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EVALUATION OF FLIPPED CLASSROOMS IN UNDERGRADUATE MATHEMATICS COURSES

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Abstract: *Traditional instructor-centered higher education classrooms provide limited opportunities for student engagement, concept exploration, and student-instructor interaction, all of which significantly contribute to academic success. Using advances in technology, flipped classrooms offer alternative solutions to many of these challenges. A flipped classroom employs a pedagogical method combining online and in-class activities. Students study the instructional portion of the lesson at home via a video, thus opening up time for guided problem-based learning in the classroom. This paper presents results of prior and ongoing research into the flipped classroom as implemented in first-year college mathematics courses. Of particular interest is: (i) student learning outcomes and learning progress by examining grades, course evaluations, benchmark assessments, and portfolios (ii) student perception of flipped classrooms by conducting surveys. Preliminary results and anecdotal experience show students positively view flipped classroom lessons because they promote more active and engaged course experiences. Further data is needed to evaluate students' learning outcomes.*

Keywords: *blended learning, flipped classroom*

1. INTRODUCTION

Blended learning (BL) has taken on several definitions over time, including: (i) to combine or mix modes of face-to-face and online teaching, (ii) to combine various pedagogical approaches to produce an optimal learning outcome with or without instructional technology, (iii) to combine any form of technology usage with face-to-face training [1][2]. The goal of the blended learning approach is to combine the best features of in-class learning with the best features of online learning in order to achieve active, independent learning [3].

Implementation of BL can take many forms. According to Staker and Horn, [4] there are four basic models of BL: the rotation model, the flex model, the self-blend model, and the enriched-virtual model. The rotation model can include station rotation, lab rotation, individual rotation and the flipped-classroom model.

In the flipped classroom model, the primary method of delivering the instruction is through online teaching [5]. In this format, there is an emphasis on shifting portions of the in-class instruction and activities to an online format, to allow for face-to-face learning activities, including interactive labs, simulations, project design/development and problem solving. It should be noted here that in-class instruction does not have to be completely eliminated in this model.

A growing body of literature has shown positive experiences using different formats of flipped classrooms [6]. The flipped classroom is intended to foster meaningful learning as a shared responsibility between students and instructors [7]. This work implements a rotation model in two first-year mathematics courses, with a particular focus on the flipped classroom model. The paper is organized as follows: Section 2 describes the flipped classroom format used, followed by Section 3 which describes the technical considerations and implementation, including the e-platform, active learning strategies and assessments used. In Section 4, a brief perspective on the implementation of this blended classrooms is presented. Section 5 presents results and analysis of the flipped classroom implementation in undergraduate mathematics courses. Section 6 concludes the paper.

2. A FLIPPED CLASSROOM FORMAT

Our model for the format of flipped classroom we implemented was inspired by active learning strategies used both in class and online. In this model, students initially completed the instructional aspect of the lesson online, either at home or at school at their own pace. The online portion of the lesson components dictate the in-class activities, and each lesson has the main goal of enriching the in-class time with active learning strategies. Unlike a traditional classroom, where students complete the practice problems as part of their homework, in a flipped classroom students work on practice problems in-class. Finally, students' level of mastery is evaluated with a diverse and appropriate set of assessments throughout the semester. Course assessments shown in Figure 1 mainly relate to the graded assessments necessary to complete the course such as quizzes, homework, and a final exam. In this work, assessments are mainly implemented to assess critical thinking and problem solving skills.

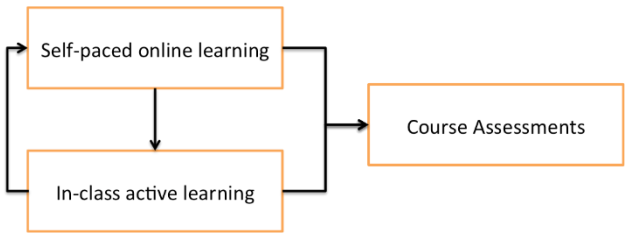

Figure 1. Flipped classroom model

Online learning components in flipped classrooms include a rich mixture of instruction-based, game-based, inquiry-based and problem-based learning content and activities. In this particular case, students are enrolled in a 5-week mathematics review course. Students' performance in this course is used to determine their placement in subsequent courses. Lessons are structured so that 80% of the content relates to foundation topics, while 20% of the content relates to advanced topics.

Online assessments are used to gather data about students' progress, as well as to provide interactive features in the online lessons. To enforce student completion of online assignments prior to class, they are asked to fill out a short questionnaire upon completion of the online unit. Student are asked the following: 1. if they completed the online assignment, 2. to give a small summary of the lesson, and 3. to provide comments or questions about the lesson. These assessments also help the instructor to gauge students' progress and content understanding. These assessments were given throughout the duration of the course. All assessments contribute to either a participation or a homework grade. The content gradually progresses form basic concepts into more advanced ones. (Figure 2).

