Lecture Video Analytics as an Instructional Resource

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***Abstract*—This Innovative Practice Full Paper explores how classroom lecture video analytics can be employed as an instructional resource. Lecture videos supplementing or replacing traditional classroom instruction are common in academic settings, and have been shown to contribute positively to student satisfaction and student academic performance. Lecture video usage patterns also contain information that can be employed by instructors to improve course offerings. This paper presents a video lecture analytics framework that transforms extensive usage data into easily understood visual formats. This analytics suite is part of the Indexed Captioned Searchable (ICS) lecture video system that is widely used at the University of Houston. The paper reports on a case study that contrasts the nature of usage of lecture video in a traditional face-to-face undergraduate course on *Human Physiology* and a graduate course taught in the flipped classroom format on *Introduction to Psychological Statistics*. The data provided by the analytics suite is analyzed for usage patterns across students, across lectures, and across the dates that the course is active, in order to develop insights into the course content and student behavior. The paper illustrates how lecture video analytics can be employed by an instructor to understand student behavior and improve coursework.**

***Index Terms*—Lecture videos, lecture video analytics, video usage patterns, flipped classroom**

I. Introduction

In recent years, it has become common to upload video recordings of lectures to supplement traditional classroom instruction. In some educational models, such as online courses, or the Massively Online Open Courses (MOOCs), these recordings replace classroom instruction entirely. In others, such as flipped classrooms, instructors provide lectures on the course materials as online video recordings, and class time is used to ask questions regarding the material, or for in-class assignments.

Video of classroom lectures is a versatile learning resource. Tablet PCs, which allow free mixing of prepared (PowerPoint) viewgraphs with hand annotations and illustrations, are often employed for teaching and simultaneous recording of lectures. Advantages include excellent resolution, as the video consists of PC screen shots, and low video production cost, as no camera or operator is needed. The videos typically include whatever the professor is projecting on the screen (e.g., PowerPoint slides, animations, annotations, formulas, algorithms, or drawings) and the instructor's voice. The literature has established that lecture videos are a highly effective learning resource, and that providing lecture videos as supplements to traditional classroom instruction increases student performance, class participation, and student satisfaction [2], [7], [12], [21]. The Indexed Captioned Searchable (ICS) videos project in development at the University of Houston seeks to address one of the major flaws of this medium. The material a user is interested in can be difficult to find from a set of lecture videos, or even within a single lecture video, which is typically over an hour long. The ICS framework addresses this problem by automatically detecting transition points between one topic or subtopic and another, by displaying a transcript of the lecture along with the video, and extracting keywords from the video and directing users who request them to the locations where they occur [19].

In addition to providing lecture videos to students, the ICS Videos platform also logs data on how students use the lecture videos. Returning this data to instructors in an easily understood manner is important, as it allows instructors to make curriculum adjustments or academic interventions over the course of a semester. Many existing commercial lecture video presentation platforms contain a basic analytics suite that returns total views, unique views and total duration of views to the instructor. These statistics are plotted on a timeline for the instructors.

The work presented in this paper is based on an enhanced lecture video analytics suite developed by the authors that is beyond the state of the art. The usage of lecture videos is presented across the semester timeline. The usage of individual lecture videos in a course as well as the usage of sections within a video are presented in a simple modular format. The usage of lecture videos among students is also presented to the instructor.

The paper illustrates how lecture video viewing patterns can be analyzed to infer insights into a course, including student engagement and level of difficulty, for the purpose of improvements in course content and management. Two case studies are presented: one on a traditional face-to-face Biology course, and another on a flipped classroom Psychology course. The studies illustrate how the video analytics suite can be employed by instructors to gain insight into the learning process, as a basis for interventions, and for potentially improving the courses in the future. This study also shows how students tend to employ lecture video in traditional and flipped courses.

