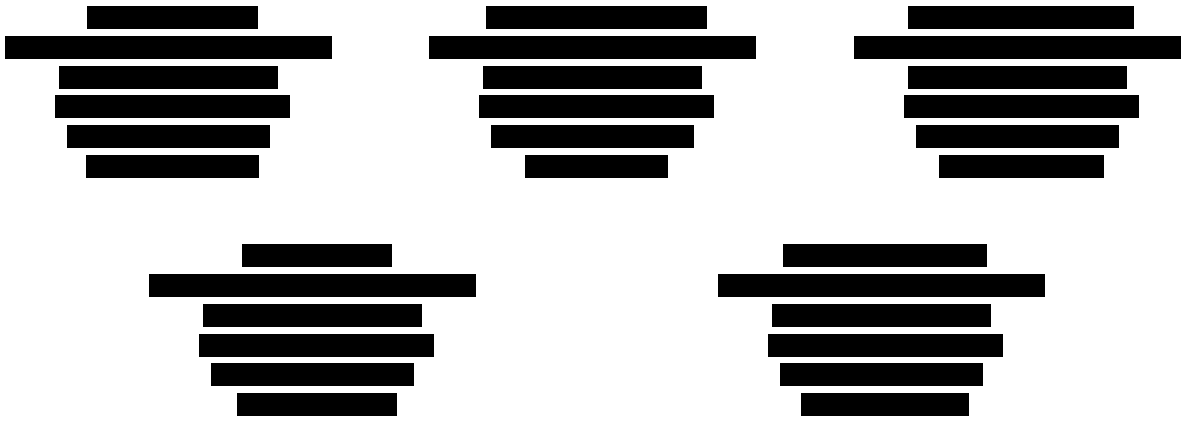
Every Click You Make, Every Break You Take, We'll Be Watching You



***Abstract*—This research paper investigates Pre-recorded Lecture Video (PLV) viewership habits and elucidates correlations between practice and course performance. The use of PLVs and Flipped Class Formats (FCFs) is becoming ever more prevalent in colleges and universities, with many motivating factors. Delivering content that was traditionally done didactically in a format that is both accessible and engaging has many benefits to not only the students but also instructors. For example, students can view and review PLVs as many times as needed, at their convenience, until they have a suitable understanding of the material. From an instructional standpoint, PLVs and FCFs allow for more interaction within the classroom, whether it is through instructor-led examples or peer-to-peer learning activities. As with any new instructional technique, there are best practices that maximize both student performance and satisfaction, often guided by research. Previous studies have investigated both student use and interaction mechanisms of PLVs, specifically their level of viewership and completion of conceptual check-point questions that could be answered while or after watching assigned videos. Students who had substantial viewership and interacted with the PLVs through the answering of questions witnessed a statistically significant increase in their course grades when compared to those who did not. However, viewership and interaction with a PLV do not tell the whole story. To this end, it is important to understand how students use PLVs, and more specifically, what habits they form while watching PLVs and how this behavior affects their performance in the course.**

During two years, a total of 445 students enrolled in a sophomore-level Statics and Mechanics of Materials 1 course were instructed using PLVs and an FCF. The students were required to view PLVs before class (on the University's approved Learning Management System, Canvas, using Panopto) and answer basic conceptual questions on Top Hat. Student viewership data (date and time watched, minutes delivered, etc.) was collected through Panopto. PLV viewership habits, namely full-watching (e.g., watching and skipping, watching and rewinding), partial-watching (e.g., in-complete watching, skipping), and no viewership, were ascertained. Additionally, normalized viewership and average number of views per video were characterized. Correlations are drawn between viewership habits and final course grade. It was seen students in the lower-performing group displayed poor habits with the PLVs (i.e., had low normalized viewership, did not view many videos), whereas the students in the middle and higher performing groups displayed much better viewing habits (i.e., the opposite of low-performing students) and therefore performed better in terms of final course grade. It was also seen that the Top Hat cohort had a greater upward mobility than their Traditional textbook counterparts.

***Index Terms*—Flipped class format, online lecture videos, engagement with digital media**

I. Introduction

In recent years, the traditional model of education has experienced a significant transformation, largely driven by advancements in technology and pedagogical innovations. One particularly favored approach that has gained traction in educational institutions worldwide is the Flipped Classroom Format (FCF). Traditionally, instructors would conduct didactic lectures during class time, resulting in a teacher-centric approach. However, the FCF "flips" this arrangement by moving the lecture component outside the classroom, thereby allowing class time to be more student-centered. This approach affords students the chance to engage with course content before class through Pre-recorded Lecture Videos (PLVs). This, in turn, creates time during class for questions and enhances interaction among students, the instructor, and teaching assistants [1]. Interaction is facilitated through various activities such as instructor-led example problems and collaborative in-class peer worksheets. It has been shown that implementing this newer pedagogy increases student performance [2]. In addition, exposure to this educational approach has improved student perceptions of the FCF itself, with students finding it to be superior to traditional teaching styles, which will be detailed in the following.

A study [3] conducted in 2020 surveyed undergraduate Civil Engineering students (n = 37) to gain insight into their FCF course content and learning activities; this was done through an anonymous online survey. The online survey consisted of Likert scale questions where the highest possible rating was indicated by "5−Completely Agree" and the lowest score indicated by "1−Completely Disagree". Over 95% of student respondents indicated they agreed or completely agreed with the course content being comprehensive, the course content being understandable, and the learning activities being suitable to understand the course topics. Following this survey, three focus groups (n = 6, n = 5, and n = 4) were conducted to gain further insight into how the students felt about the class while also affirming the survey results. The interviews revealed that many students favored the FCF and suggested that they would like it applied to other courses. In another study conducted at the University of North Dakota, students who participated in an FCF were asked which class format they preferred, either the FCF or the traditional lecture. The results indicated that they preferred the FCF over the traditional lecture.

