Time for Reflection: Development of Twenty Short Videos to Introduce New Topics and Engage Students in Circuit Theory

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One of the essential components of the Kolb Experiential Learning Cycle is allowing students the time to reflect on new experiences prior to abstraction and application of new material. Most commonly this is attempted by assigning readings from a textbook, but research suggests that few students complete these readings. This discouraging fact has prompted the use of videos to supplement pre-class readings to introduce new material in courses such as Circuit Theory. Unfortunately, most existing video resources on Circuit Theory topics are overly long, dull, or lacking in production quality. In addition, many of these videos are monetized by running advertisements, which may deter students from watching. To overcome these issues, 20 short videos were created for an introductory circuits course. These videos are generally shorter than five minutes, are written with simple, real world or pop culture illustrations and humor, and include a worked-out example. The videos are freely available on YouTube, without advertisements. The efficacy and value of the videos were assessed via course exams and quizzes, an end-of-course student survey, and YouTube analytics. The results indicate that 85% of the students felt that the videos helped them prepare for class, and 92% would recommend the videos to students taking Circuit Theory at another university. When asked how much they would pay for the set of videos, the average response was $19.30. The videos may have also had a positive impact on student learning. Students having access to the videos scored 8.36% higher on the final exam than did comparable students taking the same exam the previous year. This paper contributes to electrical engineering education by providing a freely available set of videos that other instructors may use to increase student engagement and learning.

Introduction

One way to enhance student learning is to involve students in experiential learning. This can be as complicated as laboratory experiences or projects, or as simple as providing students an active role in lecture. To facilitate student involvement in a lecture format, students must be prepared to contribute to the discussion of new material.

One common model for experiential learning is the Kolb Experiential Learning Cycle [1,2], which has four steps: 1. Introduction of new experience, 2. Reflection on this experience, 3. Abstraction of this experience, and 4. Application of this experience. An essential component of this cycle is allowing students the time to reflect on new experiences. If students are introduced to a new topic during lecture, little reflection can take place prior to abstraction or application of that material. This makes it important for students to be introduced to new content prior to class. Most often, this is attempted by assigning readings from textbooks. However, research suggests that students take advantage of few textbook features, preferring to use the text as a reference, rather than a self-study guide [3]. One study suggests that as few as 24.8% of students read the textbook prior to class [4]. One alternative is the development of videos that introduce new material prior to class to help students prepare and have time for reflection.

While this alternative is not novel, finding a unified set of videos that cover both DC and AC circuits is challenging. In addition, most existing video resources are overly long, dull, or lacking in production quality, and many videos include advertisements which may deter students from

watching. To overcome these challenges, a unified set of 20 pre-class videos was developed to supplement textbook reading assignments as a means to introduce new material to students, allowing time to reflect upon new content prior to lecture. The videos cover topics common to many Circuit Theory courses at a variety of universities [5]. Some topics were very basic (Ohm's Law, Kirchoff's Laws) while others were more complex (Thevenin's Theorem, AC Circuits). It is particularly important to introduce the complex topics before class, as these are beyond pre-requisite knowledge from Physics 2 [6]. These videos are presented in this paper as a resource to other educators interested in adopting them in their Circuit Theory courses.

To assess the efficacy of these videos, both direct and indirect assessment tools were used. As a direct metric, student exam scores for the four course exams were compared to those from students who took the same course the previous year, without the videos. In addition, student video quiz results were used to assess whether or not students watched and retained video information. As an indirect metric, students were surveyed about their experience with the videos.

The specific questions we aimed to answer through these direct and indirect assessments included:

1. Did students watch the videos?
2. Did students perform better because of the videos?
3. Did students feel that they were better prepared for class because of the videos?
4. Were the videos an appropriate length?
5. Did the humor in the videos make them memorable?
6. Did students value the videos?

Literature Review

The literature is rich with descriptions of methods that have been used in an attempt to increase the quality and amount of pre-class preparation. We classify methods reported into two major categories: those that involve reading a traditional textbook, and those that do not. Some of the literature is evidence based, while others are written as resources for instructors to try new methods.

