them access to videos. Another study examined faculty perspectives on the benefits and challenges of hybrid classes. The benefits included increased faculty awareness of students' challenges in the subject, improved instructor–student relationships, enhanced ability to recognize common learning bottlenecks, and a reduction in instructor preparation time [13]. The challenges included a significant initial investment of time to create online videos, quizzes, and in-class activities and the difficulty of getting students to work either individually or in groups on in-class activities [13].

Previous studies have examined the effect of hybrid pedagogy on student outcomes, engagement, and attitudes and the benefits and challenges of implementing it, but few studies have explored student behavior while viewing videos developed for hybrid classes. We currently have limited understanding of such matters as the following: How many times do students play a video and for how long? What percentage of all course videos do students play? Does video duration affect the number of times a video is played or the length of time it is played? Are there periods in a semester when video playing increases or decreases? What videos accumulate the most and least plays, and why? What are students' reasons for playing or not playing videos? Finding answers to these questions will help faculty to create videos that students will watch in full and to effectively integrate them into a hybrid curriculum.

LITERATURE REVIEW ON STUDENT'S ONLINE VIDEO-VIEWING BEHAVIORS

Many studies have chosen to examine students' online video-viewing behaviors in massive open online courses (MOOCs) because these courses primarily deliver their content through online videos. For example, Li et al. (2015) [15] examined the relationship between students' video interactions (e.g., pausing, forward and backward seeking, and speed changing) and the perceived difficulty of video contents, video-revisiting behaviors, and class performance for selected MOOCs. The study setting was two electrical engineering undergraduate MOOCs that included videos of professors presenting lecture materials with PowerPoint slides and a digital pen. Between the two courses, 94 videos, less than 20 minutes in length, were made available to 31,880 active students (i.e., those who watched at least one video) for a combined total of 588,953 video-viewings. There were no midterm or final exams, but students completed weekly quizzes that permitted multiple attempts. The study found that replays and pauses were the most frequent actions for videos that students perceived to be covering difficult subjects but fast forward patterns were the most frequent actions for videos perceived to be covering less difficult subjects. Furthermore, strong-performing students tended to interact less with the videos compared to weak-performing students.

Another study by Guo, Kim, and Rubin (2014) [16] examined the relationship between student engagement (i.e., measurement of how long students watched each video and whether students attempted to answer post-video assessment problems) and video production characteristics (e.g., video length, video type, and production style). The research setting was four math and science MOOCs in Fall 2012, which included a total of 862 videos, 127,839 active students, and over 6.9 million video-viewings. The average video length was 7 minutes, 46 seconds (obtained from Kim et al. [17], which analyzed the same videos and student data). The findings showed that the median engagement time for students was at most 6 minutes, regardless of video length. Videos shorter than 3 minutes had the longest engagement times. Students replayed tutorial videos more frequently than lecture videos. The average duration of viewing time was 2 to 3 minutes.

Using the same data as Guo et al. (2014) [16], Kim et al. (2014) [17] compared video incompletion and viewership peaks with student activity. Higher video incompletions were found for longer videos, videos that were watched more than once, and tutorial videos (compared to lecture videos). Student activities that were responsible for viewership peaks were as follows: starting from the beginning of new material, returning to missed content, following a tutorial step, replaying a brief segment, and repeating a verbal explanation.

Lastly, Breslow et al. (2013) [18] examined a 14-week undergraduate circuits and electronics MOOC. The course included weekly 10-minute lecture videos narrated by the lead instructor. The course materials included tutorials, an electronic textbook, a discussion forum, and a Wiki post.

Students spent most of their time on the lecture videos, but a discussion forum was also popular. Old homework problems were accessed most often during exams (students had access to all online resources during exams). The discussion forum was the most frequently used resource for students who were solving homework problems.

Although previous studies on MOOC students' video-viewing behaviors provide important information about how they interact with online videos, the findings may not translate to the video-viewing behavior of students in traditional university courses using a hybrid curriculum owing to major differences in students, pedagogy, and assessments between MOOCs and university courses. Students enrolled in MOOCs tend to differ widely in age, prior experience, knowledge, learning abilities, and motivations for watching videos or taking the course [18, 19]. For example, studies found that MOOC students come from more than 190 countries, are between 20 and 40 years of age, and have a college degree [18, 19]. Further, the completion rate of MOOCs is less than 10% [20], and students drop courses at various points during the courses' timespan [18]. In comparison, university students are not as diverse in terms of age, prior experience, and knowledge, and they have similar motives for taking classes, which typically revolve around meeting degree requirements. Hence MOOC students may use online videos differently from the way that students in university courses use them, and they also may not represent general online video-viewing behaviors [16]. Another major difference between MOOCs and university courses is the way that materials are delivered and learned. Although discussion forums and online face-to-face interaction are available to MOOC students, the primary method of teaching and learning in MOOCs is online videos. It would be difficult and even intimidating to actively interact with relatively unknown MOOC students from all around the world. On the other hand, students in university courses, especially in hybrid courses, have access not only to videos but also to their peers, teaching assistants, and instructors [21]. Even in strictly online university courses, interacting with other students may not be as intimidating as it likely is in MOOCs. Therefore, students in university courses may not have to rely as heavily on online videos as students in MOOCs, and this can affect video usage and interactions. Finally, MOOCs and university courses may employ different types of assessments. Owing to the sheer number of MOOC participants, automated assessment may be a necessity (e.g., by using multiple choice questions, possibly with multiple attempts), whereas a university course assessment could include short answer questions or proctored hand-written exams, which could also affect video usage and interactions. Therefore, it is important to examine video-viewing behavior for both MOOC students and university students in hybrid or traditional courses.

