Investigating student-learning gains from video lessons in a flipped calculus course

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Abstract

The flipped classroom has garnered attention in post-secondary mathematics in the past few years, but much of the research on this model has been on student perceptions rather than its effect on the attainment of learning goals. Instead of comparing to a "traditional" model, in this study we investigated student-learning gains in two flipped sections of Calculus I. In this session, we will focus on the question of determining learning gains from delivering content via video outside of the classroom. In particular, we will compare student-learning gains after watching more conceptual videos versus more procedural ones. We will share qualitative and quantitative data gathered from surveys and quizzes, as well as results from in-class assessments.

Keywords: Flipped Classroom, Video Lessons, Learner-Centered Teaching, Calculus

Background

Learner-centered or active classrooms are those which change the role of the instructor from "sage on the stage" to "guide on the side" and encourage students to construct their own meaning while engaging in authentic problem-solving. Recent research has consistently showed that active classrooms improve student learning in a variety of fields; for example, in 2014 the National Academy of Sciences published a meta-study of 225 studies on student performance and failure rates in undergraduate science, technology, engineering, and mathematics (STEM) classrooms employing active learning components. Their analysis suggests that students in traditional lecture classrooms are 1.5 times more likely to fail than students in classrooms including any type of active learning techniques (Freeman et al., 2014).

The flipped classroom structure is one example of an active learning method that has become increasingly popular. This classroom structure takes on many forms, but the common trait is that most of the initial content delivery happens outside of the classroom while in-class time is spent solving problems, often in small groups, to assimilate the new knowledge and to deepen understanding. Some instructors deliver content through assigned readings from a text or other source, while others use videos that they made or found online. The core idea is to use classroom time for challenging problem solving where students can draw support from their peers and instructor; this design more effectively uses the experience and knowledge of the instructor to guide students through the topic at hand.

Literature Review

As the flipped classroom has gained popularity among undergraduate STEM educators, more literature has appeared. Much of the initial literature on flipped classrooms only described the varying structures of such classrooms or the particular technologies employed by teachers using a flipped classroom. The controlled studies published on this classroom model have often focused on student perceptions of and attitudes towards the structure rather than its impact on the attainment of learning goals. For example, Foertsch, Moses, Strikwerda, and Litzkow (2002) described the use of a specific video streaming software in an engineering classroom, and reported student opinions of the videos and software, and Ford (2015) described her activity structure in a math course for pre-service elementary teachers. Strayer (2007) gathered data on a traditional and flipped introductory statistics classroom to evaluate the learning environment of each structure, and found that students enjoyed the innovation and cooperation in the flipped class, but had a low “comfortability” with the learning activities in this environment. Roach (2014) found that 76% of his economics students believed that video lectures helped them learn, and the same percentage would take another class using the flipped format.

While lecturing as been a staple of academia for close to a millennium, the flipped classroom structure might be seen as a return to an even older system of teaching where classroom time was centered around academic debate and discussion rather than the transmission of information, just using newly available technologies. This recent resurgence dates to at least the mid-1990s when Eric Mazur, a physics professor at Harvard, started using team learning and in-class activities as ways to stop lecturing (Mazur, 1996). Jonathan Bergmann and Aaron Sams (2012) started using video lectures in the mid-2000s and are often credited with pioneering the flipped classroom and its current popularity. Since then, many educators in a variety of fields and at a wide range of institutions have started using this structure. For example, Gaughn (2014) wrote about her experiences running a flipped history classroom, and Findlay-Thompson and Mombourquette (2014) published research from their flipped business classroom. Bishop and Verlager (2013) did a meta-analysis of the literature on flipped classrooms in all areas of STEM, as well as economics and sociology. Additionally, the research ranges from high school level (Johnson, 2013; Moore, Gillett, & Steele, 2014) to upper division medical courses (Sharma, Lau, Doherty, & Harbutt, 2015). Education-focused video repositories like Khan Academy are available on the web, and many have spoken about their experiences with various forms of the flipped classroom at local and national professional meetings (e.g., in 2014 the Joint Mathematics Meetings included a session titled *Flipping the Classroom* with 37 different talks).