Methods tested or suggested to improve reading rate and effectiveness include: requiring students to complete a reading exercise connected to the reading [7, 8, 9], using in-class quizzes [10, 11, 12], testing on material in the text that was not covered in lecture [10, 12], assigning shorter readings [10], preparing pre-college students to use textbooks successfully [13, 14], awarding extra credit [11, 15], adopting textbooks early [16], and using in-class activities to demonstrate the intrinsic importance of reading [17].

Non-textbook based methods include the use of video in the context of "flipped" lectures [18], use of eText books [19, 20, 21], use of web-facilitated discussion tools [22, 23], and use of video or multimedia presentations in a similar manner to this study [24, 25, 26, 27]. Regarding the latter, Stelzer et al [24] describe the use of multimedia learning modules (MLM) to support an introductory electricity and magnetism course at the University of Illinois. Their results suggest that multimedia modules can have a significant positive impact on "post-lesson assessment," and student exam performance. Sadaghiana [25] reports using the same MLMs at Cal Poly Pomona. Their study indicates that students would rather view the MLMs than read the text, and consider

the MLMs beneficial to their learning. Fraley et al [26] implemented the use of pre-lesson videos and quizzes for a first-year engineering course at Michigan Tech. They prepared roughly 30 videos on a number of topics, but mostly on software tools (Excel and MATLAB). Based on analysis of scored course assessments, they concluded that watching the videos leads to an increase in score, suggesting that the students who watch the videos learn the course material more effectively.

Of the videos created for the present study, all but one were less than 5 minutes long, while the remaining video was just over 6 minutes long, which is consistent with the well-known rule of thumb that online videos should be less than 6 minutes in length [28]. However, we note that there is not universal agreement on this rule [29, 30, 31].

All of the videos produced include an element of humor as a means of engaging students. Use of humor has been studied as a means for creating a classroom environment that is conducive to student learning in STEM fields [32, 33], but not, apparently, for online videos. There is evidence, however, that videos produced with a "more personal feel" (which could include humor) can be more engaging [28].

Methods for Video Production

The topics covered in the videos described in this paper are shown in Table 1. The first fourteen videos deal with DC circuits, including foundational content such as Ohm's and Kirchoff's Laws, as well as more complicated topics such as operational amplifiers and maximum power transfer. The remaining six videos cover similar topics in AC circuits. As AC Circuits generally require the same procedures as DC, but with phasors, six videos effectively covered the bulk of what was deemed important by the course instructor.

Each video followed the same general structure. First, a seemingly unrelated anecdote from pop culture is presented. Then, this anecdote is related to the Circuit Theory topic to be introduced, along with an introductory description of the theory and the procedure and a worked-out example. Finally, the memorable take-away points of the video are reiterated before the video ends.

The main part of these videos is the presenter speaking to the camera, which may allow the audience to feel some sense of connection with the presenter. During these segments, a variety of images are shown which relate to what is being said in a humorous way. Often these images are pop culture references or puns.

Table 1: Content of videos.

DC Circuits			**AC Circuits**	
1. Ohm's Law	6. Nodal Analysis	11. Operational Amplifiers	15. Phasors and Impedance	18. Superposition in AC
2. KVL	7. Supernodes	12. Thevenin's Theorem	16. Nodal in AC	19. Thevenin in AC
3. KCL	8. Loop Analysis	13. Maximum Power Transfer	17. Loops in AC	20. AC Power
4. Voltage Division	9. Superloops	14. RC Circuits		
5. Combining Resistors	10. Superposition			

The following procedure was used to produce these videos:

1. Write and revise a script which outlines the video and specific references.
2. Record the worked-out example in Panopto screen capture software, using Notability or Microsoft OneNote with a Wacom tablet serving as the input.
3. Upload and process screen capture through Panopto.
4. Change the podcast setting on Panopto to encode the primary screen video at 1080p.
5. Download the resulting mp4 file.
6. Record the live video. Live video was captured using a GoPro Hero 5 Session camera set to capture 1080p resolution. This camera was chosen for its relatively low cost and worked adequately for the purpose of these videos.
7. During the live video recording, audio is captured through a Blue Yeti USB microphone connected to an Apple MacBook Pro, streaming audio into Garage Band, which was set for Narration Vocal input.
8. Transfer audio and video files into iMovie.
9. First editing pass to synchronize audio and video and remove mistakes made in recording, cutting the length down as much as possible while retaining the essential elements of the video (Introduction, Transition, Theory, Example, Conclusion).
10. Import screen capture footage into iMovie and edit to match the voiceover.
11. Carefully listen to the video and add humorous annotations and reference images relevant to what was being discussed. These images were found using Google, with most coming from Wikimedia Commons.
12. Final check of video to catch any remaining mistakes.
13. Export to m4v file, the standard iMovie encoding.
14. Upload file to YouTube and back up accompanying project files.

The entire production process required 5 to 8 hours for each 5-minute video. While this initial cost is very high, it is intended that these videos will be used for many years to come, and that other universities may adopt them as a resource. The playlist containing all of the videos can be found at https://www.youtube.com/DMExplains, in the Dr. McPheron Explains Circuits playlist (https://bit.ly/2Jq32K2), give the reader a feel for the particular style of these videos, a screenshot is shown. Figure 1, captured from the video on resistor combination, displays an image of Apple's Siri, making a pun on 'series'. This type of pun-based humor is chosen to avoid offending the audience, and because it has experientially shown to be effective with engineering students.

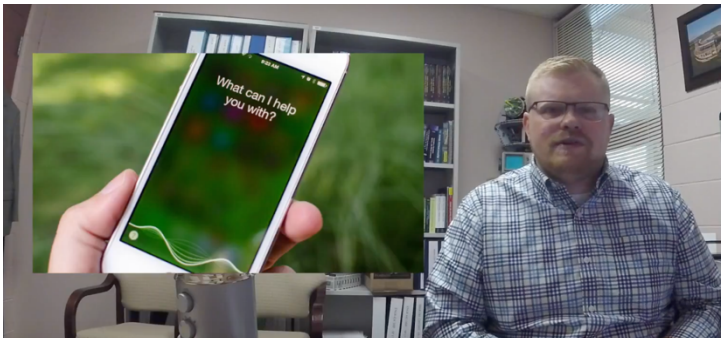

Figure 1: Example of a reference to the "Siri's Resistors" in the video about combining resistors.

Assessment and Discussion

While there is distinct value in producing and presenting a new resource for engineering educators to employ, some level of assessment is necessary to encourage adoption. Both direct and indirect measures were used to assess the efficacy and value of the videos.

Direct Assessment

To directly assess the efficacy of these videos, two tools were used. The first tool was a set of four unannounced quizzes, the purpose of which was to determine if students did, in fact, watch the videos. These multiple-choice quizzes were administered at the beginning of four of the lessons for which videos had been assigned. The content of the quiz questions was split between topical knowledge discussed in the videos, and questions measuring if students watched the videos (e.g., questions about the humor and pop culture examples). Each question was scored as either correct or incorrect. Quizzes 1 and 2 had three questions each, while Quizzes 3 and 4 each had two questions. Table 2 shows the quiz results. The overall average for all four quizzes was 7.5/10, suggesting that many students did watch the videos.

The second direct assessment tool used were the four course exams. The exam results were compared to those of the previous year, in which the videos were not available, to provide a direct measure of student learning gains. The fourth and final exam was identical between years and was graded by the same instructor using the same grading scale. This could be done because final exams are not returned to students after grading. Exams 1-3 were not identical between years because these exams *are* returned to students which could have contaminated results by students having access to last year's exams. The 2017 exams did cover similar topics as the 2016 exams. The control group (students taking the Circuit Theory course in 2016) included 69 students with an average incoming GPA of 3.0396, while the experimental group (students taking the course in 2017) included 51 students with an average incoming GPA of 3.0675.