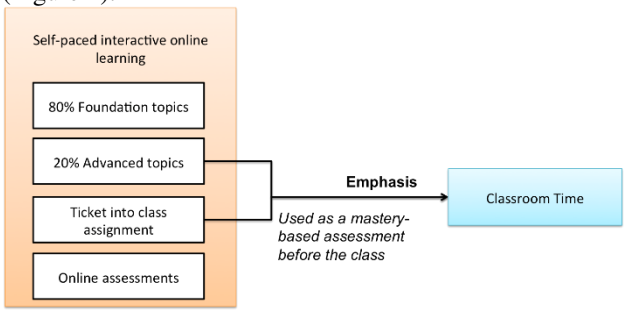

Figure 2. Online learning portion of the flipped classroom

Because a flipped classroom is a learner-centered model, each student is responsible for coming to class prepared. At the beginning of each class, the instructor is able to quickly address any misconceptions or confusion about a particular topic apparent in the assessment feedback (Figure 3). Students' preparedness enables them to actively engage in class discussions from the very beginning.

Learner-centered active learning design in the flipped classroom model enables students to develop critical thinking and problem-solving skills. The goal is to provide students with fundamental concepts, motivate them to learn more about these concepts, and create opportunities for them to further explore these concepts through different active learning strategies (problem solving, experiments, discussions, presentations, simulations, etc.). At the end of each class, students report their findings or summarize their discussions for the whole class. Verbal and written explanations by the students increase their ability to articulate their research, results and strategies [8].

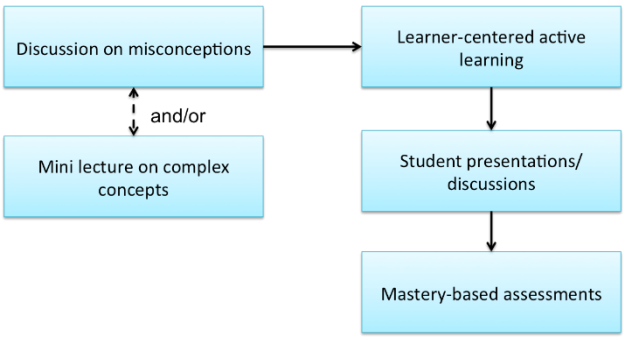

Figure 3. Classroom portion of the flipped classroom

3. TECHNICAL CONSIDERATIONS AND IMPLEMENTATION

According to student feedback, this was the first time any of them had been in a blended classroom. The idea of a blended classroom seemed to be engaging for some, while others were a little more apprehensive.

Helping students register for an online course required a lot of instruction and demonstration during in-class time. To help with this process, students were batch enrolled by the instructor. However, batch enrollment still required students to register for the course and to activate the account.

Due to the short duration of this course, for the first two weeks students were just asked to watch Khan Academy videos and to take notes and formulate question based on the videos. The second half of the term, a more formal blended classroom model was implemented using edX. Because this was the first time edX was used in this application, the lessons took a considerable amount of time to prepare and make available. Some students immediately began work on the assignments and seemed very engaged, while others expressed frustration because their preferred method of learning was direct classroom instruction. The majority of the topics covered in the course are review topics, and students were encouraged to seek alternative methods to help them understand the material, such as tutoring and additional videos.

The main goals of this course were to review mathematics concepts and to evaluate students' skills and performance. Students' outcomes in this course helped to determine their math course placement in the following semester. Students who have made gains in this specific program are those who portray good soft skills, such as work ethic, homework completion, attendance, and advocacy.

E-Learning Platform

Content materials were made available to students via Khan Academy videos and by using the edX platform.

Khan Academy breaks down topics into a sequence of examples with step-by-step explanations and practice questions to test students' understanding. The format of an edX lesson in this course is as follows: students are asked to watch a video; each video has a transcript running simultaneously; additional resources, such as content pdfs are also provided. The edX platform was implemented in the second half of the term to allow time for students to familiarize themselves with the technology and the platform itself. The benefits of edX in this blended classroom are many. Students can view lessons in their entirety and complete activities. Instructors can monitor students as they take the assessments to see what students are doing right or wrong. The interaction with the activity provides students with real-time feedback. Instructors have the ability to choose from a wide variety of assessments and a variety of communication tools.

Lessons on edX are structured so that the learning objectives and outcomes are outlined at the beginning of the lesson, followed by short explanation of the importance and relevance of the topic to every-day applications, when possible. A short summary of the topic and a video are provided for students to view the content material via different methods of instructions. Each section is followed by questions students need to answer on edX, and by questions for students to think about for future class discussions. At the end of each lesson, there are other resources provided for students who wish to find additional practice problems or more in-depth information.