Studies of student video-viewing behaviors in university courses can be divided into two categories: Those that examined video interactions via students' self-reported surveys and those that examined them via a video management system. Studies that examined video interactions from students' end-of-semester self-reported surveys have reported that (1) students preferred a video length of around 20 to 30 minutes [5, 22, 23], (2) most students watched videos at least once [23], and (3) the percentage of students who viewed videos changed over a semester [10]. Other studies have sought to explain why students played lecture videos multiple times [5, 12]. However, such studies may not be the most accurate way to collect data on viewing behavior because they may incorporate students' biases, or students may incorrectly recollect their viewing habits at the end of a semester. A video management system that collects data (e.g., number of plays, percentage of video completion) on a daily basis for each video would provide more accurate accounts of when and for how long videos were played.

Some studies have used a video management system to examine the video-viewing behavior of students in science and engineering university courses. For example, Dazo and colleagues [24] examined an introductory computer science course that implemented a hybrid classroom format across three different semesters. The course had an average enrollment of 20 students per semester and provided 25 lecture videos with an average video length of 47 minutes. The study examined students' video usage, including the number of times videos were accessed, the percentage of video contents played, the times when students viewed videos relative to the start of the class, and the number of plays per student for each video. In one of the semesters having the highest video usage by students, the study found that 98% of students accessed the videos, students viewed at least 85% of the videos' contents, all students watched some portion of the videos prior to coming to class, and students on average played each video twice (although downward trends were observed as the semester progressed). Pinder-Grover and colleagues [25, 26] examined students' usage of supplemental videos in an introductory materials and manufacturing course. Different types of videos (e.g., 15 mini-lecture videos with a duration of 5 to 10 minutes, 13 homework solution videos with a duration of 10 to 15 minutes) were available to almost 400 students across two semesters. The study found that students watched only specific portions of homework solution videos, whereas they watched the entire mini-lecture videos. Kinsell, Mahon, and Lillis (2017) [27] examined 133 students' video usage in a sophomore-level biochemistry class over a 12-week semester. Students had access to four lecture videos with a duration of less than 6 minutes. They found that the number of views increased as the semester progressed and reached a peak immediately before the exams.

Other studies have examined student video usage, but only outside of the engineering or science context. For example, Morris and Chikwa [28] examined usage of videos no longer than 25 minutes by 108 first-year students in a food science course. The videos were made available 2 weeks prior to the exams on the content in the videos, and 56% of the students watched the videos. Elliott and Neal [29] examined how over 700 students used videos in an economics course. Over the 24-week course, 70 videos of recorded lectures with a duration of approximately 50 minutes were made available to students. The number of views increased throughout the semester, with views peaking during exam weeks. The study also noted that most students watched only portions of the lecture videos.

To our knowledge, the study by Gross and Dinehart [30], which examined the video-viewing behavior of sophomore-level students in a hybrid undergraduate mechanics course, is the one that most closely resembles our study. The study involved lecture videos, which students were expected to watch prior to each class, and videos of example problem solutions, which students could watch immediately after each class. Gross and Dinehart found that half of the students watched at least 53% of the videos in their entirety prior to class and that the percentage of lecture videos completed declined over the semester. Only half of the students watched 10% or more of the videos of example problem solutions, and the viewership of example problem videos was consistently low throughout the semester.

Although the Gross and Dinehart study provided a glimpse of students' video-viewing behavior, the hybrid class that they studied implemented a slightly different type of hybrid pedagogy in which the instructor posted lecture videos only prior to the class in which the lecture was delivered and posted example problem videos only after solving the problems in the class. Furthermore, no credits were given to students for watching videos prior to each class. It will be worthwhile to examine students' video-viewing behavior when both lecture and example problem videos are posted prior to each class, when students receive some form of credit for watching videos before class, and when students are asked to solve new problems on their own in class by applying knowledge gained from watching the videos. Studies are also needed on whether students' video-viewing behavior changes during exam periods and for different topics (possibly due to the level of topic difficulty) and why students do or do not play videos.

METHODOLOGY

Research Questions

To create effective hybrid classes, it is important to understand students' video-viewing habits and their reasons for playing videos. Understanding how students interact with and perceive the required videos in hybrid classes can help faculty produce engaging videos that provide positive video-viewing experiences, increase student view rates, and improve student outcomes. Understanding student video-viewing behaviors can also help faculty to better integrate videos with other components of a hybrid class (e.g., in-class quizzes and assignments and mini-lectures). Therefore, the purpose of this study was to examine students' video-viewing habits in a large-enrollment sophomore-level hybrid Mechanics of Materials (MoM) course. We examined the following research questions:

1. Did students play the videos that were available for this hybrid MoM course?
2. When did students play videos the most or the least often over the 16-week semester?
3. What videos were played the most and the least? What can be said about these videos?
4. What were students' attitudes toward the videos, and what were their reasons for playing or not playing videos?

This paper addresses the lack of empirical studies examining the video-viewing behaviors of students and their reasons for deciding to play or not play videos in a hybrid sophomore-level engineering undergraduate course.