The exam results are shown in Table 3. The experimental group performed slightly better on the first exam, slightly worse on the second, modestly better on the third, and much better (9 percentage points) on the final exam. A multiple regression model showed that even after controlling for students' incoming GPA, the experimental group scored 8.36 percentage points higher on the final exam than the control group. Given that the course was otherwise identical in the two years, this substantial improvement in final exam score may be attributable to the videos. The fact that the latter two exams showed more improvement than the first two exams may indicate that the videos were more helpful for the more advanced course topics such as Phasors, Mesh and Nodal Analysis in AC, Thevenin's Theorem in AC, and Superposition in AC.

Table 2: Quiz results.

Quiz	1	2	3	4	Overall
Average	98%	59%	73%	78%	75%
Standard Deviation	14%	29%	39%	31%	29%

Table 3: Exam results.

Exam	2016		2017		Cohen Size Effect
	Mean	Standard Deviation	Mean	Standard Deviation	
1	74%	12%	75%	13%	0.10
2	81%	12%	80%	13%	-0.02
3	82%	12%	85%	8%	0.28
Final	79%	15%	88%	9%	0.70

Indirect Assessment

In addition to the direct assessment tools described above, two indirect measures were used to assess the efficacy and value of the videos. First, students were asked to evaluate the videos in a multi-part end-of-course survey. Forty-six of the fifty-one students taking the course in 2017 completed the survey, a response rate of 90.2%. Second, YouTube analytics were used to assess the extent to which students watched the videos.

Student Survey: Quantitative Results

The student survey included ten 5-point, Likert scale items, with 1 being 'Strongly Disagree' and 5 being 'Strongly Agree'. Students were asked to rate agreement with the following statements:

1. I watched most of the pre-class videos.
2. The pre-class videos helped me prepare for class.
3. I understood the material better thanks to the pre-class videos.
4. I think the pre-class videos helped me do better in the course.
5. If I didn't have these videos, I still would have prepared for class.
6. I feel that the humor in the videos made them more memorable.
7. I found the humor distracting.
8. I wish I had pre-class videos in my other courses.
9. I would recommend these videos to students taking Circuit Theory at other universities.
10. I would watch these videos even if they had advertisements.

In addition to the Likert-scale items, three other quantitative prompts were included in the survey. Students were asked to estimate the number of videos that they watched out of 20. Students were also asked to rate the length of the videos on a 5-point modified Likert scale with 1 being 'Too Short' and 5 being 'Too Long'. Finally, students were asked to provide a numerical response to the prompt: "If I had to pay for the set of videos as a resource, I would pay:".

The results of the ten Likert-scale items are shown in a 100% stacked bar chart (Figure 2), which allows for clear observation of agree responses and disagree responses [34].

With regards to the assessment questions posed in the Introduction section, the results of the student survey suggest that:

1. Students did watch the videos. As shown in Figure 2, 87% of the survey respondents either agreed or strongly agreed with the prompt "I watched most of the pre-class videos." In addition, students reported watching an average of 16.7 of the 20 videos, with a standard deviation of 2.69.