More recently, research studies used classroom data to evaluate the success of flipped classrooms. Lape et al. (2014) and Mason, Shuman, and Cook (2013) compare grades on individual assessment questions in engineering between flipped and traditional sections of the same course and found few cases of statistically significantly higher scores in the flipped classroom, but no cases where students in a lecture section outperformed students in a flipped section. Wilson (2013) found that students in a flipped section of statistics did outperform their lecture counterparts on exams and the course post-test. In mathematics in particular, McGivney-Burelle and Xue (2013) flipped a unit in a Calculus II course and showed that student grades on exams and homework were higher for the flipped section than the traditional section. Love, Hodge, Grandgenett, and Swift (2014) found that students in a flipped linear algebra course had greater improvement in exam scores than those in a traditional section, and outperformed them on the final exam. Additionally, PRIMUS has a forthcoming special issue on research in flipped classrooms that will increase the literature within mathematics education.

Research Question

Since students in the flipped classroom model do introductory learning of topics outside of the classroom, it is prudent to investigate the effectiveness of the content delivery method. The classroom in our study most often introduced new content outside of class through the instructor's own video-recorded lessons. Studies about using video have been conducted previously; for example Zappe, Leicht, Messner, Litzinger, and Lee (2009) investigated how students used online lecture videos to learn in an undergraduate engineering course, including the percentage of videos watched, students reviewing unclear segments, and time spent per video. In this paper we investigate the effectiveness of these videos on the learning gains made by students enrolled in two sections of a standard first semester calculus course. In particular, we explore student-learning gains from watching videos outside the classroom to determine students’ development of conceptual understanding and procedural skills in calculus.

Methods

Participants

The participants were undergraduate students in a first semester calculus course at a large university in the Mid-Atlantic United States. Of the 59 students in the study, 51 (86%) were freshmen, 5 (8%) were sophomores, 2 were juniors, and 1 was a senior. The majority of the students were male (64% male, 36% female). Four students withdrew from the course before the end of the semester. More than 80% of the students had previously had a course in calculus, generally in high school. The majority of the students were majoring in STEM fields. The students were divided into two sections (34 students in one section, 25 in the other) and generally covered the same material on the same days.

Classroom

This was the third semester that the instructor had run a flipped Calculus I classroom. Before each class, students would have a pre-class assignment, such as watching a video or completing a reading. Nearly all class sessions started off with a short quiz related to their pre-class assignment. The majority of class time was spent on group-work activities. The students worked in groups of 2–4 and the instructor would interact with the groups one-on-one. Students were also given homework and practice problems to be completed outside of class.

Data Sources

Over the course of the semester, we gathered qualitative data from the students, including student feedback about specific video lectures (for example, questions like "What did you find confusing?" or "What helped clear up confusion?"), student answers to post-video or post-activity questions or problems (calculus content questions to evaluate learning gains), and student surveys about their perceptions of the class structure and their learning gains. Aggregate quantitative data, such as assessment scores and course grades, were also recorded. We used video recording on certain class days to help the instructor objectively evaluate and improve student-teacher interactions in the classroom. This data was used to make changes to course attributes in order to increase potential learning gains, as well as to consider the general effectiveness of the class model.

Analysis

We created rubrics to analyze the written feedback from students. For example, the rubric shown in Table 1 was used to analyze responses to a question asking students to describe L'Hôpital's Rule. We then used two-tailed pairwise comparisons ($\alpha = 0.05$) to compare groups of students (e.g., students who had previously viewed a more conceptual video about the mathematical content versus a more calculational video) or to compare pre- and post-test results. Written responses were also categorized so that we could view trends in the data.

Table 1.
Rubric Used for Scoring Responses to Conceptual L'Hôpital's Rule Question

Score	Explanation
0	Answer was blank or made no mention of tangent lines.
1	Answers either lack "functions act like their tangent lines", or say something about tangent lines but neither "slope" nor "compare".
2	Answer states that functions act like their tangent lines near a point, and that one can find limits of $f(x)/g(x)$ (or compare $f(x)$ and $g(x)$) which have indeterminate forms by comparing the slopes of their tangent lines.

Students were also given some in-class surveys consisting of Likert-scale questions. The surveys generally asked students about their perceptions of the class structure and their learning gains. Aggregate quantitative data, such as assessment scores and course grades, were also used to look for prevailing student trends.