Research Context

Course Description and Students

This section of the paper describes the examined hybrid course, its enrolled students, how a typical class in the course operated, the assessments used to assess student learning, and how the course's videos were created.

The Mechanics of Materials (MoM) course at the studied large land-grant Midwest university aims to develop students' understanding of the fundamentals of solid mechanics. It covers 34 topics (e.g., plane stress, plane strain, stress-strain relationships, material behaviors, and member deformation due to torsional, flexural, and combined loadings) over a 16-week semester. It is a three-credit-hour course that meets three times a week (Monday, Wednesday, and Friday) for 50 minutes. In Fall 2016, the first author taught two MoM sections using a hybrid format, the first use of this approach for the MoM course at the university. One class had 71 students and the other 94. Demographic information for these sections, obtained from the Office of the Registrar following receipt of approval from the IRB office, is presented in Table 1.

Both sections were taught by the same faculty and had the same teaching assistant (TA), who assisted the faculty with class logistics (e.g., distributing and collecting papers) and answered students' questions during class periods. Five undergraduate graders were hired to grade student assignments and exams during the semester.

Course Structure

On the first day of the course, students were informed that it would be taught using a hybrid format. They were asked to watch the videos assigned for a class topic prior to coming to the class. For each topic, a folder was created in an online learning management system (Blackboard). Every folder contained a Portable Document Format (PDF) version of the lecture, example slides, a lecture video, and one to three example problem videos.

Table 1. Student Demographic Information.

Demographics	N (%)
Gender	
Female	25 (15)
Male	140 (85)
Resident status	
U.S. citizen	151 (92)
International student	14 (8)
Statics (prerequisite course) letter grade	
A	34 (21)
B	67 (41)
C	44 (27)
D	20 (12)
Mechanics of Materials letter grade	
A	23 (14)
B	61 (37)
C	52 (32)
D	14 (8)
F	15 (9)

A typical class period was divided into segments. The first five minutes were spent administering a quiz consisting of three to four multiple choice or short answer questions on the videos students were asked to watch prior to the class. The purpose of the quiz was to encourage students to watch assigned videos and to check their understanding of the video content. After collecting students' answers, five minutes were spent going over the answers in class. A mini-lecture on the topic of the day was then presented for the next 15 minutes. During this lecture faculty reviewed the lecture slides, re-emphasized important and difficult concepts, and answered students' questions about the videos or topic content. The purpose of the mini-lecture, a practice recommended for hybrid courses by Leicht et al. [22], was to provide enough information to remind students of the video contents without completely reviewing them. Sometimes a problem from the example problem video was briefly discussed to address common misconceptions about how to solve it. During the last 25 minutes of the class students completed an in-class assignment consisting of a printed handout with two problems on it. The problems dealt with the day's lecture topic and required students to calculate answers, which were written on a board so that students could check their work. While students solved these problems, the faculty and the TA walked around the classroom and answered questions. At the end of the class, students were asked to submit their write-ups. At the end of the day, a complete write-up of the problem solutions was posted in the online topic folder.

The philosophy behind the hybrid approach that we applied in this class aligns with that of Craig [31], who said that students develop an understanding of MoM topics best when (1) they are made aware of the fundamental concepts and theories associated with the topics (in our hybrid class, via lecture videos), (2) systematic problem-solving procedures are taught through example problems (in our hybrid class, via example problem videos), (3) they have ample opportunity to practice solving problems while receiving help from experts (in our hybrid class, via in-class assignments), and (4) the relevance of what they are learning is demonstrated by assigning problems that deal with real-world engineering matters (in our hybrid class, via homework and supplemental problems).

Course Assessments

Three mid-term exams and a final exam were administered to assess students' learning. Each exam covered nine topics taught over a span of approximately three to four weeks. Prior to these exams, a test (called "Exam 0") was administered to determine what students had retained from the Statics course, a prerequisite for MoM, as a way to assess how prepared they were for the MoM course. The course included 103 online homework (HW) problems taken from the assigned course textbook and three take-home supplemental HW problems developed by the faculty member. In-class quizzes and in-class assignments made up the rest of the course assessments. Table 2 shows the percentage allocations for assessments along with their due dates and the day they were administered during the 16-week (116 days) semester.

Online Videos

The first author created 89 videos using a tablet and pen display technology (Wacom) and video editing software (Camtasia). The videos consisted of narrations of PowerPoint slides by the first author. The slides and narration scripts were created prior to the video recording. Both classes were assigned all of these videos.

Table 2. Types of Assessments, Percentage That Each Accounted for in Overall Grade, and Due Date and Day Administered.

Type	Grade Percentage (%)	Due Date (Day Administered*)
Exam 0 (Statics)	5	Week 3 (17)
Mid-term exams: Exams 1, 2, and 3	50	Week 5, 9, and 13 (31, 59, 87)
Final exam: Exam 4	20	Week 16 (116)
Homework	10	Every Thursday
Supplemental homework 1, 2, and 3	3	Week 4, 7, and 14 (22, 47, 99)
In-class assignments	9	Almost every day
In-class quizzes	3	Almost every day

* In a 116-day semester.

Table 3. Lecture and Example Video Information.