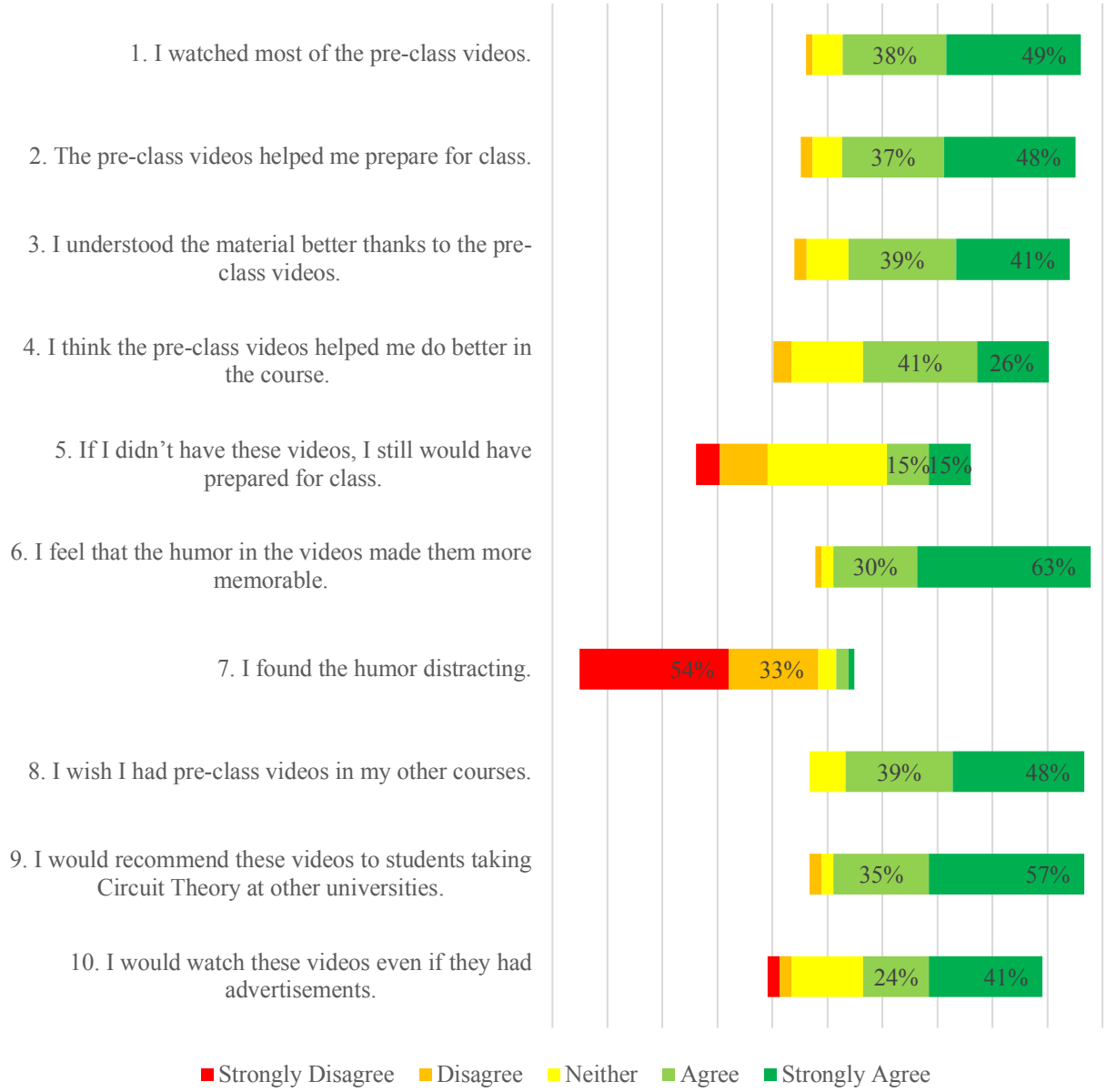

Figure 2: Likert scale survey results, displayed as a 100% stacked bar chart. Note that question 7 was intentionally negative weighted to mitigate acquiescence bias.

2. Students may have performed better because of the videos. 67% of respondents agreed or strongly agreed with the prompt "I think the pre-class videos helped me do better in the course."
3. Students felt better prepared for class because of the videos. 85% of respondents agreed or strongly agreed that "the pre-class videos helped me prepare for class," while 80% agreed or strongly agreed that "I understood the material better thanks to the pre-class videos." The student response to the prompt "If I didn't have these videos, I still would have prepared for class" was neutral and may reveal more about the students themselves than the videos. If nothing else, the neutral result indicates that students were not blindly agreeing with every prompt.

4. Students found the video length to be appropriate. Forty of the forty-six respondents thought the videos were neither too short nor too long, while the remaining six thought they were slightly too short. No respondents stated that they were too long.
5. Students believed that the humor worked well. 93% of students agreed or strongly agreed that "the humor in the videos made them more memorable" while only 6.5% "found the humor distracting." The latter item was intentionally reverse coded to check for acquiescence bias, and the large number of disagree responses suggests that the respondents were indeed expressing their opinions.
6. Students did value the videos. 87% agreed or strongly agreed with the prompt "I wish I had pre-class videos in my other courses" and none disagreed. 92% agreed or strongly agreed that "I would recommend these videos to students taking Circuit Theory at other universities." When asked how much they would pay for the set of videos, the average response was $19.30 (S.D. = $21.63). Some students were not willing to pay much (17 students said they would pay $5 or less), but many were (15 said $20 or more, and 7 said $50 or more). Figure 3 shows the distribution of responses to this last question, which shows that, although the mean is $19.30, the distribution is clearly skewed closer to $10.

