FLIPPED CLASSROOMS IN COLLEGE: CALCULUS STUDENTS' PERCEPTIONS AND PERFORMANCE

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Abstract

Classroom flipping is a teaching model that uses technology to interchange the roles of traditional lectures and homework. In flipped classrooms, students view video lectures at home on their own time, while classroom time is devoted to group work, homework, or other activities that actively engage the students with the material. This model has received considerable attention in the last few years, especially at the school level; however, there is still little research evidence about the effects of flipped classrooms on student performance and learning outcomes. In this study we explored the effects of flipping a calculus class; in particular, we studied two main aspects: performance and attitudes. Specifically, we analyzed the impact of this teaching model on students' performance on graded coursework. In addition, we evaluated students' perceptions of the classroom flipping model by analyzing students' responses to Likert-scale items as well as open-ended questions eliciting their teaching and learning preferences. In this paper we report the results of this study and discuss the implications for future research and practice to enhance the undergraduate learning experience of mathematics.

Keywords: Innovative teaching models, technology and pedagogy, flipped classroom, mathematics.

1 INTRODUCTION

It is well known (e.g., [1,2]) that student engagement in the classroom has positive effects on learning outcomes. However, traditional instruction models often prioritize an instructor-centric lecture approach, whereby an instructor delivers information to a (more or less) passive audience. In the past, given limits on resources and technology, this method of instruction has been deemed necessary, but rapid advances of technology in the last decade have changed the landscape of education worldwide. Recently, teachers have been developing new teaching models that incorporate technological developments into the classroom in innovative ways. One common hope is that through technology, we can increase student engagement and develop critical thinking in the classroom.

It is now relatively easy to faithfully recreate instructor lectures in an easily-delivered format through online video lectures. Through common and affordable technology, instructors can create narrated videos with slides, writing, views of the instructor talking, or some combination of those and other presentation options. Studies have suggested that student learning could be enhanced with video lectures as an alternative to in-class lectures [3,4,5,6]. Video lectures have been incorporated into courses and are beginning to appear in *blended* or *hybrid* courses that incorporate online video lectures and some amount of in-class meeting. The positive impact of these models on students' performance are supported by the findings of several research studies [7,8,9]; however, the changes to course structure and presentation inherent in an online or hybrid course are drastic and numerous, so there are many different variables affecting student performance. In this study we used a more measured approach. Without changing schedule, the number of hours of face-to-face time with students, problems assigned, or lecture material covered, we exchanged the homework and lecture components of the class. That is, students watched video lectures as homework and worked on homework problems in-class, in small groups, with the instructor playing the role of a facilitator. This is the central idea of the *flipped classroom* model.

As defined by Baker [10], classroom flipping is a form of blended learning that aims to retain the efficiency of the lecture while adding interactivity to engage the student. In its simplest form, it takes the traditional lecture-homework dichotomy and flips it around. In this simple form there are no added pieces (discussion boards, learning software, special projects). Student learning gains are expected to come from the fact that lectures may be equally as effective when viewed by video as in the classroom, while homework can be a more effective learning tool when done in collaboration with other students and the guidance of the instructor.

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The classroom flip has become more popular in recent years, and it has been found that students respond positively to a flipped classroom [11,12,13]. Furthermore, initial evidence (much of it anecdotal) suggests student learning gains; however, many of the implementations thus far have been by instructors who, along with recording lectures for home, carefully planned and implemented classroom research projects, multimedia presentations, social gatherings, and other more elaborate tools and activities for students. An open question is whether the learning gains by students in these cases could be attributed to the additional resources and techniques put at their disposal in these courses. In this study we concentrated on the actual flipping model with minimal changes made to the traditional course design. The purpose of the study presented here was to explore the effects of the basic premise of the flipped classroom model on mathematics students' attitudes and performance.