Video Information	Lecture Videos	Example Problem Videos
Total number of videos	34	55
Minimum video length (min:sec)	2:22	0:59
Mean video length (min:sec)	10:49	5:37
Maximum video length (min:sec)	18:53	21:37
Combined length of all videos (hr:min:sec)	6:07:37	5:09:17

Two categories of videos were created: lecture and example videos. The lecture videos provided overviews and rationales for topics, fundamental concepts, relevant theories, applied assumptions, and equations needed to solve problems. One lecture video was recorded for each of the 34 MoM topics. Some lecture videos included historical events in various engineering disciplines, to ground these topics in real-life events. Example problem videos, on the other hand, presented systematic approaches students might use to solve example problems. To reduce video duration and make more time for explanations, long equations and complex portions of solutions were written on the slides before beginning the recording. PowerPoint's laser pointer feature was used during the narration to highlight equations, diagrams, and pictures. All videos were edited to remove speaking mistakes (e.g., "um" and "okay"). Table 3 presents information about the lecture and example problem videos. Sample lecture slides with annotated key features, lecture videos, and example videos for specific MoM topics can be found at the following links, respectively:

https://iastate.box.com/v/T19lectureslides

https://iastate.box.com/v/T19lecture

https://iastate.box.com/v/T19example1

https://iastate.box.com/v/T19example2

Three topics were covered per week. A week's worth of videos was made available for students a week in advance, and students could play them as many times as they wanted. Students could not download the videos, but they could download lecture and example problem slides. Students could view posted videos (and materials) until the end of the semester. Only students enrolled in the two hybrid format sections could access the videos.

Method

Data Collection

Data on students' video-viewing behavior were collected using an online video management website (Vimeo). Before the semester began, all videos were uploaded to this website and linked to a student learning management system (Blackboard). To access the videos, students logged into

Blackboard and clicked video links in topic folders. The video management system then called up the Vimeo link associated with the selected topic. An analytic feature available in Vimeo allowed collection of the number of plays and percentage of video completion for each video for each day. Neither individual students' video plays nor any student-identifiable data were collected. Vimeo compiled the data into CSV files, which were downloaded and analyzed.

Data on students' attitudes toward videos were collected from an in-class two-page anonymous evaluation form administered on week 10 of the 16-week semester. The form consisted of Likert-type and open-ended questions on the instructor, course format, and videos, and students were given 20 minutes to fill it out. All student responses were electronically transcribed for analysis.

Data Analysis

Quantitative and qualitative analyses were performed to answer the four research questions. Descriptive analysis was performed on the data obtained from the video management system to determine the number of video plays and the percentage of video completion for each day (RQ 1 & 2), the average duration of play per video (RQ 1), and the videos that garnered the most and least plays (RQ 3). Correlation analysis was performed to determine whether video length affected the number of plays or the percentage of video completion (RQ 3).

Inductive analysis was performed on responses from the student evaluation forms to determine how students described the videos and students' reasons for watching or not watching the videos (RQ 4). Specific steps taken were as follows: The research team (1) read all responses, (2) generated temporary bins that combined similar reasons or ideas observed from the responses, and (3) revised bin definitions as the team came to consensus for each bin. Each bin resolved into a reason for students deciding whether or not to watch videos.

RESULTS

This section of the paper presents answers to the four research questions, obtained from examination of the video data and student course evaluations.

Question 1: Did Students Play the Videos That Were Available for This Hybrid MoM Class?

The 89 videos were played 10,762 times over the 16-week semester. This is equivalent to each video being played 121 times on average. (Note: A play was counted when a student hit the play button.) The videos were played from start to finish 4108 times, which equals 38% of total videos played. On average, when videos were played, 78% of the total video contents was viewed. A majority of the videos were played using desktop computers and laptops (87%), followed by smart

Table 4. Summary of Viewing Data for Lecture and Example Problem Videos.

Data Collected	Lecture Videos (n = 34)	Example Problem Videos (n = 55)
Total number of plays*	4372	6390
Total number of finishes**	1518 (35% of total lecture videos played)	2590 (41% of total example problem videos played)
Average viewing duration per video (min:sec)	8:18	4:14
Average percentage of video completion***	80%	77%

* Total number of plays = The number of times a person hit the play button on a video.
**Total number of finishes = The number of times a video was played all the way to completion.
***Percentage of video completion = The furthest time point that a video was played to in its timeline during a single session divided by the total length of the video.

phones (12%) and tablets (1%). Table 4 presents a summary of the viewing information for lecture and example problem videos.

The results show that not all 165 students watched all 89 videos, as this would have resulted in up to 14,600 total plays. However, for videos that were played, students watched almost all of the video, as revealed by the high percentage of completion for both lecture (80%) and example problem (77%) videos. The percentage of the total number of video finishes was slightly higher for example problem videos (41%) than for lecture videos (35%).

Question 2: When Did Students Play Videos the Most or the Least Often Over the 16-Week Semester?

Figures 1 and 2 present the number of video plays and the video completion percentages per day, respectively. The percentage of video completions is high for most days, meaning that if students played videos they watched them almost all the way to the end.