Multiple studies have shown similar results, with students indicating they enjoy the application of the FCF to their courses [4]–[9].

FCFs have been shown to positively affect student performance in the classroom. A study [10] conducted recently compared student performance in a Mechanical Engineering course where one cohort was taught as a traditional didactic lecture (n = 99) and the other an FCF (n = 313). This study was conducted over multiple semesters. To assess the students' performance in the course, their three exam scores, as well as final grades, were compared between the two cohorts. A series of hierarchical multiple regression analyses were performed on their exams and final grades to establish if gender, ethnicity, or the classroom format affected the students' performance. It was shown that classroom format had a statistically significant effect on their first and second exam scores, where the FCF cohort was more likely to score higher than the traditional cohort. Similar results have been seen in both a Software Engineering course [11] and an Introductory Computer Design course [12], where again the FCF cohorts outperformed the traditional lecture cohorts. The FCF has been shown to increase class performance, but interestingly enough Dang et al. saw the largest improvement occurred among the bottom two-thirds of their FCF course [13].

The flipped classroom model hinges on students engaging with lecture materials before class, effectively replacing the traditional in-class lecture. This typically involves providing PLVs for students to watch before class. Understanding how students interact with these videos is vital for gauging their performance in the course. In a study [14] conducted by Dazo et al. on an undergraduate Computer Science course, the effectiveness of the FCF was examined across three semesters: fall 2014, spring 2015, and fall 2015. The study tracked student interactions with PLVs and compared them to their course grades. Three key variables were devised to assess student engagement: videos viewed, content coverage, and punctuality. The 'videos viewed' variable measured the percentage of PLVs accessed out of the total provided for the course. 'Content coverage' offered insights into the percentage of each video watched by students. Lastly, 'punctuality' indicated how many hours before or after class time students engaged with the videos, with positive numbers denoting viewing before class and negative numbers after. Initial findings from the fall 2014 semester revealed a significant lack of engagement with the videos. To address this, reflective questions were added to the PLVs in the spring 2015 semester. However, this did not substantially improve engagement. Consequently, midway through the semester, participation in discussions related to the videos was made mandatory. This participation requirement continued into the following semesters.

To investigate the relationship between the students' viewing habits and class performance a Spearman correlation was conducted between the students' final course grades and each of the three variables described earlier. For the fall 2014 semester, all the variables positively correlated significantly with the final course grade. In the spring and fall 2015 semesters, only the punctuality variable positively correlated significantly with the final course grade. It was believed the reason there were more correlations present the first semester was due to a large portion of the students not engaging with the videos, therefore the smaller portion of students that did properly prepare for the course were likely to perform better than their counterparts. Though these metrics provide insights into how students' performance is potentially linked to their viewing habits, they do not thoroughly quantify how the students are engaging with the PLVs themselves.

Given the extensive research demonstrating the positive impact of FCFs on student performance, along with the limited exploration into how high-achieving students utilize this format and their potential benefits for low-performing students, this study aims to investigate the correlation between students' behaviors when watching PLVs and their academic outcomes. Previous research [15] into how students engaged with PLVs with lecture video questions showed: students who engaged with lecture video questions after watching the PLVs earned half a letter grade higher than those who did these tasks in reverse order; students with a higher normalized viewership earned almost a whole letter grade better in the course than students with lower viewership metrics; students who had a high correctness to attempts ratio (i.e., earnestly tried to answer the lecture video questions) earned a whole letter grade higher than students were merely attempted to obtain participation points. This prior research set the stage for determining what behaviors students had when watching PLVs, and how these behaviors may be correlated to their performance in the course. To date, no such pattern has been identified. Therefore, by analyzing students' video viewership patterns, we aim to identify trends that show a significant impact on student performance.

II. Methodology

Table I provides basic demographic information about the population of students within this study, specifically their major and level of study. It is interesting to note: Mechanical Engineering and Bioengineering majors have the largest percentages of students at 44% and 37%, respectively; the course is predominantly administered to sophomore-level students, with sophomores comprising 68.4% of the total population, followed by junior-level students at 25.8%, and; sophomore-level Mechanical Engineering students are the largest subset of students at 34.6%, following by sophomore-level Bioengineering students at 22.9% of the total population. Approximately 68% of the students within the study's population were male, with females comprising the largely remaining portion, and a very small percentage of students identifying as "other."

The researchers examined the impact of these students' viewing habits on their academic performance by observing said habits of an undergraduate Statics and Mechanics of Materials I course over a two-year period. This particular course was taught by three instructors and adhered to an FCF model. One of the researchers was the instructor of record for all but two of the seven total sections involved in the study. The students in all sections were tasked with viewing PLVs and completing corresponding video questions before attending class. The PLVs were administered via the university's Learning Management System, Canvas. The video questions were administered online through Top Hat. The Fall 2022 semester and the Fall 2023 semester had 66 and 70 PLVs, respectively. A comprehensive set of 175 video questions was administered to help gauge students' grasp of the course material, primarily focusing on their ability to recall fundamental information covered in the videos (reflecting the foundational level of Bloom's taxonomy [16]). Though there were more videos for the following semester, no extra video questions were yet created. Full details about the course development and design can be found in [17]. It is noted that of the seven sections, two used traditional textbooks while the other five used an interactive, online textbook through Top Hat [18]. The sections employing the conventional textbook were examined independently from those utilizing the online interactive textbook.

To understand how student PLV viewing behaviors affected their performance in the course, or if there were noticeable habit changes between the student groups, seven variables were created and observed. The students from each section were categorized into three groups based on their final course grades so they could be analyzed

TABLE I
BASIC DEMOGRAPHICS OF STUDENT PARTICIPANTS IN THE STUDY, NAMELY MAJOR AND LEVEL WITHIN THEIR ACADEMIC CAREER.