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This paper is organized as follows: Section II discusses prior work related to video analytics tools used for classroom lectures. Section III presents the framework employed to support lecture videos that motivated this research. Section IV explains how usage data is logged and how the analytics graphs and charts are generated. Section V presents two case studies that employ the analytic graphs for different types of courses. Section VI contains conclusions.

II. Related Work

Common lecture video systems, such as Echo360 and Mediasite, as well as the ubiquitous YouTube channels, provide access to user analytics [6], [15], [9]. A review of the state of the art in lecture video analytics is presented in [4]. The analytics suite for ICS Videos employed in this research is another state of the art tool developed with the goal of providing insight into student usage for instructors.

The literature clearly indicates that lecture videos are a highly effective learning resource for students across a number of different metrics including course satisfaction and stronger rates of student participation [2], [3], [7], [12], [19], [21], [16]. Viewing lecture videos is also positively correlated with improved student performance in some studies [16] [21]. The common concern that student attendance may be negatively impacted by the availability of lecture videos is generally not supported by evidence [2]. In situations where the attendance did decline, the negative effects could be easily mitigated by instructors [16].

A variety of studies have been done on student usage of lecture videos when they are made available to them. The most common use of lecture videos is to prepare for exams and quizzes. The same conclusions were reached by studies based on self reporting [2], [8], [14], [13] as well as automated tracking [16]. Studies have also shown large variations in usage across videos and across students. As an example, a study of medical students in two basic science courses revealed that 60 percent of students viewed under ten percent of lecture videos available to them, while less than ten percent of students viewed more than forty percent of available lecture videos [14].

III. Background

A major weakness of the video format is the inability to quickly access the content of interest in a video lecture. In previous research, the authors developed the ICS videos platform with Indexing, Search and Captioning capability designed for quick access to video content. Indexing adds logical index points, each in the form of a snapshot representing a video segment that can be accessed directly, search enables identification of video segments that match a keyword provided by the user, and captioning adds the transcript of the video in a separate panel. [1]. A snapshot of the player highlighting the key features is shown in Figure 1. The framework is discussed in detail in [5], [17], [18], [20].

The ICS video system has been used widely at the University of Houston in science, technology, engineering, and mathematics (STEM) coursework for several years. Students are surveyed each semester about the lecture videos and specifically about the indexing, captioning, and search features. In this section, we present selected results from previous studies that focus on the students' perceived value of videos. Students were asked to rate the importance of lecture videos in comparison to other resources made available by faculty, including professor's lecture notes, student's own notes, and the textbook assigned for each class [2], [19]. The results are shown in Figure 2. The students gave the highest rating for professor's lecture notes. Of the 1960 students who responded, 84.0 percent of the students considered them to be *very important*, followed by lecture videos, with 63.6 percent of students reporting that this resource was *very important*. The results support earlier studies that have shown that providing full or *complete* lecture notes can be beneficial to students [1], [10], [11].

Figure 3 shows how another group of 444 students used the videos. The most common usage of of videos was reviewing the material that was difficult, or reviewing to prepare for quizzes and exams. Videos were also used as a replacement for attending the class. In our studies, the student attendance did not decrease with the availability of videos.

Research in this project clearly demonstrated that i) PC based video lectures are a very valuable student resource, ii) the framework developed to enhance videos with indexing and search features is efficient, effective, and a significant improvement over the state-of-the-art, and iii) indexing and search capability significantly enhance the value of lecture videos.

The research presented in this paper is a result of significant interest among instructors employing this lecture video platform in having access to the usage analytics to help enhance coursework. Interviews with three instructors using the ICS Video system indicated that they found the basic usage analytic graphs useful and were interested in employing them in their courses.

IV. Lecture Video Analytics Suite

The lecture video platform employed in this research includes usage analytics associated with semester long courses. The key features are as follows:

- Usage can be presented for a single lecture video, all lecture videos within a course, or all courses in the system.
- Usage can be presented for individual users or aggregated and presented for all users.
- Usage can be presented across the timeline, typically for each day or week of a course.

Typical usage of the video analytics suite is illustrated with example graphs in the next section of this paper.