The number of plays indicated by the line graph in Figure 1 varies depending on the day. For example, during a university holiday (day 15) and Thanksgiving break (days 89 to 97) videos garnered few to zero views. Around the time of Exam 0 (day 17), there were hardly any views relative to other days. (It should be noted that no videos covered the Exam 0, or prerequisite, material). On days

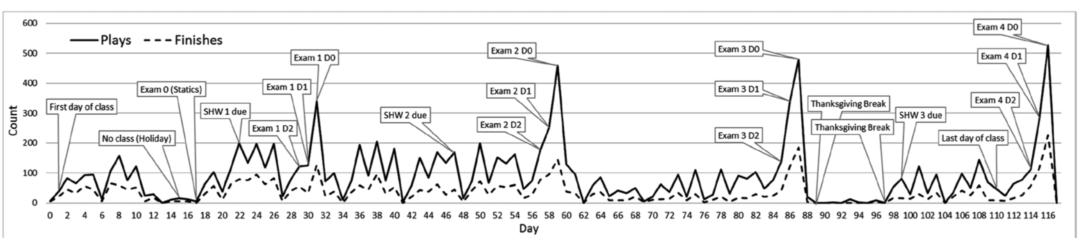

Figure 1. The number of plays and finishes from days 1 to 116.

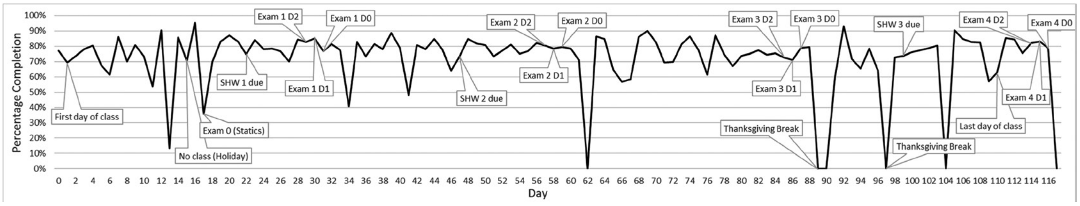

Figure 2. The percentages of video completion from days 1 to 116.

when the three supplemental HW problems were due (days 22, 47, and 99), there were relatively few video plays.

The number of video plays increased during the exam periods. Specifically, the number of views began to increase two days before the exams, and the highest number of views occurred on exam days (days 31 [Exam 1], 59 [Exam 2], 87 [Exam 3], and 116 [Exam 4]). The final exam day garnered the most video plays (527) for the entire semester. (Note: All three mid-term exams were held in the evening at 8:15 pm and the final exam was held at 4:30 pm, giving students time to view the videos before the exams.) Of the total number of plays (10,762), 3346 were played in the two days leading up to the four exams (that is, two days before, one day before, and on the day of the exam). In other words, 31% of the total plays occurred on only 12 days in the entire 116-day semester. The high percentage of video plays during exam periods indicates that students watched videos to prepare for the exams. A pattern of increased video viewing in the days leading up to exams has also been found in other studies performed in different settings (e.g., an undergraduate biochemistry class [27] and an undergraduate economics class [29]).

Question 3: What Videos Were Played the Most and the Least? What Can Be Said About These Videos?

For Research Question 3, we examined whether the duration of the video and the topic affected the number of plays and the percentage of completion. Results from the correlation analyses showed that when videos were approximately 1 minute to 22 minutes long (range = .98 to 21.62 minutes), video length was not related to the number of video plays ($r = .16$; $p > .05$) or the percentage of watched length per video, which was estimated by dividing the watched length by the total video length ($r = -.17$; $p > .05$). This pattern was found for both lecture videos and example problem videos. The results show that faculty who create videos that are between 1 and 22 minutes long can expect a similar number of plays and video completions. It should be noted that even though the longest video was close to 22 minutes, only eight of the 89 videos were longer than 15 minutes. Hence, most of the videos were within the literature's suggested range of video lengths (less than 15 minutes [25, 26]). Videos that were longer than 15 minutes covered challenging topics and examples that required longer and more careful explanations. It is possible that students may have appreciated the explanations and understood the difficulty of the topics or problems enough to watch videos in their entirety, without dropping out in the middle. Furthermore, since these longer videos comprised less than 9% of the total videos, students may have not minded their length so much.

Table 5 lists the top 10 most-played videos. The most-watched video was a lecture video on combined loading, played 246 times by 165 students. A video on a closely related topic, combined loading in three dimensions (3D), was played 213 times. Other frequently played videos covered gear power and deflection by integration. Table 5 shows that example problem videos were also popular: The top six most-played videos include four example problem videos.

The reason the topics listed in Table 5 garnered high viewing rates may be explained by the topic content, specifically with respect to the difficulty of understanding the topics' problem-solving procedures and concepts. For example, combined loading and combined loading 3D require students to examine the magnitude and direction of multiple normal and shear stresses acting on a point on a three-dimensional structure as a result of multiple forces and moments. Deflection of integration requires students to derive elastic (deflection) curve equations by completing double integrations and recognizing correct boundary and compatibility conditions in order to calculate integration constants. The topic on gear power requires students to set up a reference coordinate system and calculate the rotation angle of shafts connected by gears. Solving the problems presented for the topics listed in Table 5 involves a multi-step procedure that requires a solid understanding of not only these specific topic concepts but also concepts taught earlier in the MoM course. In other words, students must be able synthesize multiple concepts taught over multiple weeks in order to solve problems for the topics listed in Table 5. Generally, students will misunderstand one or two of these many concepts, which sets them up to make mistakes on these problems and undermines

Table 5. Top Ten Most-Played Videos.