	Major										
Level	Mechanical Engineering	Bioengineering	Materials Science Engineering	Industrial Engineering	Engineering Science	Civil Engineering	Chemical Engineering	Electrical Engineering	Duquesne 3+2 Program	Undeclared	Total
Freshman	0	0	0	0	0	0	0	0	1	0	1
Sophomore	154	102	17	13	1	0	0	0	0	19	306
Junior	35	56	10	4	6	1	0	1	0	2	115
Senior	6	5	0	8	2	1	1	0	0	0	23
Total	195	163	27	25	9	2	1	1	1	21	445

against the various variables to explain potential viewership habits. The first variable analyzed was denoted as "Average Normalized Viewership" (Avg. Norm. View.). This variable takes the time a student spent watching a video and divides it by the length of said video. This was done for every unique view of a lecture video and then averaged over the total number of unique views the student had. A unique view is accounting for the fact that students could watch the video more than once at a different time. That is to say, if the student watched the video on Tuesday and then watched the same video again on Wednesday, that would be two unique views for that one lecture video.

The next variable that was observed was labeled as "Total Full." This indicates when a student's unique view was the same length as the duration of the corresponding lecture video. This does not necessarily mean the student did in fact watch the whole video. This will be described in greater detail later. The next variable, "Total Partial," is similar to the one that was just discussed. It is when a student's unique view length is shorter than the duration of the lecture video. This again is tallied for each case and is totaled at the end. Both of these variables, theoretically can be greater than the number of total videos, as students have the ability to watch videos multiple times.

When a student fast-forwards in any part of a unique view, this is noted as a skip. All the skips for each unique view are then summed to form the variable denoted as "Total Skip." Whenever a student goes back in time while engaging with a lecture video, this is counted as a rewind for a unique view. Again, these were all summed to form a variable, adeptly named "Total Rewind." Skips and rewinds can occur more than once for a unique view, as one can imagine a student may purposely be rewinding or skipping ahead in search of a specific instance within a lecture video.

To help demonstrate how the variables were applied to the students' viewership habits, Fig. 1 was created. The x-axis is the time duration of a single video from start to end. The y-axis is what the variables would look like based on the viewing habits. From Fig. 1, it is seen that the variables "Full" and "Partial" can be applied independently. A student may watch the video all the way through, or start the video and simply stop watching it prior to the video completion with no rewinds or skips. However, the "Skip" and "Rewind" variables can not be applied on their own. A "Full+Rewind" can occur when a student watches a portion of the video and rewinds at any point. As long as the time delivered is equal to or greater than the duration of the video, that view will be tallied as both a "Full" and "Rewind" behavior. A "Full+Skip+Rewind" can also occur, as described in Fig. 1. A "Full" and "Skip" cannot simultaneously occur as the time delivered would never be equal to or greater than the length of the video. A "Partial+Skip" can occur if a student is watching the lecture video and then skips at any point. As long as the minutes delivered for that view are less than the duration of the video, it would be tallied as both a "Partial" and "Skip" behavior. The same can occur for a "Partial+Rewind," and even a "Partial+Rewind+Skip" behavior (with each behavior being tallied individually). A variable not shown in Fig. 1 is Did Not View, or "DNV." As one would surmise, this variable was tallied when a student did not view a lecture video.

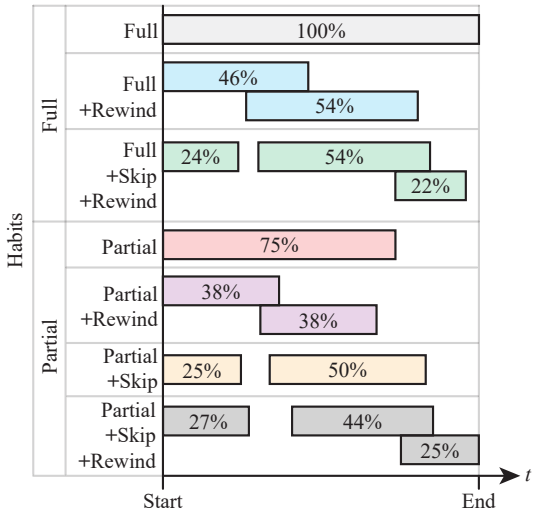


Fig. 1. Descriptions of possible viewing habits based on defined variables. The percentages are used as an example; 100% viewership would indicate a "Full" watch behavior, and anything less places the viewership behavior into the "Partial" category.

One-way between-subjects Analysis of Variances (ANOVAs) were run on the interactive, online textbook cohort to elucidate differences between the groups, and each of the variables discussed above. Before performing a one-way ANOVA, all assumptions were investigated to ensure the accuracy of the results. These assumptions, such as normality, homogeneity of variance, and significant outliers, were all assessed using IBM SPSS Statistics. To check for normality and homogeneity of variance, the Shapiro-Wilk and Levene's test for equality of variances was used, respectively. If a statistically significant difference was detected at a significance level of 0.05 among the groups, subsequent post-hoc analyses were performed to identify these variances; Tukey's Honestly Significant Difference (HSD) test was employed for pairwise comparisons.

The cohorts who used the traditional textbook were analyzed using a Kruskal-Wallis *H*-test to investigate if there were any statistically significant differences between the groups. The Kruskal-Wallis *H*-test is a non-parametric test that is commonly used if the assumption of normality cannot be met [19], which was the case for all variables besides one, "Total DNV." This is noted in Tab. III.

III. RESULTS AND DISCUSSION

In the following sections, student behaviors related to PLVs for the interactive, online textbook, and the traditional textbook, are

presented. Further investigation into how a student's pre-existing GPA influenced their viewership habits, and ultimately course grade, is shown.