[1]The research on ICS Videos platform has led to a commercial product called Videopoints (http://www.videopoints.org) that is available to educational institutions

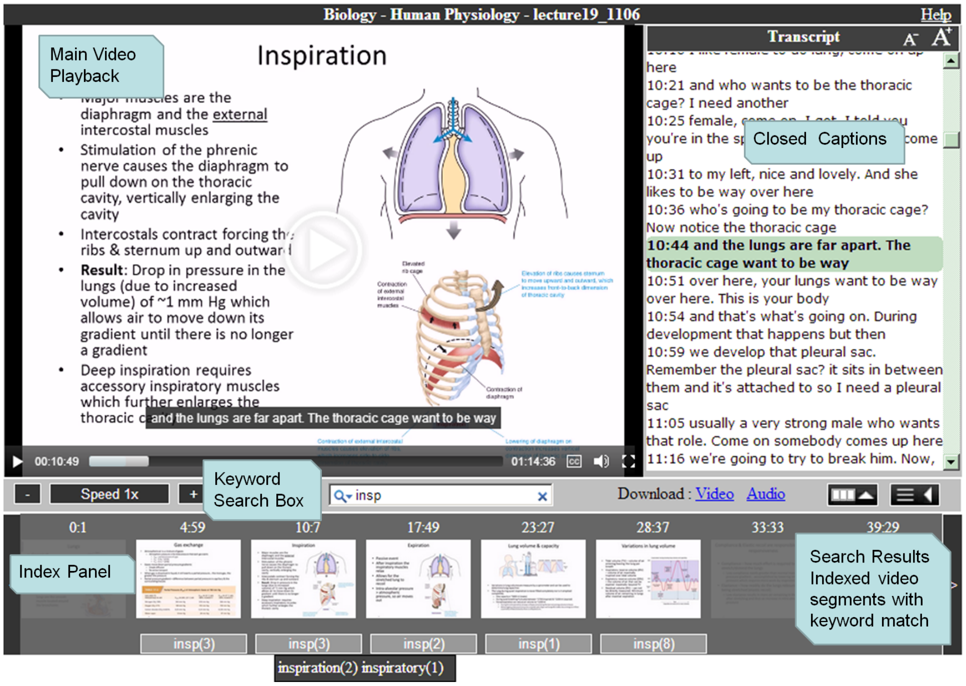

Fig. 1. A snapshot of the ICS Video player

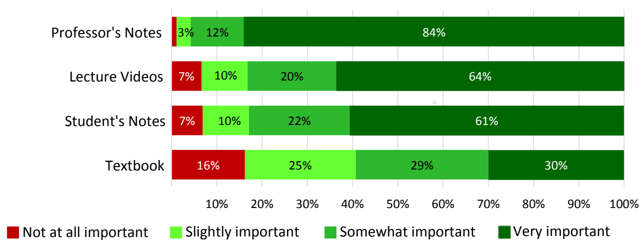

Fig. 2. Student ratings of the value of instructional resources(N=1960)

Fig. 3. Student-selected purpose of video use(N=444)

The lecture video system logs a variety of information on how users interact with the system, including the user's ID, the IP address of the device the user is watching from, the speed at which the user is playing the video, the date and time the user begins watching, and the time codes within the video at which the user starts and stops watching. In addition, the system also generates a session identifier when a user first navigates to an individual video. This identifier does not change if a user pauses the video, clicks on an index point, or seeks a different location in the video, but it does change if the user closes the video, then navigates back to that video. This session identifier is used to determine the number of unique accesses in the graphs. This allows a wide variety of aspects of usage to be presented to instructors, including how many people view videos, which videos are viewed the most often, when are videos viewed the most often, and what sections of videos are viewed the most often.