Topic No.	Topic Name	Video Type	Video Duration (min:sec)	No. of Plays	Mean % Completion
28	Combined loading	Lecture	11:35	246	75
11	Gear power	Example problem 1	6:53	237	68
19	Deflection by integration	Example problem 1	7:20	235	77
29	Combined loading 3D	Lecture	18:53	213	73
12	Angle of twist	Example problem 1	6:36	182	72
16	Normal stress flexure	Example problem 1	7:22	182	84
1	Introduction	Lecture	7:04	180	73
2	Normal and shear stresses	Lecture	12:28	178	71
25	State of stress	Lecture	15:23	170	72
10	Torsion shear stress strain	Lecture	12:51	168	75

their confidence in their ability to solve them. Thus the reason these videos were played so much may be that the topics are so difficult that students needed to watch the videos multiple times to solidify their understanding of the concepts. This proposition is supported by a Nan and colleagues (2015) paper [15] about video-viewing in an electrical engineering MOOC that showed that videos perceived by students as covering very difficult topics had multiple replays.

It is interesting to note that the Topic 1 and Topic 2 videos were among the top 10 most-played videos. Possibly students played them early in the semester to gauge the usefulness of videos in helping them learn the course content.

Table 6 lists the top 10 least-played videos. There are several possible reasons why these videos garnered so few plays. First, many of these topics (e.g., Topics 35 and 36) are of a stand-alone nature, meaning that the concepts, equations, and theories needed to solve problems in these topics are all covered in one topic lecture video. Compare this to the way that solving problems for the topics listed in Table 5 involves synthesizing and applying concepts learned over multiple weeks (e.g., combined loading).

Second, the problem-solving procedures for the topics listed in Table 6 overlap with those for topics covered earlier in the semester. For example, many students are comfortable with Topic 32, strain transformation, because the approach used to solve for strains is exactly the same as the approach used to solve for stresses taught in Topic 26, stress transformation, except for three different equations. Because students had already been exposed to stress transformation solutions, many of them would have been comfortable transferring these solutions to strain transformation analysis, thus leading to low video plays.

Third, two of the topics listed in Table 6 (Topics 7 and 15) were covered extensively in the prerequisite Statics course. These topics are taught again in MoM to ensure that students understand them

Table 6. Top Ten Least-Played Videos.

Topic No.	Topic Name	Video Type	Video Duration (min:sec)	No. of Plays	Mean % Completion
32	Strain transformation	Example problem 2	4:13	43	77
7	Determinate axially loaded member	Example problem 3	1:03	59	83
32	Strain transformation	Example problem 1	5:53	61	74
35	Failure of brittle material	Example problem 2	6:26	63	95
15	Shear moment diagrams	Example problem 2	7:30	68	76
7	Determinate axially loaded member	Example problem 2	2:46	73	77
35	Failure of brittle material	Lecture	6:35	77	81
31	Mohr’s circle absolute max.	Example problem 2	6:36	79	74
36	Stress concentration	Lecture	10:52	80	83
21	Indeterminate beams and shafts	Example problem 2	4:20	81	69

well, because they are the basis for more difficult topics in the course: deriving internal and shear moment equations and indeterminate axial loading. Because students had seen determinate axial and shear moment diagrams before, they may have been less motivated to play these topics' videos.

Question 4: What Were Students' Attitudes Toward the Videos, and what Were Their Reasons for Playing or Not Playing Videos?

One of the open-ended questions in the anonymous in-class evaluation form administered in week 10 asked students to comment on how useful the videos were in helping them learn course content: "Please comment on how useful videos have been to helping you learn course material." We asked this question to examine student perceptions of the value of the videos. Of the 136 students (of 165 total) present in the class on the day the evaluation was given, 113 students (83%) had positive comments, 13 students (10%) had negative comments, seven students (5%) had no comments, and three students' (2%) responses were not related to videos.

Students who said positive things about the videos described them as "extremely helpful," "clear," "easy to understand and follow," "excellent," "effective learning tool," "useful," and "great." Further analysis of these responses determined students' reasons for watching videos, which are summarized in Table 7.

Table 7. Students' Reasons for Watching Lecture and Example Problem Videos.

Reasons for Watching the Videos (number of students)	Sample Student Responses
To understand and clarify concepts (n=32)	• *"I tend to use the videos to try and clarify a problem I am having or when I don't understand a concept."* • *"I…mostly just read the slides, but when I don't understand clearly I go back and watch the videos to help clarify."* • *"Although the examples provided in the videos are often far more simplified than the assignment problems, they do help to understand the basic concepts needed to approach assigned problems."*
To ask questions and complete in-class assignments during class periods (n=25)	• *"The videos are good with providing the info before class so if you have issues you can ask questions."* • *"The lecture videos are equal to if not better than an in-class lecture since you can replay any section as many times as you need and then you can [be] prepared with questions for in class."* • *"The videos are very useful in teaching me the material before class so that I am familiar with the material before class and can work on the in-class assignment with minimal trouble."*
To review for exams (n=11)	• *"Great, [the videos] can be used to learn the material and review for exams."* • *"The videos are extremely helpful because they are good for review, plus they have examples for us to go through."*
To complete homework problems (n=9)	• *"Having quality lecture videos away from class has been very helpful for studying/doing the homework assignments."* • *"The videos are great. I love being able to re-watch them as I work on homework."*

