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Flipped Classroom Model in Calculus II

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Abstract The flipped classroom is a teaching innovation model where the typical lecture and assignment elements of a course are reversed. In flipped classroom content delivery includes video lectures watched outside of the classroom, at home on their own time of the students, while classroom time is devoted for learner-centered activities such as active and problem-based learning. This model has received significant attention in the last few years; however, there is still little experimental research evidence about the effects of flipped classrooms. In this article, we implemented a modified and enhanced design of flipped classrooms model for one semester of calculus II course in order to assess student performance, student perception in general and based on gender, course syllabus coverage rate, completion rate, and students' memorization efficiency. Our study shows that students perceived the flipped classroom model as a positive experience, and especially appreciated the benefits of viewing lectures on their own time and at their own pace. Additionally, they performed better than students in traditional classrooms, although the performance gains were not high enough to be statistically significant but promised. Also, the result showed that female section performed better in the flipped model than male section.

Keywords New teaching models, Flipped classroom, Mathematics, Technology, Student performance, Student perceptions

1. Introduction

As early as 1982, Baker had a vision of using electronic means to "cover" rote material outside of class [1]. The barriers he found to accomplishing that goal included a delivery method of the material and the question of "what to do with the time that moving the lectures allows" [2]. The delivery barrier disappeared with the advent and implementation of the Learning Management System (LMS is a software application for the administration, documentation, tracking, reporting and delivery of e-learning education). In the fall of 1995, an early edition of an online content management system allowed Baker to place lecture notes online and retrieve them to show during class meetings. He realized during a lecture that the students were capable of retrieving the slides themselves, and encouraged them to do so. Once he "gave away all the content for the class," he realized he needed to make the class time more meaningful. He developed an action plan centered on four verbs: clarify, expand, apply, and practice.

> *The basic concept I applied in that class was to move the rote transmission of information that had been the content of my lectures out of the classroom (delivered instead through network-delivered presentations) and to use the opened-up class time for the students to work on application of the principles from that content while I was there to see what they were doing, answer questions and make suggestions [2].*

Student survey responses in the two flipped courses indicated positive student perception toward the classroom flip. Representative student comments indicated that the learning was more personalized, the cooperative groups fostered critical thinking, and the online resources provided students with more control over their learning. Baker presented the concept to conferences between 1996 and 1998, and in 1998 began to refer to the method as "The Classroom Flip" [2].

At approximately the same time, Lage, Platt and Treglia [3] designed and implemented a similar procedure. They referred to the concept as "The Inverted Classroom" and similarly held the expectation that students would view lectures in advance of class, then spend class time clarifying difficult concepts and working in small groups. They stated that "inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa. The use of learning technologies, particularly multimedia, provides new opportunities for students to learn". They used the inverted teaching method on five sections of an economics course. Student perceptions measured using a survey instrument with Likert-scale and open-ended questions revealed positive student perceptions about the course. Representative comments on student surveys revealed that it was easier to

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ask questions, learning from peers was different and enjoyable, and that the video lectures taught a lot.

Strayer [4] reported that in most instances where the classroom flip is used, the goal is to create an active learning environment during class meetings, while ensuring content coverage. Strayer's conceptual framework is derived from Piaget's theories of active learning.

> *The classroom flip is usually motivated by a desire to learn through active participation in the classroom. What exactly is meant by active participation? Is not all learning active, whether from a book, a lecture, or small group activity? Piaget says that learning occurs not when a person merely copies an idea, but when a person acts on it. [4]*

Many in-class activities that take place once a classroom is "flipped" are constructivist in nature, whereas the pre-class activities are very "traditional". Brooks and Brooks [5] compared aspects of traditional and constructivist classrooms. They pointed out that traditional classrooms strictly adhere to a fixed curriculum, students are viewed as "blank slates" onto which information is etched by the teacher, and students primarily work alone.

Providing students with an audio version of a lecture is one way to create a flipped class. A podcast is a series of audio or video files which can be subscribed to with an iPod or other device. Evans [6] provided 200 communications students with audio podcasts. The researcher used a Likert-scale questionnaire that compared the participants' attitudes toward lectures, podcasts, and taking notes to aid in comprehension. The results suggest clear benefits perceived regarding the podcasts. Survey results revealed that students believed the podcast to be an efficient, effective teaching style that can help them learn.