Implemented Active Learning Strategies

The in-class lesson began with a brief review and summary topics from the previous class, followed by an overview of the new lesson. Students were then asked to provide feedback and to ask questions. The feedback provided by students was used to informally gauge their prior knowledge and overall understanding of the topic. After the overview of the new lesson, students separated into their small groups to work on different activities for approximately 20 minutes, before the reconvening and reporting challenges faced and strategies used to complete activities to the entire class.

Classroom activities were based on small group work. Students were randomly assigned to their groups. In-class activities required that students apply mathematical concepts to solve and explore application problems. For example, when reviewing the system of linear equations, students easily remembered how to solve these types of problems using methods such as graphing, elimination and substitution. However, students had difficulty when they were asked to think about possible applications for systems of equations. It was evident that students were struggling to transfer mathematics concepts and prior knowledge to other applications. For a specific rate problem, students were asked to act out a problem that required them to make time, distance, and rate measurements and calculations. Students explored the effects of changing the measured parameters and discussed what and how much information would be needed to solve different scenarios in this rate activity. Problem solving techniques and methodologies were discussed within the small groups and also shared with the whole class. Students were then asked to take turns presenting their work to the rest of the class.

Participation grades were assigned using a rubric, self-evaluations, and peer-evaluations.

Assessments

Students were assessed via formal and informal formats, with the aim of evaluating their content knowledge, progress, and mastery of fundamental mathematics concepts. Formal assessments were grade-based, and these included quizzes worth 20% of their final grade, homework worth 20%, participation worth 40%, and a final exam for the remaining 20%. Quizzes were given on a weekly basis and used mainly to measure learning comprehension of topics covered in the most recent week. However, quizzes also contained a few cumulative questions from previous lessons. Most of the quizzes were administered in-class, with the exception of the last quiz, which was on edX. Regular assessments are beneficial for both students and instructors. The instructor is able to identify any common gaps or misconception and use this information to guide planning of lessons, assessments and activities. For the students, assessments provide concrete evidence of progress and standing in the course.

Homework assignments were initially paper based, but by the end of the course, were gradually changed to an even distribution of paper-based and online assignments.

Participation is weighed heavily to encourage students to actively participate in classroom activities. Participation grades are assessed using a rubric which measures the following categories: answering questions in class, responding to instructor feedback, quality of group work, in-class contribution, feedback for instruction, and feedback for fellow students. Grades for in-class activities have two components, a graded group assignment and a graded individual assignment. One student's work was chosen at random to grade for the content and completeness of the assigned work. Every student in the group then received the same grade.

Informal assessments are based on observations of students' interaction and engagement within their group and in the classroom. Verbal questions were often posed during each class session to help monitor students.

4. EXPERIENCE

Implementing a flipped classroom using an eLearning platform provided new opportunities to promote student learning and engagement, but there were also many challenges. Students seemed to have mixed opinions about the use of an online platform. It is likely that this was exacerbated by the short duration of the course. There were many challenges for instructors and students related to the technical aspects of the flipped classroom. However, students' feedback showed that as students

gained familiarity with the blended classroom and edX platform they began to enjoy and appreciate having the material presented to them in different ways.

One markedly noticeable result of implementing blended learning in this course is that, in comparison to previous years, students communicated with and asked for help from the instructor more often and more willingly.

Many students also seemed to be working outside of class with the same group of students they were assigned to work with for in-class group work. In addition to promoting content learning, using in-class and online methods also influenced social behaviors, giving students a more holistic learning experience.

5. RESULTS ANALYSIS

At the end of the course, students were asked to complete an anonymous survey about their experience in this flipped classroom. Although there were 43 enrolled students, only 11 completed the survey.

Table 1 shows that the majority of students regularly watched the assigned videos, and although they felt the instructor encouraged student engagement, the helpfulness of group work was not rated as highly as was expected.

Table 1: Students' response to engagement in the course*

Survey Question	Mean +/- SD
How often did you watch the videos?	1.82±1.25
Did you find group-work helpful?	2.36±1.03
Did your instructor encourage engagement?	1.73±0.90

*Data based in 11 survey responses. SD indicates standard deviation. Likert scale items measured on a 6 point scale: 1 = always, 2 = very frequently, 3 = occasionally, 4 = rarely, 5 = very rarely, 6 = never

Table 2: Students' confidence level influenced by videos and in-class review*

Survey Question	Mean +/- SD
Confidence about material after watching the video but prior to class	1.55±0.52
Confidence about material after watching watching the video and reviewing in-class	1.55±0.52

*Data based in 11 survey responses. SD indicates standard deviation. Likert scale items measured on a 3 point scale: 1 = extremely confident, 2 = somewhat confident, 3 = not very confident

As shown in Table 2, students' confidence level regarding a specific topic seems to be greatly influenced by whether or not students watched the assigned videos prior to coming to class. However, students perceived that their confidence level was not affected by reviewing these topics in the classroom. Ideally, the in-class review and activities would have enhanced the students' knowledge, and therefore also their confidence regarding a particular topic.