As summarized in Table 7, students had a variety of reasons for watching videos. Some of the reasons align with previous literature findings. For example, students typically watched lecture videos or videos of computer screens with audio commentary to understand or clarify complex concepts [25, 26, 28]. Lecture and example videos were often watched to review for exams [26] and to complete homework problems [18]. Many students also liked the fact that they could start and stop the videos, which presumably allowed them to learn at their own pace. This finding is evident in the previous literature [28, 32, 33] and in the student responses below:

- *"I appreciate the fact that I can rewind the video and go over material I don't understand right away multiple times."*
- *"I like the videos because they allow me to pause and play as needed when taking notes."*

Finally, many students found the example problem videos useful, possibly because they liked the videos' step-by-step approach to solving problems. This finding is evident in these students' responses:

- *"Videos are very helpful, specifically the example videos that show step by step how to do a problem."*
- *"They have definitely been helpful, more so when there are example problems that are worked through too."*

These positive results show that integrating videos into hybrid pedagogy could improve learning and retention in courses like MoM, which is a required, fundamental, large-enrollment course. Our students' overwhelmingly positive responses indicate that incorporating videos helped to make this class a positive learning experience for them. Having a positive experience in the MoM course is especially important because it is often taken during the sophomore year, a time when students are highly susceptible to transferring out of engineering [34].

There was also a group of students who disliked the videos. These students (n = 13) described the videos as not "overly helpful," not "useful," and not "enjoyable" and said the videos left them "confused."

Table 8 summarizes the reasons why some students didn't play the videos. These students found the videos to be too long, making it difficult to concentrate on them. One student specifically stated that it was challenging to pay attention to videos longer than 10 minutes. Another student thought the videos covered too much material too quickly, while two others mentioned that the videos were not helpful because they *"just touched the surface of the subject"* and were only *"nice to get an idea of what will be taught in the next class."* These student responses highlight the importance of balancing the amount of information provided with video duration. The delicacy of this balancing act is highlighted by contrasting student statements: Some liked the fact that they were able to view videos multiple times because they were short (in the words of one student, *"The videos*

Table 8. Student Reasons for Not Watching Lecture and Example Problem Videos.

Reasons for Not Watching the Videos (number of students)	Sample Student Responses
Difficult to concentrate when watching long videos (n=2)	• *"The videos do a good job of preparing the student for the lecture. [But] sometimes the lecture videos can be a little long and begin to make me lose focus."* • *"Videos are very useful, but hard to pay attention to when they go over 10 minutes or so."*
Not enough details in the videos to learn materials in depth (n=2)	• *"They are nice to get an idea of what will be taught in the next class but are not overly helpful in actually teaching the material."* • *"I think that you [faculty] just touch the surface of the subject and to try and relate that to homework is difficult."*
Different preferred style of learning (n=2)	• *"The videos help me learn but not as much as I wish they would. I'm more of a face to face learner, so it's been more of a struggle with this class."* • *"Don't enjoy out of class lecture videos, prefer instructors lecturing."*
Information overload in a short amount of period (n=1)	• *"The videos cover a lot of material in a short period of time, which is a lot to take in all at once."*

are great; the best part is the fact that they are short in length, which means I don't mind watching them again"), but others said they couldn't watch them because they were too long. Finally, some students simply preferred the instructor-centered approach over the hybrid approach. These findings add to those of existing studies that also identified students' reasons for not watching online videos. Among these reasons are not knowing videos existed [26, 28], not having time to view videos [26, 28], thinking that the videos would not help them to understand the course content [28], and not needing videos to learn the materials or choosing to use other course components to learn materials [26].

DISCUSSION

Suggestions for Creating Videos and Offering Large Hybrid Courses

This study suggests five strategies for creating effective videos and in-class quizzes for hybrid courses in required sophomore-level large-enrollment engineering courses.

First, create separate videos for lectures and for example problems for each topic covered in the course. Doing this yields the following advantages: (1) Students can take breaks from lecture and example problem videos, (2) students know what to expect when they play a video, (3) students can decide which videos to play depending on their needs, (4) faculty can produce shorter videos, and (5) faculty can add example problem videos as needed. As a student wrote on the mid-term evaluation form, *"I like how the lectures and examples are split into separate videos. It makes things easier to find."*

Second, educate students early in the semester about the purpose of the videos, to ensure that their expectations are in line with the video contents. For the classes studied in this paper, the lecture videos were intended not to cover textbook content, provide historical details, or derive long equations but rather to motivate students to learn a topic, provide a topic overview and key concepts, and provide the information necessary for using topic concepts and equations to solve problems. Students should be instructed to refer to a textbook or other references if they want additional information. Additionally, sharing how other students have used the videos (Table 7) may help them to view the videos in a new and more positive way.

Third, create one video for each example problem and make sure that it explains important concepts and provides a detailed approach to solving the problem. If more example problems are needed, create a separate video for each so that students can trust that an example problem video will cover only one example problem. It is important to provide ample explanations of the steps needed to solve problems instead of just writing up solutions. Students prefer videos that, for example, explain why certain equations are suitable for a given problem, clarify assumptions that have been made, and describe how a problem resembles or is dissimilar to previously discussed problems, rather than videos that just write out solutions with no explanations. Finally, write out long derivations and complex equations before starting to make the video, to avoid spending a lot of time in the video doing this.