A. Interactive Online Textbook Results

The analysis of the seven variables mentioned earlier has been conducted, and the findings will now be presented in the sequence they were introduced, starting with the cohort that used the online, interactive textbook (denoted Top Hat). Before running a one-way ANOVA on these variables, Shapiro-Wilk was used to determine normality. All groups departed significantly from normality ($p < 0.05$) for all seven variables. However, since the sample sizes are roughly equal in size and significantly greater than 40, normality was assumed for all groups [20, 21].

To better understand what kind of viewership habits the different groups of students displayed, and if they were significantly related to their final course grades, a one-way ANOVA was performed between their final course grades and Avg. Norm. View. Normality was assumed due to the sample sizes, as mentioned earlier, but Levene's test showed that the groups violated the conditions of homogeneity. To account for this violation, a Welch's ANOVA was implemented instead [22]. It was determined that the groups did differ significantly from one another, $F(2, 206.91) = 7.985$, $p < 0.001$. These results are summarized in Tab. II. Since the homogeneity of variances was violated, a Games-Howell post-hoc test was conducted for the pairwise comparisons [23]. This revealed statistically significant differences between the <80 group and both the $80-86.\bar{9}$ and ≥ 87 with p-values of 0.001 and 0.026, respectively. The post-hoc analysis revealed that the lowest performing tercile (<80) significantly differed from the other two terciles ($80-86.\bar{9}$ and ≥ 87), with p-values of 0.001 and 0.026.

Next the researchers were interested in whether the "Total Full" watching habits had an impact on the student's performance in the course. Similar to earlier, normality was assumed and it was indicated that there were significant differences between the variances. A Welch's ANOVA was used to examine if there were any statistically significant differences between the groups. The results indicated there was a significant difference, $F(2, 222.98) = 7.985$, $p = 0.002$. A Games-Howell post-hoc analysis revealed significant differences between the <80 group and both the $80-86.\bar{9}$ and ≥ 87 groups, with corresponding p-values of 0.001 and 0.026, respectively.

A one-way ANOVA was implemented to discern if there was a difference between the groups for the "Total Partial" variable. Beforehand, normality was again assumed and the conditions for homogeneity were met based on the results from Levene's Test ($p = 0.055$). The one-way ANOVA revealed there was a statistically significant difference between groups ($F(2,348) = 4.063$, $p = 0.018$). To determine which groups were different from one another, a pairwise comparison of means was performed. Tukey's HSD showed the only difference occurred between the <80 and ≥ 87 groups ($p = 0.013$).

The following variables, "Total Skip" and "Total Rewind," did not satisfy the conditions for a one-way ANOVA as they both violated homogeneity. Therefore, a Welch's ANOVA was used to determine if there were any differences between the groups for both variables. It was seen that the groups, when compared with the aforementioned variables, did differ significantly from one another. The results for the "Total Skip" and "Total Rewind" were $F(2, 219.12) = 8.820$, $p < 0.001$ and $F(2, 209.75) = 8.000$, $p < 0.001$, respectively. The above-mentioned variable, "Total Skip," displayed statistically significant differences between the lower tercile and both the $80-86.\bar{9}$ ($p < 0.001$) and ≥ 87 ($p = 0.012$) terciles. Meanwhile, only the <80 and $80-86.\bar{9}$ groups differed ($p < 0.001$) from one another for the "Total Rewind" variable.

The last two variables satisfied all conditions for a one-way ANOVA, as normality was assumed based on the sample sizes, and Levene's Test determined that the groups did not break homogeneity. The ANOVA showed that there was a significant difference between the groups when compared with the variables "Total DNV" and Average Number of Views (Avg. No. Views). The results were $F(2, 348) = 11.006$, $p < 0.001$ for the "Total DNV" variable and $F(2, 348) = 5.368$, $p = 0.005$ for the "Avg. No. Views" variable. The differences in groups for the "Total DNV" occurred between the <80, and both $80-86.\bar{9}$ and ≥ 87, with a p-value of < 0.001 for each. The "Avg. No. Views" variable had a noticeable change between the lower and higher terciles with a p-value = 0.004, as indicated by Tukey's HSD post-hoc analysis.

B. Interactive Online Textbook Discussion

As depicted in Fig. 2 a), all the mean plots of the seven variables have been normalized and laid over one another to help visualize, not only one habit but how the numerous habits of the grouping of students is compared against their final course grade. This was done for looking at one habit individually does not encompass the totality of the students' habits as they appear to be intertwined together. The data shown in Fig. 2 a) aligns with what was discussed earlier where it is noticeable that the lower tercile (<80) group of students had statistically significant different viewing habits than the students grouped in the middle and higher performing terciles ($80-86.\bar{9}$ and ≥ 87).

Looking at the Avg. Norm. View. in Fig. 3 a), there is about a 40% and 25% difference between the lower and middle terciles and the lower and higher terciles, respectively. It seems logical that as Avg. Norm. View. increased among the groups, that the performance increased within the course. One would expect that the more time you spent engaging with the videos, the better your understanding of the course material, and the higher your final grade would be. Interestingly, the middle tercile had about 25% higher Avg. Norm. View. than the higher performing tercile yet they did not perform as well. This difference was not found to be statistically significant, however looking at this one variable alone might not give enough detail about the viewing habits of students.

The normalized mean plot in Fig.3 a) shows a linearly increasing trend from the lower to higher performing terciles. The largest increase occurred from the lower to middle tercile with an increase of about 35% in "Total Full" views. Then an approximate increase of 10% from the middle to higher tercile. The large increases seen between the lower, and both the middle and higher terciles, align with the post-hoc test results discussed above. It appears that the higher-performing students had more "Full" views than the lower-performing students, and this is shown to be statistically significant. It appears that watching the video in "Full" may lead to a positive effect on the student's performance.