Group work was performed in most of the class sessions to encourage engagement and participation. However, group-work was the lowest-rated activity by students.

Student's effort on homework activities is rated more highly than that of in-class activities (shown in Table 3). In Table 4, students rate their participation and engagement in classroom discussions quite high. This may mean that students slightly prefer whole-classroom activities to small group work, or that the structure of small group work needs to be revised.

Students were given a rubric to use as guide to meet participation expectations. However, there were no clear guidelines on how students should interact or what they should expect when working within their small groups. Even the online lessons and tutorials were uniformly structured; objectives and outcomes were clearly listed along with the lesson's instructions. These activities listed in Table 4 were seen as important factors that enhanced students' learning.

Table 3: Students' rating on effort*

Survey Question	Mean +/- SD
Effort in homework assignments	1.88±0.98
Effort during in-class activities	2.09±0.30
Overall rating of this course?	2.09±0.30

*Data based in 11 survey responses. SD indicates standard deviation. Likert scale items measured on a 5 point scale: 1 = very good, 2 = good, 3 = barely acceptable, 4 = poor, 5 = very poor

Table 4: Evaluation on students' resources and their effect on learning*

Survey Question	Mean +/- SD
Learning materials and resources were helpful	2.27±0.79
I think I did better in the course because it was a flipped classroom	2.27±0.90
Online tutorials helped me to understand a concept	2.00±0.45
Watching videos and reading material prior to to class enhanced my learning	1.73±0.65
Teaching and learning methods promoted understanding and application of key concepts	1.73±0.47
I participated and engaged in course discussions	1.88±0.98

*Data based in 11 survey responses. SD indicates standard deviation. Likert scale items measured on a 5 point scale: 1 = strongly agree, 2 = agree, 3 = undecided, 4 = disagree, 5 = strongly disagree

In Table 5, students identified performing an activity as their preferred method of learning. This reaffirms the need for flipped classrooms. Flipped classrooms are conducive to a classroom environment that is student-centered. Active learning activities allow students to step out of their comfort zone to engage and participate in small-group and whole-class activities.

Table 5: Activities that help students learn best*

Which of the following activities do you believe helps you learn best?	%
Reading a textbook	18.2
Listening to someone talk	9.1
Performing an activity	72.9

*Data based in 11 survey responses.

The survey given to students also contained open response questions. A few responses to each question are shown below.

Although, group work was the activity with the lowest rating in the survey, group-work and the use of videos were the two aspects students identify as liking best about the FC. Students reported that:

"Among many things the group work aspect stood out as positive … as well as interactive opportunities to participate"

"I like how we interacted with other students and did a lot of group work"

"I was in control of how many times I watched the videos"

Students' responses to what they liked least about the FC were a little more mixed. They wrote:

"Better group work"

"More teaching in class"

"If I didn't get the videos, sometimes I couldn't do the homework"

Finally, students were asked to rate their preferred method for the online component of the course. Did they prefer the online method used in the first half of the term (Khan Academy alone), or the method used in the second part of the term (edX platform, which included some Khan Academy videos)? The results for this question were quite surprising, since the students voiced their disappointment when the edX platform was implemented. Students reported:

"The edX videos were much more beneficial for me because the information added onto the videos was much more cleaner"

"edX because it made feel like I wasn't in middle school"

"edX only because it was directly related to my grade. I feel like I could have "winged it" in class without watching the videos, but with edX I actually had to do the work which was better for me content wise"

6. CONCLUSIONS AND FUTURE WORK

Students' perceptions of this flipped classroom were mixed, but there is an overall positive view of the lipped classroom, as shown in Table 3. Students believe the online resources and assigned activities directly correlate to an enhanced learning experience. Despite minor technological setbacks and student reluctance to embrace a new learning environment, students have proven to be committed to their learning. Their completion of assignments, and their overall effort are evidence of this commitment.

In comparison to courses taught in previous years, it was apparent that the student-instructor and peer-peer interaction increased drastically. Increasing communication and interaction between the instructor and the students is very valuable, because with increased interaction, students are able gain skills that help them become engaged and independent learners. This increase in communication also means that the instructor is able to know the students on more personal level and therefore have a better understating of their progress and their understating of math concepts. Knowing the students also allows the instructor to plan and modify lessons and activities quickly in direct response to the needs of students.

The full effects of the flipped classroom on student learning outcomes have not yet been evaluated. Future work intends to analyze student's perceptions and learning outcomes in flipped classroom. The dynamics of small group versus whole class dynamics will also be reviewed and modified to create more structured small group interactions.

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