Fourth, keep an eye on the number of plays for each video throughout the semester. High play numbers for particular videos may indicate that students are struggling with particular topics or example problems. In this situation, students can be assisted by providing additional example problem videos, spending more time in class explaining concepts, or giving additional in-class example problems. On the other hand, a low number of plays may indicate that students have a good understanding of the contents covered, opening the option of administering more complex and challenging problems or spending less classroom time on the topics covered in the low-play videos. The number of video plays can be used to detect what is confusing or interesting to students while a course is in progress and to make adjustments accordingly. The number of video plays per topic can also be used along with the end-of-semester course evaluation to improve a course for future classes because they indicate topics that may need more teaching or improved pedagogical aids.

Fifth, it is a good idea to provide quizzes as incentives for students to watch videos. In this study, short in-class concept-check quizzes accounted for 3% of the final grade, which encouraged students to watch videos before classes and to ask clarifying questions about videos during class. The quizzes were designed based on common misconceptions that students had on each topic. The quizzes in combination with videos allowed for rich discussions early in the class period, which led nicely into the class's mini-lecture or in-class assignments. The in-class quizzes were developed by class faculty, the TA, and undergraduate students who had taken the course. Good resources on developing in-class quizzes can be found at Felder and Brent (2016) [35] and Svinicki and McKeachie (2014) [36].

Recommendations for Future Studies

Several avenues of research can be pursued based on this paper's findings. The video-viewing habits of individual students can be examined, in contrast to the habits of an entire class of students, as was examined in this paper. Focusing on individuals could reveal whether different groups of students view videos differently. For example, the viewing habits of high-achieving students may differ from those of low-achieving students. Furthermore, the viewing habits of students whose first language is English may differ from those for whom English is a second language. Investigating students' video-viewing habits according to student characteristics and correlating viewing habits with performance in class may lead to recommendations on ways to improve videos to better serve different groups of students.

Another line of research could investigate the effect of providing new categories of videos and videos that implement innovative features available in video learning management (VLM) systems on student satisfaction, interest in a course, and retention of course materials. Examples of new video categories include demonstrations and lab experiments, which could help connect theories discussed in lecture videos with real-life applications. An example of the innovations made possible by VLM systems would be adding the ability to ask faculty a question while viewing a video.

A third possible type of research could be comparing the effect of hybrid and other pedagogies on student learning. In the current study, although many students had positive comments about a hybrid class that involved watching videos, it is unclear whether the hybrid approach increased their performance/grades more than other approaches would have (e.g., an instructor-centered approach such as lectures or a student-centered approach such as cooperative learning). Additionally, it is unclear whether the hybrid approach leads to higher student performance on topics that are traditionally difficult to master (e.g., as mentioned earlier, combined loading and deflection by integration). Studies that compare the effect of pedagogical approach on student performance could help faculty make empirically supported decisions on whether to adopt a hybrid approach.

CONCLUSION

This study examined how students interacted with videos in a hybrid course. Undergraduate students enrolled in a large required sophomore-level MoM engineering course watched videos specially created for the course. When students played videos, they watched most of the video content. The number of plays and video completion percentage did not vary for videos with a duration between 1 and 22 minutes. The number of plays increased a couple of days prior to exams, and the highest rates of playing occurred on exam days.

Some videos garnered more plays than others. Videos that addressed difficult topics garnered many plays. Students played videos for a variety of reasons: to learn and understand materials, to review for exams, and to complete HW and in-class assignments. Some students did not enjoy learning via videos because they had difficulty concentrating on them, the videos did not provide enough or the right type of information, or they preferred a learning style that does not include video watching. Most students, however, found the videos to be a great resource that supplemented their learning. These findings will help faculty understand how to use video play rates to guide video development, specifically when to revise videos or create additional ones.

Future studies could compare the video-viewing habits of students with different characteristics, for example, domestic and international students, part-time and full-time students, and high-achieving and low-achieving students. Such studies could produce recommendations on how to tailor videos for different groups of students. Future studies could also determine the relationship of different video-viewing habits to student in-class performance.

ACKNOWLEDGMENTS

We gratefully acknowledge the support by the Miller Faculty Fellowship and the Engineering-Liberal Arts and Science Online Learning Grant from Iowa State University. We also wish to thank Jordan Hildebrand, an undergraduate research student at Iowa State University, who provided invaluable assistance to develop the introductory video of this paper. We would also like to thank the *Advances in Engineering Education* reviewers and editors for providing constructive feedback, which helped us improve the paper.

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AUTHORS

Benjamin Ahn is an Assistant Professor in the Department of Aerospace Engineering at Iowa State University. His research focuses on (1) the adoption of innovative pedagogy and technology to improve students' ability to learn technical knowledge and master problem solving skills, (2) the development and assessment of professional skills in engineering students, and (3) the use of mentoring to develop students' inquiry, investigation, and discovery skills during their research experiences.

Devayan D. Bir is a Ph.D. student in the Department of Aerospace Engineering at Iowa State University. He earned his B.E. from Hindustan University, Chennai, India and a M.S. from Iowa State University at Ames in Aerospace Engineering. His current research interests include student retention, online and flipped instruction, and STEM at the K-12 level. He is particularly interested in teaching undergraduate students and has taught Mechanics of Materials at the university.