Students were also asked to react to the prompt "I would watch these videos even if they had advertisements." These results are shown in Figure 2. This result had a majority agreement (65%), but also had several who disagreed and 4% strongly disagreed. Not only are advertisements a little self-serving (although revenue would be minimal) they represent an undervaluation of student's time. If the point is to get students to watch to the end, shorter time is likely better than longer.

Student Survey: Qualitative Responses

Students were also asked to qualitatively comment on what made the videos effective or ineffective. Of the 46 students completing the survey, 38 (82.6%) provided a qualitative response. Of the 38 responses, 29 were positive (76.3%), expressing appreciation for the videos' humor (10 responses), their utility in previewing/introducing the lesson topics (8 responses), their short length and concision (6 responses), and their inclusion of example problems and real-world connections (5 responses). Of the remaining 9 responses, 2 were unclear and 7 were at least somewhat critical of the videos as offered. The most common negative responses highlighted feelings that the videos went too fast (4 responses) or were too short and basic (2 responses).

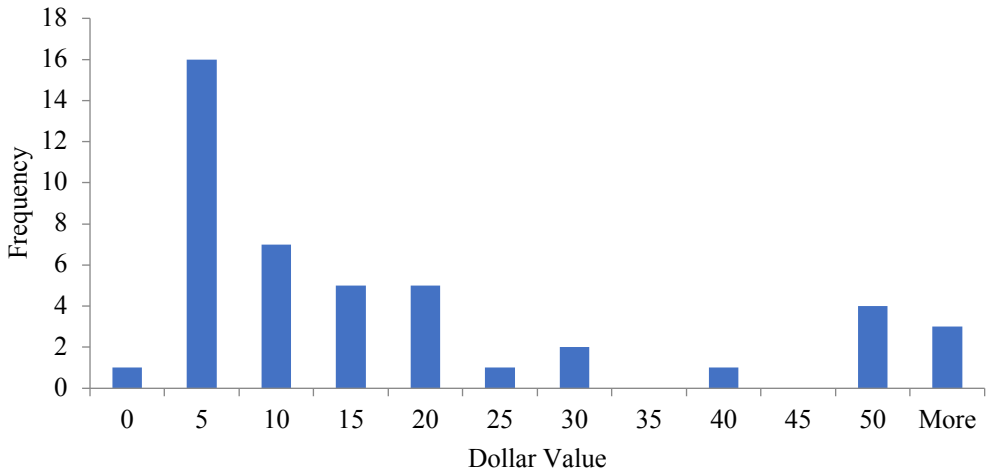

Figure 3: Distribution of responses when students were asked how much they would pay for the set of videos.

YouTube Analytics

The total number of views of each video, as of the end of the course, are shown in Figure 4. It should be noted that these view counts include anyone who viewed the video on YouTube, not just the students enrolled in the Circuit Theory course. The first five videos in the series were shared with the Physics 2 course, which may have resulted in higher view numbers. In addition, the first video was promoted through social media (Twitter, Facebook, and LinkedIn). With the exception of these early videos, we believe that most of the video views were by students enrolled in the Circuit Theory course, because the videos do not currently rank highly enough in YouTube search results to be readily found by someone not specifically looking for them.

Excluding Video 1, the average number of views per video was 65.9, or 29% greater than the number of students enrolled in the course. Even allowing for the possibility that some viewers were not enrolled in the class, it seems likely that a fair number of students did watch the videos. The video with the least views was Video 20, about AC power.

As seen Figure 4, view counts were inconsistent over time. The number of views per video decreased over the course of the semester, consistent with prior research suggesting that use of online resources decrease over time [35]. The sharp decline after Video 13 could be due to any of several factors. The frequency of videos dropped after Video 13, and students may have fallen out of the habit of watching them. Or, the students may have gotten too busy with obligations to other courses later in the semester. Lastly, viewers who were not students in the class may have been less interested in the more complex (AC circuits) videos.