2 RELATED LITERATURE

As a recent phenomenon in its current form, there are relatively few articles in the literature exploring the benefits and drawbacks of the flipped classroom model. However, the components of a flipped classroom -- video lectures, active learning – have been studied in depth in other contexts. In this section we review some important studies that focus specifically on blended learning environments at the college level that most closely align with our conception of the flipped classroom.

Baker [10] pioneered the use of Internet technology to flip the classroom with the fundamental assumption that

> *... the new information technologies would provide a way for faculty to present 'lecture' material, but that the shift in method of delivery would open up classroom time for teaching and learning strategies that emphasized the role of the learner in a cooperative environment (p. 11).*

His study was conducted in undergraduate communication courses that included online lecture notes, online discussion groups, and online quizzes. He found that students perceived more collaboration and interaction among students, more attention from the instructor, and a higher level of critical thinking compared to their other classes of similar size. Around the same time, Lage, Platt, and Treglia [12] used a similar model that they called the *inverted classroom* to teach an undergraduate introductory economics class. They aimed to remove lectures from the classroom so that face-to-face time could be devoted to variety of learning activities that would suit all learning styles. Similar to Baker, they found that students generally preferred this model. In subsequent years, other instructors have followed their lead and studied the flipped classroom in different contexts.

Foertsch, Moses, Strikwerda, and Litzkow [4] developed an online streaming video and multimedia application to teach a course for engineering majors. The students viewed videotaped lectures outside of class and class time focused on solving problems supervised by the professor. The results from the students' evaluation of the online lecture version of the course indicated that the flipped classroom improved the usefulness, convenience, and value of the course for the majority of the students. More recently, Zappe, Leicht, Messner, and Litzinger [13] conducted a study in a large architectural engineering course using a similar teaching model to explore students' usage and perceptions of the flipped design. Their findings rendered positive results in both aspects. Mason, Shuman, and Cook [14] taught a mechanical engineering class using a traditional format in one year and using a flipped format the subsequent year. They studied the effectiveness of the flipped classroom model by comparing content coverage, quiz and exam scores, and students' perceptions. Their results showed that in the inverted classroom model the instructors were able to cover more material, the students performed similarly or better on comparable quizzes and exams than the traditional classroom students, and that the students found the new format satisfactory and effective.

Other researchers have implemented the flipped classroom by using forms of technology other than video-taped lectures to free up class time. In particular, Strayer [15] used an intelligent tutoring system (ALEKS) in an introductory statistics course to help the students learn the content outside of class while class time was spent on activities specifically designed to enhance their learning of the material presented in ALEKS. He found that the inverted classroom model improved cooperative learning and classroom innovation but that the students were less satisfied with the lower level of task orientation compared to students in a traditional introductory statistics course at the same university. More specifically, students in the inverted classroom had difficulty in adjusting themselves to the structure of the class, and they struggled with how to orient themselves to the in-class activity.

These studies have shown increases in student satisfaction and participation in flipped classrooms and have hinted that performance gains are possible; however, these researchers have pointed to the need for further evidence of the effects in different contexts [14], further comparisons measuring changes between groups [13], as well as further evidence of its impact on students' performance.

3 METHODS

There are many types of blended learning approaches of various degrees of scale and complexity. For the purposes of our study, we defined a flipped classroom as one in which the time devoted to lecture and the time devoted to homework were switched, but no additional materials (lecture notes, slides, problem-solving activities, other technologies) were developed or provided. Relative to the existing literature that references flipped classrooms [10,12,15], this is a minimalist model meant to highlight the differences, if any, in simply exchanging lecture and homework. In addition, we looked at both students' perceptions and their performance. Specifically, the research questions we address in this paper are the following:

1. What are students' perceptions of the different characteristics of the flipped classroom model?

2. How does student performance compare between students who participate in a flipped classroom and those who do not?

3.1 Participants

Participants included 116 students enrolled in seven sections of a college business calculus course in Fall 2012. All sections were taught by experienced instructors and coordinated by one of the authors of this paper. There were, on average, 28 students in each section by the end of the semester. The coordinator ensured that the material covered was the same across all sections and that the same pace was maintained throughout the semester. All quizzes and exams were the same across sections. The students were 57% male and 43% female. In terms of class level, 74% of students were at the Sophomore level, 12% First year, 13% Junior, and 1% Seniors. Fifty one percent of students declared Business as their major, while the others were distributed between different majors in Liberal Arts and Sciences, Exploratory majors, or were still undecided.