Results

While data analysis is still ongoing, in this section we share a subset of results from our study. In particular, we share students' overall opinions about video use and data around one class period specifically designed to help us see differences in the ways students learn conceptual and procedural content via video.

Several times throughout the semester, students were given surveys where they could voice their opinions about the structure of the class. When asked to compare learning a new topic outside of class via reading assignment versus watching a video, students overwhelming preferred videos (86%). However, when asked what part of their class structure had the greatest positive impact on their learning, 56% of students said the pre-class videos and readings, whereas 46% said the in-class activities and interactions.[1] We also asked the students to state their beliefs on how the videos increased both their conceptual understanding and computational skills in the class (see Table 2). For both questions, the majority of the class believed the videos greatly or significantly helped their mathematical understanding and skills, although more of the students found video helpful for their conceptual understanding than their computational skills.

Table 2.
Students' Beliefs About Video Usage

	Greatly	**Significantly**	**Moderately**	**Slightly**
Conceptual understanding	38%	38%	24%	0%
Computational skills	20%	40%	30%	10%

So the students believed the videos were helpful, but what objective evidence for learning gains could be seen in the students' work in the classroom? Prior to an in-class activity about L'Hôpital's Rule, we had the students watch an introductory video about the topic. However, we split the classes into two groups: one group watched a more conceptual video, and the other watched a more procedural video (n = 23 for each group). At the beginning of class, the students were given an assessment about L'Hôpital's Rule, with one question asking for a more conceptual explanation and the other asking for a more procedural explanation. We then had the students form groups of 2–3 so that each group contained at least one student who had watched each video. We videotaped the class session. At the end of class, students were given the same assessment as before to help us see what changes in their understanding occurred due to their group discussions.

Video data analysis is still ongoing. However, preliminary analyses seem to indicate that students gained knowledge from watching the videos and were able to share that knowledge with other students. We have completed scoring their responses to the pre/post assessment using rubrics like the one described above (0–2 scale). The students' average results can be found in Table 3. Results indicate that students who watched the more conceptual video were able to answer the more conceptual question on the pre-class assessment, but were not able to answer the more procedural question. The opposite was true for the students who had watched the procedural video.

[1] Percentages add up to more than 100% because students could choose more than one answer.

Table 3.
Average Scores on L'Hôpital's Rule Assessment

	Conceptual Question		Procedural Question	
Group	Pre	Post	Pre	Post
Watched conceptual video	1.39	1.48	0.09	1.26
Watched procedural video	0.04	1.35	1.74	1.57
Significantly different? (p-value)	Yes $p < 0.001$	No $p = 0.210$	Yes $p < 0.001$	No (barely) $p = 0.057$

After working in groups, both groups of students were able to answer the conceptual and procedural questions. No statistically significant differences were found in the two groups' post-class assessment average scores. However, the difference in their post-assessment scores for the procedural question was just barely insignificant.

Implications and Discussion

In reviewing the pre-class assessment results, we were not surprised by how well the students did on the question that related to the type of video they had viewed. However, more than 80% of the students in the class had taken at least one calculus class before. As such, we thought some students would be able to answer both questions successfully, which was not the case. Also, we were surprised by how well both conceptual and procedural understanding was improved by the students working in groups. Our results seem to indicate that students learned conceptual and procedural content from the videos and were able to share that knowledge.

However, there still are some open questions from the data. The post-class assessment scores on the procedural question were just barely insignificantly different and students felt the videos helped them more with conceptual knowledge than with learning procedures. This means we need to take into consideration what content educators teach via video. However, because of the small number of students in this study, more research needs to be done to determine if there is a statistically significant difference in learning gains from more procedural videos than more conceptual ones.

Last, teachers thinking about using videos in their classes should know that students will get at least a basic understanding from videos, whether the videos be more conceptual or procedural. Video lessons alone, however, are not enough; the content from the videos should be clarified and reinforced in class through discussion with peers.

Open Questions

- What balance of conceptual and procedural videos should be used to have the greatest impact on student-learning gains?
- What effect does the use of video-recorded lessons have on specific populations of students (e.g., gender, course of study, non-traditional students, etc.)?
- In what ways are students using the videos? Are they actively engaging with the video lessons (instead of just passively listening like with a lecture)? How can we make the videos more useful and productive for the students?

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