In addition to the overall downward trend, the data show clear peaks for videos that were assessed by pop quizzes (Videos 5, 11, 13, and 19). Even though the quizzes were unannounced, there were two sections of the course, and there was no way to prevent cross talk between the first and second sections. This could have resulted in Section 2 watching at an elevated rate to prepare for the quiz. Indeed, the overall average quiz score in Section 2 was 79%, while in Section 1 the average was 72%. A single quiz represents only 0.2% to 0.3% of the overall course grade. Despite this small

contribution, it seems it was enough motivation for Section 2 to watch the videos. In future implementations, it may be valuable to give a quiz after every pre-class video.

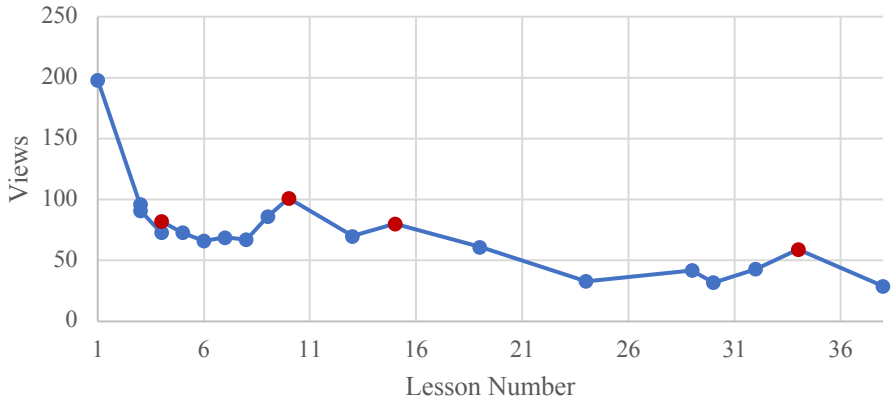

Figure 4: View counts for the 20 pre-class videos described in this paper. Each video is represented by a data marker. Red points indicate videos that were assessed by pop quizzes.

In addition to the number of views per video, YouTube Analytics also provides data on audience retention within each video. On average, viewers watched 63% of the videos (this is a grand average over all videos). The maximum average watch percentage was 75% (for Video 19, Thevenin in AC and Video 10, Superposition) and the minimum average watch percentage was 54% (for Video 18, Superposition in AC). Perhaps not coincidentally, students performed worse on the Superposition in AC and AC Power problems on the final exam than they did on the other problems. The videos for those topics had the worst retention and the fewest views, respectively. Figure 5 shows the question by question results of the final exam in 2017 which highlight that the Superposition in AC (Q5) and AC Power (Q3) questions had much lower averages.

In terms of time, the average video length was 3:43 and so the average video watch time was just 2:21. Unfortunately, this implies that students could not be bothered to spare an additional 1:20 to finish each video. This result is likely skewed by those viewers who watched only the first 10-15 seconds of a video (perhaps due to YouTube's Autoplay feature, or because they were channel surfing) and then closed the video.

Conclusions

This paper describes the production of a set of 20 short pre-class videos to help prepare students for lessons in DC and AC circuit analysis. Compared to other publicly available circuit theory videos, the videos described in this paper use humor and pop culture references to engage the audience and make the content memorable, and adhere to the well-known recommendation to keep instructional videos short. The authors have made the videos freely available on YouTube, without advertisements, for other engineering educators to use.