Two groups of students participated in this study. The first group (N_1=41) was enrolled in two sections where the flipped classroom model was used. More details about the instructional design are provided in the following subsection. The second group (N_2 =75) was enrolled in six other sections of the course. These sections were taught using the standard lecture-based instruction. All sections met for 50 minutes, three times per week, completed 12 common quizzes, two common midterm exams, and a common cumulative final exam.

3.2 Procedure

There were two sections that were selected to participate in a flipped classroom. One section was taught by an author of this paper, and the other was taught by an experienced graduate student. In both sections, the majority of the instruction was standard for introductory college level mathematics, in which the instructors lectured at the board, involving the students with questions and short exercises. For two select weeks of the semester, the instructors implemented a flipped classroom -- once near the beginning of the semester as a pilot to introduce the students to the idea and structure of a flipped classroom, and again in the last third of the semester; this second week of the flipped classroom served as the focus of this study. All of the other sections were taught entirely using standard instructional methods.

The second flipped week that is the focus of this study featured material on finding absolute extrema of functions and applying calculus to solve real-world optimization problems. We selected this particular week to conduct the study because optimization problems are often regarded by the students as some of the toughest material covered in the course.

The procedure of the flipped classroom was as follows. For each day of instruction, each instructor created two to three instructional videos using a tablet computer, narrating work on a virtual whiteboard to introduce the topics for that day. These videos ranged in length from 5-15 minutes each. Students were required to view these videos prior to the corresponding class meeting, and fill out a short feedback form each day that related to the video presentations. The feedback forms were intended to help verify that students viewed the videos and to encourage them to think critically about the material presented on the videos. At the start of class, the instructor provided a short summary of the material on the videos. During class time, the students were expected to work on their homework problems for the week. These problems were selected from the class textbook, and were the same as the regularly assigned homework problems for all sections. Students were encouraged to work in pairs or small groups, and the instructors circulated around the classroom to answer questions, supply hints, and help students work through the problems. If there was a common question or issue, the instructors addressed the entire class. If any student did not finish the assigned homework, they were required to complete it on their own time at home. At the end of every week, a short 10-15 minute quiz was administered in class in all sections of the course. The quiz grades counted towards the students' final grade on the course.

3.3 Data collection and analysis

To address the first research question, we developed a Perceptions Survey with 18 items. The survey included 16 items on a 5-point Likert-scale (from 1=strongly disagree to 5=strongly agree). Seven of these items pertained solely to the video-viewing learning experience, while the other nine items were related to the in-class learning experience during the flipped class. The survey contained two open-ended questions that provided an opportunity for students to further explain any of the responses to the Likert-scale items, as well as their perceptions of how the experience could be improved. The survey was administered in-class one week after the flipped experience. Percentages of students' agreement were calculated for the Likert-scale items. A correlation analysis was used to examine the relationship among the variables. Students' responses to the open-ended survey items were analyzed to uncover patterns and recurring themes.

To address the second research question, we collected the results of the quiz corresponding to the week of the flipped experience. This quiz was on finding absolute extrema of functions and optimization. All students completed this quiz as part of their coursework and it counted towards their final grade for the course. A *t*-test was performed to compare the results of the two groups.

4 FINDINGS AND RESULTS

Of the 41 participants from the first group, only 33 responses to the Perceptions Survey could be used for the study because some of the participants were not present when the survey was administered and others submitted incomplete surveys. The analyses of the survey responses with N=33 are shown in Table 1. The total number of students is indicated in parenthesis.