The slope for "Total Partial" appears to be consistent across the three terciles, with a 20% increase from the lower to middle tercile and another 20% increase from the middle to higher tercile, approximately. Tukey's HSD revealed that the only statistically significant difference is between the lower and higher terciles where the higher tercile had about 40% more "Partial Views" than the lower tercile. This leads to the idea that the more a student interacts with the videos, whether it be a "Full" or "Partial" view, the better they perform.

TABLE II
DESCRIPTIVE STATISTICS AND COMPARISON OF MEANS OF TOP HAT DATA SET. GROUP $\geq$87, $n = 124$; 80$-$86.$\bar{9}$, $n = 105$; <80, $n = 122$.

		Group Statistics		Levene's Test for Equality of Variances	One-Way ANOVA		Welch's ANOVA		Shapiro-Wilk Test of Normality
Variable	Group	Mean	σ	Significance	F	Significance	F	Significance	Significance
Avg. Norm. View.	$\geq$87	1.81	2.14	< 0.001	-	-	7.985	< 0.001	< 0.001
	80$-$86.$\bar{9}$	2.49	3.44						< 0.001
	<80	1.17	1.67						< 0.001
Total Full	$\geq$87	10.52	12.09	0.011	-	-	6.447	0.002	< 0.001
	80$-$86.$\bar{9}$	9.65	11.97						< 0.001
	<80	5.95	9.54						< 0.001
Total Partial	$\geq$87	54.81	61.12	0.055	4.063	0.018	-	-	< 0.001
	80$-$86.$\bar{9}$	46.06	59.43						< 0.001
	<80	34.73	44.92						< 0.001
Total Skip	$\geq$87	157.62	155.10	0.002	-	-	8.820	< 0.001	< 0.001
	80$-$86.$\bar{9}$	186.31	180.10						< 0.001
	<80	105.44	126.75						< 0.001
Total Rewind	$\geq$87	26.15	33.85	< 0.001	-	-	8.000	< 0.001	< 0.001
	80$-$86.$\bar{9}$	37.47	46.12						< 0.001
	<80	18.10	25.21						< 0.001
Total DNV	$\geq$87	37.34	20.56	0.527	11.006	< 0.001	-	-	< 0.001
	80$-$86.$\bar{9}$	37.29	19.74						< 0.001
	<80	47.77	19.495						< 0.001
Avg. No. Views	$\geq$87	0.95	0.94	0.061	3.985	0.005	-	-	< 0.001
	80$-$86.$\bar{9}$	0.81	0.93						< 0.001
	<80	0.59	0.71						< 0.001

"Total Skip" and "Total Rewind" exhibit trends similar to Avg. Norm. View. All three metrics show a substantial increase from the lower to the middle terciles, followed by a smaller decrease from the middle to the higher tercile. Significant variations again were seen between the lower and middle terciles for both variables with a significant change being seen between the middle and higher tercile for the "Total Skip" variable. The middle and higher performing terciles spend much less time skipping and rewinding than the lower terciles. This, paired with the earlier observation of Avg. Norm. View., shows that in general the students in the lower tercile are not interacting with the PLVs nearly as much.

The Avg. No. Views mean plot is nearly identical to the "Total Partial" mean plot, where it appears to have a linear increase with a constant slope. The increase from the lower to middle tercile and middle to higher tercile are approximately 15% and 20%, respectively. The "Total DNV" mean plot is the only one that does not replicate any of the earlier patterns mentioned. This initially decreases about 20% from the lower to middle tercile, then is almost invariant from the middle to higher tercile.

Overall the pattern appears to be that the students in the middle and higher terciles are interacting with the videos more than the lower tercile students. This can be seen statistically through multiple post-hoc analyses where the majority of differences were between the lower terciles and both the middle and higher terciles. Looking at the mean plots helps visualize these differences. It would appear that the lack of interaction with the videos, or bad viewing habits, has lead to these students having a lower final grade in the course.

C. Traditional Textbook Results

To observe what kind of habits different level-performing students have with the PLVs, the researchers again compared their final course grades to the seven variables previously described. However, for the cohorts using the traditional textbook, the distribution of the groups departed significantly from normality for all but one variable. The sample sizes of the groups were not large enough to assume normality, therefore a non-parametric Kruskal-Wallis H-Test [19] was used to identify if there was any statistically significant differences between the groups, the subsequent results can be found in Tab. III.

The three groups were compared against all but one variable, "Total DNV," using a Kruskal-Wallis H-Test. This showed that there was a statistically significant difference between groups for the six variables as the p-values were all below 0.05, which can be seen in Tab. III. To ascertain where the differences between the groups were occurring a Dunn's test [24] was used to conduct a pairwise analysis. In addition, a Bonferroni correction was implemented because multiple hypotheses were being tested, which increases the probability of observing a significant difference by chance. This means that the possibility of obtaining a type I error (i.e., a false positive) rises. The Bonferroni correction adjusts for this by controlling the overall error rate, reducing the likelihood of false positives [25]. The outcome of these tests will be described in more detail below.

The Avg. Norm. View. variable showed significant differences between the <78 tercile, and both the 78$-$84.$\bar{9}$ and $\geq$85 terciles, with adjusted p-values of 0.002 and 0.017, respectively. This same pattern was observed in multiple other variables: "Total Full," "Total Partial," "Total Rewind," and Avg. No. Views. This pattern was not reflected in the "Total Skip" variable, where the only difference occurred between the lower tercile (<78) and the middle tercile (78$-$84.$\bar{9}$) with an adjusted p-value of 0.008.

Lastly, the groups were compared using Welch's ANOVA with the sole remaining variable, "Total DNV." This variable followed a normal distribution but violated the assumption of homogeneity of variances. The ANOVA revealed significant differences between the groups, $F(2, 59.093) = 11.098$, $p < 0.001$. A Games-Howell post-hoc test was subsequently conducted to identify where these differences occurred. Significant differences, $p < 0.001$, were once again seen between the <78 tercile, and both the 78$-$84.$\bar{9}$ and $\geq$85 terciles.