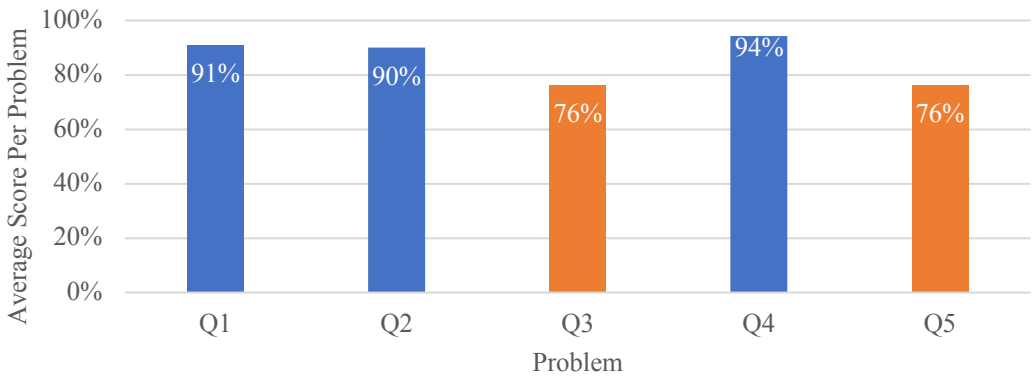

Figure 5: Results of the 2017 final exam, by problem. The orange bars highlight Q3: AC Power and Q5: AC Superposition.

Our initial assessment results suggest that the videos were utilized, were perceived as valuable by the students, and may be effective in promoting student learning. Video viewership was confirmed directly using in-class pop quizzes and indirectly by YouTube Analytics and self-reported student data. On the end-of-class survey, students overwhelmingly agreed that the videos helped them prepare for class and helped them understand the material better. Nearly all the students expressed a desire to have pre-class videos in their other courses, and nearly all would recommend the circuit theory videos described in this paper to students at other universities. On average, the students would have been willing to pay $19.30 for the set of videos had they not been provided freely.

The most intriguing finding, though perhaps also the least convincing, is that the students who took the circuit theory course in 2017, with the videos, performed 8.36 percentage points higher on the final exam than did comparable students taking the same course in 2016, without the videos. It is possible that the improved understanding of early material, aided by the videos, helped students feel more confident and perform better on the final exam, but it is difficult to be certain. Further study is necessary to verify if the significant improvement in final exam score is matched in future offerings of the course.

The assessment study does have several limitations, most notably the fact that we did not track video viewing by individual students and thus cannot relate viewership to exam performance at the student level. We considered hosting the videos on our university's Panopto server and requiring students to log in to watch them, but decided that the benefit of publishing the videos to YouTube outweighed the improved statistical power of student-level data. Publishing on YouTube brings a second limitation: we cannot be sure how many of the viewers were actually students in the circuits course. We suspect that most viewers were in the class, with the exception of the first five videos which were shared with another course, because the videos are low in YouTube's search results. This limitation is mediated by the fact that we also assessed viewership via pop quizzes and student self-reports. A third limitation is that we did not ask students how much they would have paid for the course textbook had it not been required. This might have helped to put the results about the value of the videos in perspective.

Several changes can improve the experience for both the creator and the audience if similar videos are produced for another course. The primary obstacle to creating videos of this nature is the high initial time sink. To help the creator, better filming hardware and editing software can potentially

reduce editing time and improve video quality. To reduce time spent in creation, hiring external help to film and complete the initial edits would make this process faster and more accessible to faculty wishing to create similar resources but would increase monetary cost. In order to help the audience, it is important to emphasize to the students that the videos are meant to be paused or watched repeatedly to retain the important information. Adding more regular video quizzes, with a higher percentage of the course grade at stake, may help encourage students to watch the videos repeatedly, if the emphasis alone is not enough.

To further explore student use patterns, the videos could be hosted on a server with tracking capability (if not told that the videos are also on YouTube, the students would likely not think to look there). To further understand the videos' value, students could be asked to formally compare the videos to other freely available videos and to rate each set for clarity, engagement, and perceived effectiveness. While YouTube likes and view counts assess this to a degree, most of the videos in this study have too few views to yield reliable data. To examine video effectiveness, more extensive and rigorous learning metrics could be deployed along with student-level video usage data. The ideal would be a controlled experiment, though this could be difficult in a single institution such as our own without risking cross-contamination of the control group.

Our experience with the videos prompts several deeper questions as well. What are the long-term impacts of pre-class video usage on students? Does the provision of pre-class videos hurt students' ability to critically read textbooks and other written sources? If the trend is toward video as a delivery method for what has been historically attempted by textbooks, is written media losing value? In light of this, should we be writing this paper or should we just make a video about it?

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