Quantitative and rigorous qualitative research on Flipped Learning is limited; however, there is an established body of research that supports the key elements of the model, which are built on various instructional foundations to shift from a teacher-centered to a student-centered approach to instruction. As mentioned throughout this review, a key feature of the Flipped Learning model is the opportunity to maximize student learning opportunities in the classroom by deliberately shifting direct instruction to outside of the group learning space. The emphasis on maximizing one-on-one interactions turns the focus to student-centered instruction that more actively involves students in the learning process. These approaches are commonly said to involve "active learning," defined as "the process of having students engage in some activity that forces them to reflect upon ideas and how they are using those ideas" [7]. Other relevant research on various instructional foundations includes peer instruction, priming, and pre-training. There is a growing body of research on using the Flipped Learning model with diverse student populations as well.

A substantial body of research on student-centered, active learning strategies supports the effectiveness of these approaches in increasing student learning and achievement (e.g., [7, 8]). Active learning is associated with improved student academic performance [8-12], and increased student engagement, critical thinking, and better attitudes toward learning [13]. When problem-based active learning occurs in science courses, for example, students report learning more, and their attitudes toward class improve [14]. Moreover, misconceptions are significantly reduced.

Another relevant area of research related to the potential impact of the Flipped Model is focused on the effects of preparing learners with direct instruction outside of the classroom, prior to receiving in-class instruction. Research on learning suggests some potential mechanisms by which this flipped approach might be effective. A large body of research on the effects of priming on memory indicates that when learners are exposed to particular stimuli, for example a set of facts, their memory or recall of that stimulus is improved due to their previous experience with the stimuli [15]. By providing students with direct instruction outside of the classroom, they are in essence "primed" for the active learning tasks carried out in the flipped classroom. Research on the effects of pre-training on learning is a similarly relevant area for the Flipped Learning model. One of the tenets of pre-training is to reduce the cognitive load on learners, to enable them to process information more efficiently. According to Cognitive Load Theory, there is a limit to the amount of information that can be used, processed and stored by the working memory, and overloading that limit undermines the learning process [16]. Ramsey Musallam, a San Francisco chemistry teacher and adjunct professor of education at Touro University, researched the effects of pre-training (receiving some instruction before in-class instruction) on the intrinsic cognitive load of students in an advanced high school chemistry class. Intrinsic cognitive load is a facet of Cognitive Load Theory that describes the effect of the learning environment on learning complex subjects. Musallam [17] found a significant relationship between mental effort and pre-training for students, indicating that students needed to use fewer cognitive resources to learn new material when they received pre-training. This and other studies [18, 19] suggest that pre-training may be an effective method of managing the intrinsic cognitive load and, thereby, provides one potential mechanism of the effect of the Flipped model on learning.

The classroom flip has become more popular in recent years, and it has been found that students respond positively to a flipped classroom. 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 implement the actual flipping model to a Calculus II course with no changes made to the traditional course design. The purpose is to discover the influence of the basic premise of the flipped classroom model on mathematics students' performance, perceptions, learning outcomes and completion rate.

The paper is organized as following. Section 2 outlines

the methodology used in our research. We then present the result and the discussions. Finally, further steps are discussed in conclusions.