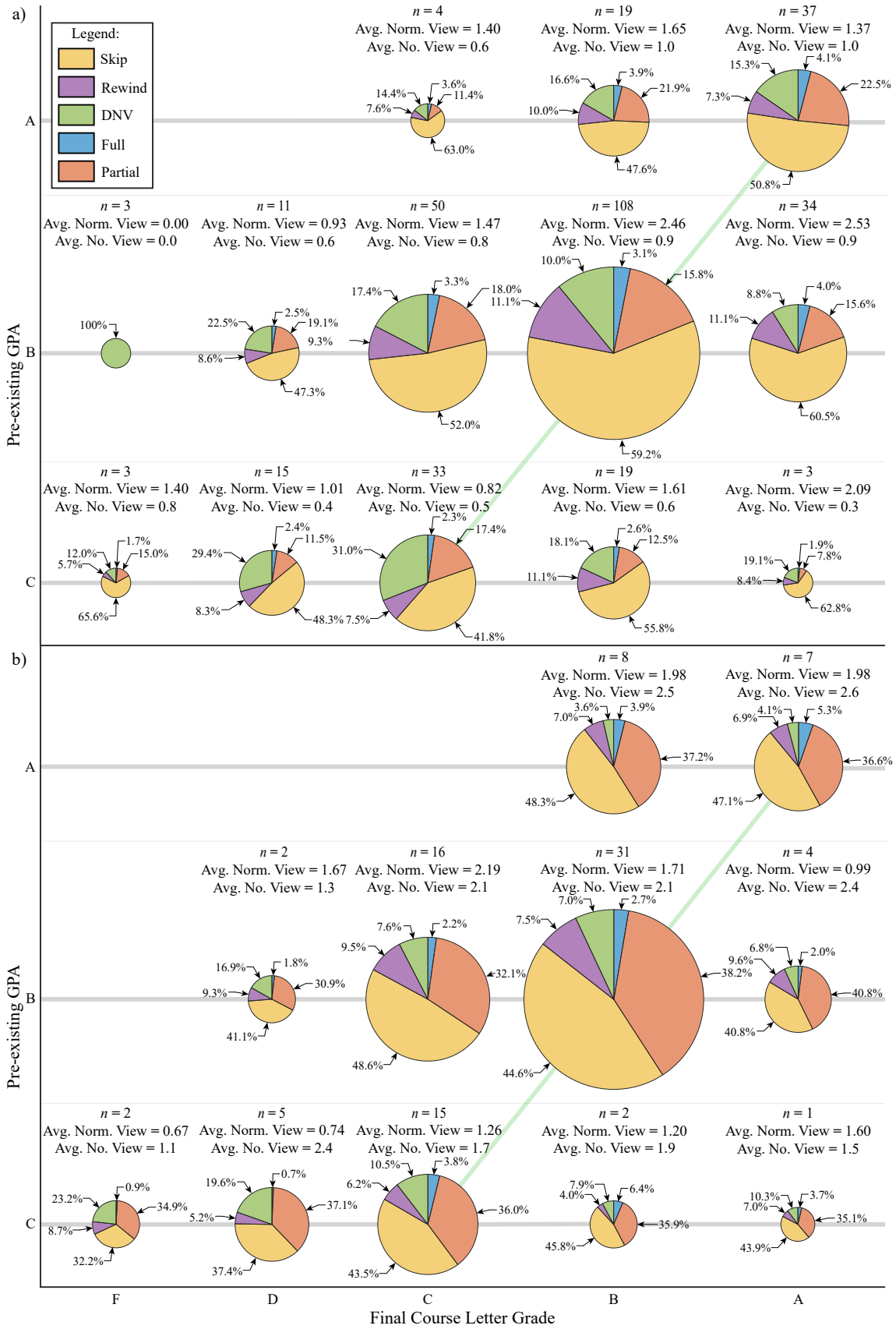


Fig. 2. Cohort metrics (population size n, average normalized viewership, average number of views, and behavior: Skip, Rewind, DNV, Full and Partial) for Final Course Grade (A, B, C, D and F) versus pre-exiting GPA (A, B and C) for students using the a) Top Hat and b) Traditional textbooks.