Between the Fall 2016 semester and the Spring 2018 semester, this project has logged usage for over 3000 different users. These users participated in 40 different course offerings in Biology, Chemistry, Computer Science, Geology and Psychology. These courses were administered in two distinct formats. In the majority of cases, instructors taught the course material through face-to-face lectures, recorded these lectures, and provided them as supplementary material through the lecture video system. In the remainder of the cases, the course was administered in the flipped classroom format, in which lectures on the course material are uploaded to the lecture video system, and class time is used for assignments or questions on the material.

In order to understand how the video analytics can assist instructors and present the differences in usage among courses, two case studies are presented in the following sections. The first is of a representative course administered with traditional in-class lectures and the second is a representative course administered in the flipped classroom format.

V. Case Studies

The main purpose of the analytics suite created in this work is to help science and engineering instructors improve coursework that employs lecture videos by understanding how the video content is used by students The nature of usage of lecture videos depends, in part, on the manner in which they are employed in a course. In this case study, two courses administered in two different styles were selected to illustrate this process.

- *Face-to-face*: In this scenario, lecture videos are provided to supplement traditional classroom instruction. A junior level undergraduate course with the title *Human Physiology* was selected. This course was taught as a face-to-face class over a long semester with enrollment around 160. The classroom lectures were recorded and made available online, typically within a day after each class.
- *Flipped*: In a flipped classroom model, substantial course content is delivered outside of the classroom lectures, in this case as a lecture video. A graduate-level course with the title *Introduction to Psychological Statistics* and an enrollment around 30 was selected. In this course, the bulk of the lecture material was made available to students beforehand as lecture videos, and the class time was used for discussions, review, and application of the concepts discussed in lectures.

The purpose of these case studies is to illustrate how video analytics can be employed to gain insight into student usage of lecture videos. We illustrate how student usage patterns vary based on the instructional style of a course. In doing so, we hope to establish a baseline for what instructors can expect to see in terms of how students use lecture videos in different course formats. If an instructor finds that students are employing videos in ways that are significantly different from the baseline, it may indicate that the class is not progressing as expected, and the instructor may choose to adapt the delivery or management of the class to improve outcomes.

A. Aggregate Daily Usage

The pattern of aggregate daily usage of a course's lecture videos by all students over the course of a semester can provide important insight into how the students are using lecture videos. The purpose of lecture videos is different for face-to-face and flipped classroom models. We explore this with our selected example courses.

The daily usage data for the face-to-face Human Physiology course and the flipped Introduction to Psychological Statistics course are presented in Figure 4. The total watch duration in hours, the number of accesses to the videos, as well as the number of unique accesses where the student started a new viewing session, are displayed.

The daily usage data for the Human Physiology course is presented in Figure 4a, while the daily usage for the Introduction to Psychological Statistics course is presented in Figure 4b. It is clear from the graphs that the usage of videos varies widely over the semester for both courses. In Figure 4a for the face-to-face Human Physiology course, there are four distinct periods of peak usage, while the usage is relatively low for the remaining duration. We verified with the course instructor that these periods corresponded to the quizzes and the final exam in the course. The usage displayed in Figure 4b for the flipped Introduction to Psychological Statistics course, is more evenly distributed in comparison. While certain days

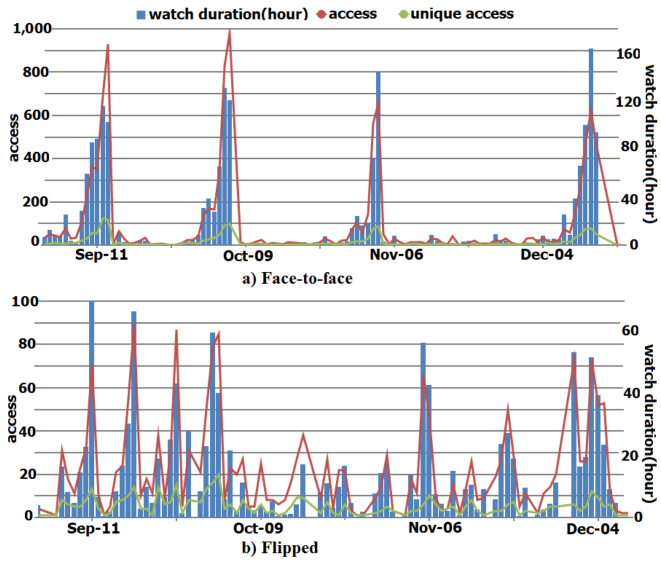

Fig. 4. Daily usage for the face-to-face Human Physiology course(a), and the flipped Introduction to Psychological Statistics course(b). Each point on the X axis represents one day in the semester.