As can be seen from the table, the vast majority (over 70%) of students reported that the videos helped them understand the concepts, as well as allowed them to learn at their own pace. While almost 60% of students would have preferred to be able to ask questions while watching the videos, a similar percentage strongly agreed or agreed that the videos helped them prepare to do the in-class problems. Overall, these results indicate that students perceived the video-viewing portion of the flipped classroom as beneficial to their learning and their preparation for class.

With regards to their in-class experience, almost 70% of the students found that starting class with a summary about the videos was beneficial to their learning. These findings corroborate what Zappe et al. [13] had found regarding the transition to the in-class activities. In addition, almost 50% of the students found the interactions with the instructor and their classmates during the flipped experience to be beneficial and over 50% felt that the flipped classroom experience helped them prepare for quizzes and exams. On the other hand, students reported little preference to devoting class time for problem solving. The latter could be attributed to adjustment issues related to the short length of the flipped classroom experience in this study. Other studies [14] have found that students need as much as four weeks to settle into the new classroom format.

About 70% of students reported that they learn better from lectures than videos. This is not surprising, as the idea of flipping the classroom is to devote more class time to active learning, and this face-to-face time is meant to supplement the video lectures. When comparing videos to the textbook, over half of them reported preference towards the videos. These findings are similar to those reported by Zappe et al. [13] and it is well known that most students at this level have difficulty understanding the material presented in mathematics textbooks. Less than 20% of students reported that the videos helped them for exams; however, only 3% of the students reported watching the videos before the exam. Once again, this may have to do with the students' familiarity with the flipped model. The videos may not have been as present in their mind when they were preparing for the exams as they were during the one-week flipped experience. In addition, instructors may not have emphasized this feature at the time exams rolled around. These findings confirm what Mason et al. [14] had found, that more scaffolding is necessary for students to be able to take full advantage of this model.

In terms of learning preferences, over half of the students reported that they preferred working through problems on their own and a similar percentage reported being less likely to attend class in the flipped classroom model. The latter is in agreement with the results from Traphagan et al. [6] who found that access to lecture materials outside of class lowers class attendance. However, in our study the instructors estimated that the percentage of students missing class during the flipped classroom week was comparable to other weeks in the semester. Given the relatively small class-size (~28 students each) we believe these estimates to be reliable.

Table 1. Student's perceptions of different characteristics of the flipped classroom model (N=33).

Survey Item	Strongly Agree/Agree	Neutral	Disagree/Strongly Disagree
The material shown in the video lectures helped my understanding of the concepts.	73% (24)	18% (6)	9% (3)
Having the video lectures available allowed me to learn at my own pace.	73% (24)	18% (6)	9% (3)
Not having the opportunity to ask questions while watching the video makes it hard to understand the video material.	57% (19)	15% (5)	27% (9)
Viewing the video lectures helped prepare me to do homework problems in class.	57% (19)	21% (7)	21% (7)
The in-class summaries of the video material given at the beginning of class were helpful.	67%(22)	21% (7)	12% (4)
The interaction with the instructor and the other students during the in-class problem sessions was beneficial for my learning.	48% (16)	42% (14)	10%(3)
I learn more from using class time for problem solving activities than listening to a lecture.	12%(4)	42%(14)	46% (15)
The combination of video lectures and in-class problem session helped me prepare for the weekly quizzes and related material on exams.	52% (17)	27% (9)	21% (7)
I learn more from live lectures than watching video lectures.	70% (23)	27%(9)	3%(1)
I prefer watching the video lectures more than learning from the textbook.	55%(18)	21% (7)	24%(8)
Reviewing the videos helped me prepare better for exams.	18% (6)	42% (14)	39% (13)
I reviewed parts of the video lectures to prepare for exams.	3%(1)	24%(8)	73%(24)
I learn more by working on homework problems on my own (normal weeks) than in class (during the video-week).	51%(17)	33% (11)	15%(5)
I am more likely to attend class during a video-week than during a normal lecture week.	6%(2)	39%(13)	55%(18)

Two additional survey questions (not reported on the table) asked students to indicate the range of time spent preparing outside of class. Students reported approximately the same amount of time spent preparing for a flipped week as they did for a regular week, indicating that the flipped classroom was not perceived by students as "more work."