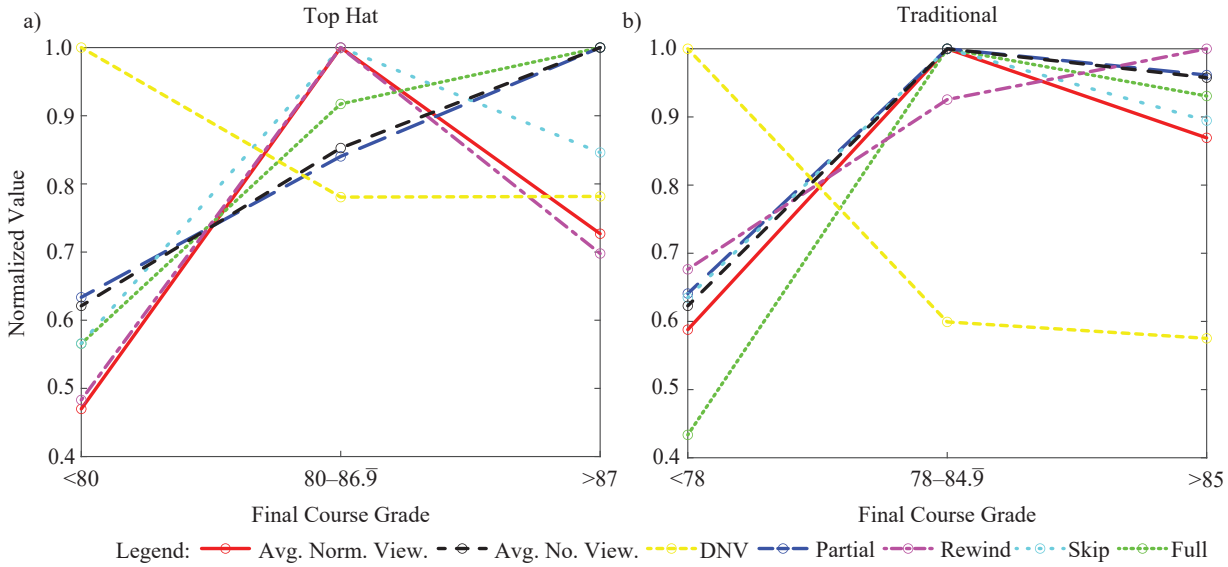


Fig. 3. Normalized Mean Plots of Variables for both the Traditional and Top Hat Textbook Cohorts

TABLE III
DESCRIPTIVE STATISTICS AND COMPARISON OF MEANS OF TRADITIONAL TEXT DATA SET. GROUP $\geq$85, $n = 29$; 78$-$84.$\bar{9}$, $n = 36$; <78, $n = 30$.

		Group Statistics		Levene's Test for Equality of Variances	Kruskal-Wallis H-Test		Welch's ANOVA		Shapiro-Wilk Test of Normality
Variable	Group	Mean	σ	Significance	H	Asymptotic Sig.	F	Significance	Significance
Avg. Norm. View.	$\geq$85 78$-$84.$\bar{9}$ <78	1.73 1.99 1.17	0.98 1.29 1.32	-	13.202	0.001	-	-	< 0.001 < 0.001 0.043
Total Full	$\geq$85 78$-$84.$\bar{9}$ <78	13.03 14.00 6.07	13.16 10.96 8.15	-	12.483	0.002	-	-	< 0.001 0.003 0.001
Total Partial	$\geq$85 78$-$84.$\bar{9}$ <78	143.81 148.81 95.37	66.60 57.17 77.87	-	11.563	0.003	-	-	0.028 0.031 0.017
Total Skip	$\geq$85 78$-$84.$\bar{9}$ <78	170.59 190.69 121.10	82.24 100.97 97.52	-	9.849	0.007	-	-	0.009 0.003 0.007
Total Rewind	$\geq$85 78$-$84.$\bar{9}$ <78	31.00 28.69 20.97	20.81 18.59 25.94	-	10.635	0.005	-	-	< 0.001 < 0.001 < 0.001
Total DNV	$\geq$85 78$-$84.$\bar{9}$ <78	22.45 23.39 39.03	12.34 13.14 16.50	0.046	-	-	11.098	< 0.001	0.159 0.390 0.058
Avg. No. Views	$\geq$85 78$-$84.$\bar{9}$ <78	2.26 2.34 1.48	0.96 0.87 1.16	-	13.802	0.001	-	-	0.049 0.011 0.004

D. Traditional Textbook Discussion

The traditional mean plots in Fig. 3 b) reveal a pattern similar to what was observed in the Top Hat cohort. Most variables show a substantial increase (30-55%) from the lower to middle tercile, followed by a slight decrease (5-15%) towards the higher tercile. This pattern is evident in the Avg. Norm. View., Avg. No. Views, "Total Partial," "Total Skip," and "Total Full" variables. This trend supports the idea that lower-performing students interact less with the PLVs than middle and high tercile students. A Dunn's pairwise comparison confirmed that the differences between the lower tercile and both the middle and higher terciles were statistically significant.

The "Total Rewind" variable exhibited a slightly different trend. Instead of peaking at the middle tercile, it increased by about 20% from the lower to middle tercile and continued to rise by another 10% from the middle to higher tercile. The increase from the lower to the higher terciles was statistically significant, further indicating that lower-performing students interact less with the videos than their peers. This finding is reinforced by the "Total DNV" variable.

For the "Total DNV" variable in the Traditional textbook cohort, the pattern mirrored that of the Top Hat textbook. There was a substantial decrease (around 40%) in the number of videos not viewed from the lower to middle tercile, which then leveled off in the higher tercile. This supports the idea that lower-performing students' viewing habits negatively impact their final course grades. However, the broad grade ranges within each tercile (with the lower tercile covering grades from C+ to F) suggest that a more granular

classification might provide better insights.

E. Pre-Existing GPA Discussion

In an attempt to better understand students' viewing habits and how they relate to their pre-existing and final course grades, Figs. 2 a) and b) were created. The y-axis is the student's pre-existing GPA, or GPA when entering the course, and the x-axis is the student's final grade in the course. The size of the pie charts is determined by the number of students that fall into a specific location in the table. Note the relative sizes between the two cohorts are different, due to the Traditional textbook cohort having very small sample sizes for some of the populations. These pie charts are then divided into normalized percentages of their viewing habits, with the colors referencing specific viewing habits denoted by the legend. The sample size, Avg. Norm. View. and Avg. No. Views are listed, from top to bottom, above the pie charts for the various distinct outcomes. This was done for both the Top Hat and Traditional textbook groups. It's important to note that no statistical analysis was conducted on these figures, and any comments are strictly observational.

Comparing the habits of students who entered the course with an A and left with an A, and those who entered the course with an A and left with a B, their habits appear nearly identical for both the Top Hat and Traditional sections. This same pattern holds for students who entered the course with a B and left with an A, and those who entered with a B and left with a B. This suggests that students with a pre-existing GPA of an A have similar habits, yet their performances differed by a letter grade. This situation is comparable to the pre-existing B students as well. Unfortunately, there is still not enough information to determine what might be causing this drop or increase in performance, although the habits are nearly the same. However, it suggests that students with GPAs corresponding to an A or B have similar habits that potentially enable them to perform higher than students entering with lower GPAs.