still display much higher usage than others, these peaks occur roughly at weekly intervals. The relevance for the instructor in this case is that the students are viewing lecture videos weekly, in line with what the flipped classroom model calls for.

The aggregate usage pattern provides important insight into student usage behavior. As examples, the usage pattern can indicate whether lecture video is being primarily used for review of the material and/or as a substitute for attending a class, whether the usage meets the expectation of a flipped classroom, and whether weekends and holidays are being used for reviews.

B. Aggregate Usage Across Lectures

The relative usage of lecture videos for different lectures in a course can provide additional insight to an instructor about the relative difficulty of the content of different lectures as well as student behavior. Figure 5 shows how much each lecture in a given course was watched by students as a group. Similar to the daily usage graph, this graph plots total watch duration in hours, the number of accesses, and the number of unique accesses, for each individual lecture video.

Figure 5a shows the viewership of the individual lecture videos in the face-to-face Human Physiology course while Figure 5b plots the corresponding data for the flipped Introduction to Psychological Statistics course. For both courses, we observe significant variation from one lecture to another; several videos are watched over 2x the average while others are watched under half the average. The most likely explanation is simply the relevance and complexity of the content in each lecture. As a trivial example, it is not surprising that the first lecture in each course is watched less than average as the first lecture typically contains logistical information for the course that is unlikely to require intensive review prior to an exam.

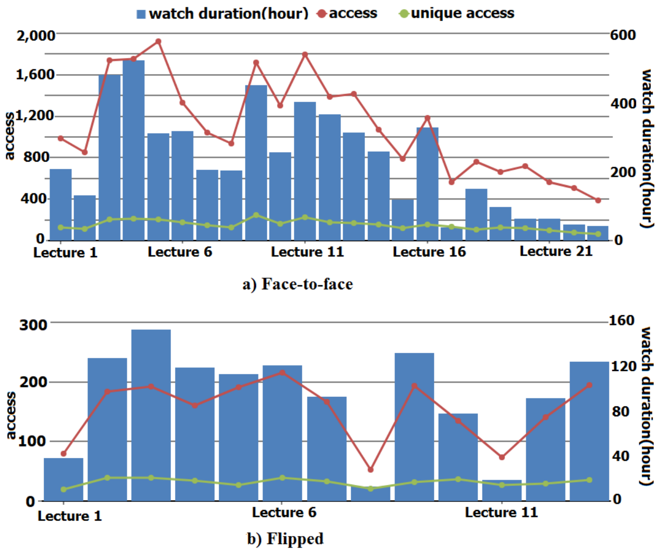

Fig. 5. Cumulative usage for the face-to-face Human Physiology course(a), and the flipped Introduction to Psychological Statistics course(b). Each point on the X axis represents one video covering one lecture in the course.