The open-ended responses revealed a few themes across all students' responses. One common theme regarding the benefits of the model was the ability to rewind or re-watch parts of the videos. For example, one student wrote: *"[I liked] That I could learn at my own pace and rewind sometimes if I didn't understand."* Another theme that surfaced was the comfort of watching the videos on their own time. One response related to this theme reads as follows: *"[I liked] The idea that I could watch the videos whenever I wanted to."* These themes echo what other researchers have found regarding online videos [16]. Several students also mentioned that this model gave them the advantage of starting to think about the material for the week ahead of time and be able to do the problems in class. A student elaborated a little more about this point: *"[I liked] Asking about homework problems and being able to get a head start on the homework rather than waiting to get the notes during the week in order to finish and understand the homework."* This finding suggests that the model could be particularly beneficial to those students who can easily grasp mathematical ideas on their own and could start working on problems in preparation for class, allowing them to discuss the more challenging problems in class with the instructor's guidance.

The analyses of students' performance on the quiz are presented in the tables below. The quiz scores ranged from 1 to 10 points, and the total number of participants who completed the quiz was 116. Table 2 shows descriptive statistics of the scores of the two groups.

Table 2. Descriptive quiz results from each group.

Group	*N*	*M*	*SD*	Std. Error	95% Confidence Interval
Flipped	41	6.49	2.13	.337	5.48 - 6.40
Traditional	75	5.94	2.03	.236	5.83 - 7.15

The mean scores were higher in the flipped classrooms; however, a *t*-test for independent samples comparison showed that the difference in the means between the two groups was not statistically significant (p>.05). The results of the *t*-test are included in Table 3.

Table 3. Results from *t*-test comparison of quiz scores.

	F	*df*	*p*
Flipped vs. Traditional	1.35	114	.1782

Although the results were not statistically significant, they are encouraging. As in Mason [14], the flipped classrooms did at least as well as the traditional; in our case, on one of the toughest topics in the course and with very little practice with the flipped classroom setup.

5 CONCLUSION

We implemented a very simple model of two flipped classrooms for one week of an entry-level calculus course in order to study both student perceptions and student performance as it relates to this teaching method. Even with little time to adjust to the novelty of the method, students generally perceived it as a positive experience, and especially appreciated the benefits of viewing lectures on their own time and at their own pace. Students in the flipped classrooms performed better on a quiz the next week than students in traditional classrooms, although the performance gains were not high enough to be statistically significant. Based on our findings, we believe the flipped classroom can be implemented relatively easily in college-level mathematics courses and has the potential to lead to student performance gains; however, care must be taken in designing a flipped classroom and further study is needed to confirm its benefits.

We propose several recommendations that echo those in earlier studies and extend them based on our experience from this study. Students should be given time to adjust to the flipped classroom, especially the problem-solving component. Many are not used to working collaboratively or to working actively in the classroom, and need practice in order to take full advantage of this opportunity. Students should also be provided with guidance on how to make the most of the video-lectures: instructors should describe when and where is appropriate to watch the videos (a student mentioned he could not learn from the videos because it was too hard to concentrate in his dorm room!), and help students to actively watch the videos by encouraging note-taking and providing associated activities (questions, worksheets) based on the video material. Instructors should also take the time to begin class with a quick summary of the videos to remind students of the material covered, address any common questions, and set the stage for problem-solving. Finally, students may need encouragement to review video material in preparation for exams.

More research is necessary to further explore the impact of this model on students' learning outcomes and to identify best practices of a flipped classroom. In addition, it would be helpful to understand the effectiveness of different implementations: for example, a full semester of flipped classes or a mix of standard and flipped classes. Research should also focus on how this model should be adjusted to fit the needs of students at different course levels, students with different learning styles, and courses with different subject matter.

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