When comparing the Top Hat textbook students against the Traditional students, there appear to be some differences. First, students in the Traditional textbook sections have a higher average number of views per video than the Top Hat groups. The "DNV" percentages are higher in the Top Hat groups as well. This indicates that the students in the Traditional textbook group watched the videos more often than the students who used the Top Hat textbook. One possibility is that the students in the Top Hat section were incentivized to use their book because the embedded questions in their book counted towards their participation grade. The students using the Traditional book, although instructed to read the textbook, had no incentive to use their book. Studies have shown that about 40% of students tend not to use their textbooks [17, 26, 27]. If the Traditional textbook cohort was not using their book as often as the other cohort, they may have been relying more on the videos to further their understanding.

Looking at the students who entered with an A in the Traditional cohort, more than half left with a grade other than an A. Most of the students who entered with a B tended to leave with the same score (about 58%), with only about 8% leaving with an A and about 34% leaving with a lower score. Students who entered with a C also tended to leave with the same grade (approximately 60%), while about 28% received a lower grade and 12% received a higher grade.

Observing the Top Hat group, a higher percentage of students who entered with an A left with an A (62% compared to 53% in the Traditional cohort). Similarly, the majority of students who entered with a B also left with a B (about 52%), but a larger percentage improved their grades to an A (31% compared to 8% in the Traditional textbook cohort). This trend continued with the C students; a larger percentage improved their grades (about 30% compared to 12% in the Traditional textbook cohort), 45% left with the same score, and only 24% left with a lower score. It seems that students in the Top Hat cohort were more likely to leave the course with the same or an improved score compared to their Traditional cohort counterparts. That is to say, when viewing the green diagonal line, or neutral line (those who entered and exited with the same GPA/course grade), there appears to be more upward grade mobility with students who used the Top Hat textbook than the Traditional textbook.

IV. Conclusion

The goal of this study was to see if students' viewing habits had an impact on their performance within a Statics and Mechanics of Materials I course. Seven variables were created using the quantitative data provided by Panopto to assess how the students were interacting with the videos. To understand if any of the habits were statistically significant, multiple analyses were performed to include, but not limited to, ANOVAs, non-parametric tests, and pairwise comparisons. All seven of the variables proved to have a statistically significant effect on the the students' final grades for both the Top Hat and Traditional textbook sections. Multiple post-hoc analyses were done to locate where the differences between the groups were occurring.

It was shown that significant differences in the Top Hat cohort appeared between the lower tercile (<80) and both the middle (80-86.$\bar{9}$) and higher ($\geq$87) terciles for the Avg. Norm. View. (p = 0.001, p = 0.026), "Total Full (p = 0.031, p = 0.003)," "Total Skip (p < 0.001, p = 0.022)," and the "Total DNV (p < 0.001, p < 0.001)" variables. The "Total Partial" and "Avg. No. Views" saw differences between the lower and higher terciles with p-values of 0.013 and 0.004, respectively. The last variable, "Total Rewind," only saw differences between the lower and middle terciles with a p-value of < 0.001.

All variables, besides "Total Skip," saw significant differences between the lower (<78) and both the middle (78-84.$\bar{9}$) and higher ($\geq$85) terciles. The variables and their respective p-values are as follows: Avg. Norm. View. (p = 0.002, p = 0.017), "Total Full (p = 0.002, p = 0.048)," "Total Partial (p = 0.004, p = 0.028)," "Total Rewind (p = 0.012, p = 0.016)," "Avg. No. Views (p = 0.001, p = 0.013), and "Total DNV (($p \geq$ 0.001, $p \geq$ 0.003)." The final variable, "Total Skip," had a significant difference between the lower and higher tercile with a $p-$value of 0.008.

Though we recognized some differences between the lower terciles and the middle and higher terciles, we still did not gain much insight in the differences in habits between the middle and higher tercile students. Without being able to corroborate the video-watching behaviors with students' interactions with either their books, lecture video questions, or homework questions, we may be missing information that differentiates the higher-performing students from the middle-performing students. The data showed that in the middle and higher performing terciles, students' habits range drastically which can be seen based on the standard deviations provided in both Tabs. II and III. That is, we see there are students in the middle performing terciles that display similar habits to students who are in both the lower and higher terciles, and vice versa. Yet, why do they perform differently from one another? It appears we only have a small piece of information regarding what may be influencing student success.

In the future, the researchers would like to investigate how long prior to, or after, class the students are engaging with the PLVs. Other studies have shown this may be play an important role in terms of students' performance within the course. Furthermore, more definitive and robust variables should be created to better identify

and understand the viewing habits of the students as well. That is, instead of just tallying the individual skips and rewinds, we could indicate whether a view was a "Partial+Skip+Rewind" instead. Previously mentioned, was the idea of correlating the times students were engaging with the PLVs and the other course assignments. This would indicate that the students are potentially using them alongside course assignments to further their understanding of the material. In the future, tracking the students' viewing habits for each lecture video and then comparing them to their exam scores and final course grades. Doing so may provide insight into if viewership habits change over time and how that change potentially impacts their performance in the course. This future work should be applied to both the Top Hat and Traditional textbook cohorts.

During this research it was seen that the Top Hat cohort appeared to have lower Avg. Norm. Viewe. values than the Traditional textbook cohort. It was noted in another study [28] that students would typically use the method they preferred when completing the course assignments in the Top Hat sections. That is, some students preferred using the PLVs to study the course material over the Top Hat textbook, and therefore would only watch the PLVs, whereas some students felt the opposite; they would only use the Top Hat textbook and essentially ignored the PLVs. This may be the cause for the change in Avg. Norm. View., but it may also be because the Top Hat group had an incentive to use the book over the PLVs.

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