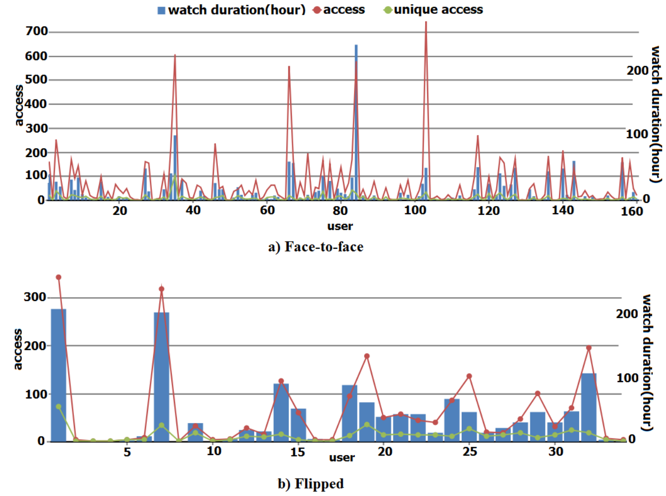

Fig. 6. Individual usage for the face-to-face Human Physiology course(a), and the flipped Introduction to Psychological Statistics course(b). Each point on the X axis represents aggregate usage by one student user over the course of the semester.

In general, the duration of viewing is expected to be positively correlated to the difficulty of the content.

We also notice that the lecture usage drops significantly towards the end of the semester for the Human Physiology course while no such pattern is observed for the Introduction to Psychological Statistics course. This may also be related to the fact that the flipped format requires watching the videos, while they are optional for the face-to-face course. More likely, the primary reason is simply that a significant portion of the class drops the course towards the end, and/or sheer exhaustion that sets in towards the end of the semester for some students. Both these trends are more likely for the large undergraduate course that we picked as the face-to-face course and less likely for the small graduate course selected as the flipped course. The graphs simply provide information for the instructor to interpret and act on as appropriate.

C. Individual Student Usage

The graphs discussed so far show the behavior of course users as a whole and not individual users. It is not clear if any observed behavior is the result of a small number of highly active viewers, or the result of a larger number of less active viewers. Further, it is important for an instructor to know what fraction of the students are actively engaging in the course with lecture videos. For these reasons, the video analytics framework also displays graphs that show how individual students use the lecture videos.

Figure 6 shows aggregate usage by each individual user over the course of the semester for a given course. As with the previous graphs, this graph plots total watch duration in hours, the number of accesses to the videos, and the number of unique accesses to the videos, for each student.

Figure 6a shows individual video lecture usage for the face-to-face Human Physiology course while Figure 6b plots the corresponding data for the flipped Introduction to Psychological Statistics course. Perhaps not surprisingly, the usage varies wildly among students. In both classes, many students watched almost no lecture videos at all, while a few logged over 200 hours, representing watching each video over 5 times on average. This is indicative of the varying effort put in by different students. The fraction of students with very low viewership was much larger in the Human Physiology course in comparison to the Introduction to Psychological Statistics course. One of the possible reasons is simply that the flipped classroom format "requires" watching lecture videos unlike a face-to-face class. In general, we consider the video watching pattern across students as important input for the instructors, although the precise interpretation depends on the content and structure of the course.

Video lecture usage pattern across the students is also summarized and displayed in the analytics suite as total usage by the most active quartile of students, as well as the most active 50% and 75% of students. This allows instructors to easily determine the relative usage by the most active and least active users. If a very high percentage of usage is from the top quartile, this is indicative of most students viewing or reviewing the lectures very sparingly, with only a small group doing participating actively. If the usage is more evenly distributed among the quartiles, this is indicative of a wider range of students making significant use of the lecture videos.

Figure 7a shows the usage by quartiles for the students in the face-to-face Human Physiology course, while Figure 7b shows the corresponding information for the flipped Introduction to Psychological Statistics. The figure clearly illustrates the wide diversity in the watching habits of users. For the Human Physiology course, the top 25% of the users account for over 80% of total video usage while the top half of users account for nearly 98% of usage. Again, this clearly shows that

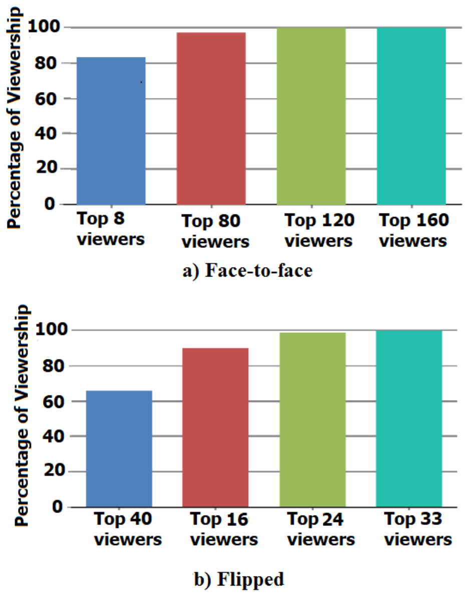

Fig. 7. Student usage for the face-to-face Human Physiology course(a), and the flipped Introduction to Psychological Statistics course(b) based on quartiles. The bars represent usage by top 25%, 50%, 75% and 100% of users.

most usage is coming from a relatively small and dedicated group of students, with large portions of the class using the lecture videos sparingly. For the Introduction to Psychological Statistics course, Figure 7b shows that usage is more evenly distributed. The top 25% of users are responsible for just over 60% of usage, while the top 50% is responsible for just under 90% of usage. Again, one of the likely reasons is simply that the flipped model requires watching lecture videos.

The previous two graphs can help the instructor understand another dimension of lecture usage, specifically the fraction of students that engage and benefit from the availability of lecture videos. With additional insight, the instructor may be able to judge the reasons for this behavior that can be varied. Some students may not need to review, some may not have time to review, while others may be relying on alternate resources like textbooks or notes for their review.

D. Summary of Usage Patterns

We summarize the key observations from analyzing the lecture video analytics for the face-to-face Human Physiology course and the flipped Introduction to Psychological Statistics course.

- The usage across the semester varied widely by dates of the semester but was more evenly distributed for the flipped course. The usage peaks prior to tests and quizzes.
- For both courses, the extent to which a lecture was watched varied significantly; from over 2x the average to less than half the average. We hypothesize this corresponds to relevance and complexity of the lecture content.
- Total usage among individual students varied a lot for both the courses. However, the variation was wider for the face-to-face course in comparison to the flipped course.

The case study illustrates how video usage analytics can be employed to understand student behavior, which can then be used to improve the course offering. Also, instructor insight is central to making the best usage of the analytics information.

VI. Concluding Remarks

This paper reports on a novel application of lecture videos: the ability to monitor the usage of this learning resource as a tool for instructors. This is typically not possible with other learning resources like textbooks and class notes. The key contribution of this work is a framework to elucidate lecture video usage patterns, which in turn can be used to improve class offerings.

The paper presented an analysis of lecture video analytics for two courses in detail; a large face-to-face undergraduate course and a relatively small flipped classroom graduate course. The objective of these case studies is to illustrate how an instructor can analyze the usage of lecture videos and use this information to understand student behavior and potentially improve course offerings. Several common expected differences between these two types of courses were independently inferred from the analytics data. Hence the analytics allow instructors to determine whether or not students are behaving in a manner consistent with their expectations for the course, and empower them to adapt if their expectations are not met.

This paper presents an exploratory study. Future work will involve working closely with instructors in conducting the courses. This will allow us to verify whether the user patterns we observed match the hypotheses we present for their occurrence. Another important direction of future work is to study the correlation between usage patterns and academic performance. For instance, it will be interesting to infer how often heavy usage of lecture videos is a result of a student struggling academically, or if it is the behavior of a student who is performing well but eager to improve in the course. Similarly it would be useful to infer how often the lack of use of videos leads to weak performance, and how often it is simply due to the fact that a well performing student did not need the assistance provided by this resource.

The ultimate goal of this research is to enhance science and engineering education by making lecture video a powerful learning companion for students and an effective course management tool for instructors.

Acknowledgments

We would like to acknowledge the contributions of several members of the ICS Videos group that developed the infrastructure for the project. We thank the students in the classes for their participation. Most importantly, we would like to thank the instructors who helped in conducting the two case studies, Chad Wayne and Christopher Barr. We also thank Richard Knapp, for his input in designing the video analytics framework.

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