2. Method

The goal of this study was to examine the effectiveness of traditional versus flipped course delivery methods for mathematics courses and especially calculus II by designing and developing new model of flipped classroom model. In recent years, calculus has become a required course not only for math, engineering, and physics majors, but also for students of biology, economics, psychology, nursing, and business. Law schools and MBA programs welcome students who've taken calculus because it requires discipline and clarity of mind. Calculus II course is mandatory for all engineering students and due to the difficulty faced students, we decided to study it. In our university, Calculus II is required by all industrial, computer and electrical engineering program. The course was taught over 16 weeks as a three credit semester-long course. The course follows traditional calculus textbook and covers integrals, sequences and series and some advanced topics. The course was assessed during the last spring semester. I had 4 sections to teach of same size, 2 males and 2 females, one male and one female section using the traditional lecturing method and the two others by using flipped classroom method. The traditional course met twice weekly, on Monday and Wednesday, for 80 minutes per session. The flipped classroom course meets one-weekly, on Thursday, for 80 minutes. All students of these sections have same major with same class level. For all sections, I used the same textbook, same order of topics, same homework and same difficulty of the exams with roughly same schedule. All students were expected to read the textbook, do homework, and solve problem examples. In flipped classroom sections students watch the video lesson that I uploaded it every Monday night just after I recorded from my normal lecture and learn the material at home then come to university and have class time to work on problems where my role is to guide them and to answer questions. In order to enforce my students in the flipped classroom sections to watch the video before the lecture, I consider the one who watch the whole video as present as in the traditional classroom sections and absent in the opposite scenario, and after three absences student receive warning letter and dismissed from the course after 6 absences. Additionally, the attendance grades worth 10% from the whole grade of the course. The software to watch the video is developed in house where I can track every student, if they watch the whole video, part of it, which part or frames are repeated and how many times…etc. Additionally, students can chat with other online students during watching the video lecture.

The main goal of this research is to assess the flipped classroom model in Calculus II course by studying and analyzing:

- Student performance through quizzes and exams.
- Student perception of the flipped classroom model
- Course syllabus coverage
- Completion rate
- Students' memorization efficiency through the feedback of the instructors of other courses where Calculus II is pre-requisite.
- Gender conception

3. Results and Discussion

A. Student Performance

The analyses of students' performance on the quizzes and exams averages are presented in the Fig. 1. The quiz/exam scores ranged from 0 to 100 points, and the total number of participants who completed the quiz was 120. We see the performance of students in the flipped model better than traditional one except for quizzes 5, 6 and 8. These quizzes cover a very abstract topic that's why students in traditional model performed better. Fig. 2 shows the performance result between the male and female in the flipped classroom model (60 students). We see that female sections perform better than male sections in the flipped model.

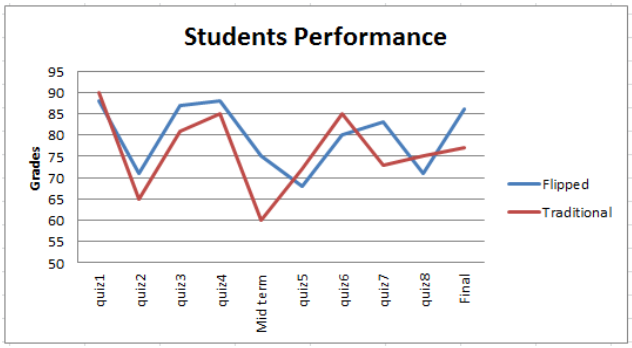

Figure 1. Student performance comparison

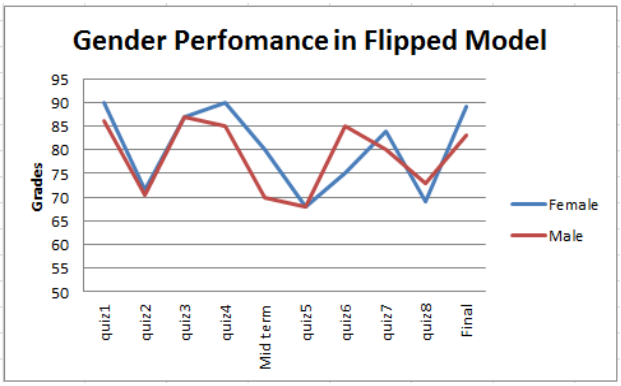

Figure 2. Gender performance comparison

The mean scores were higher in the flipped classrooms in both figures; however, a t-test for independent samples comparison showed that the difference in the means between the two groups was not statistically significant ($p>.05$). Although the results were not statistically significant, they are encouraging.

B. Students Perceptions of the flipped model

In order to assess the students' perceptions in the flipped classroom model, we used the online survey technique and in-class discussion. We created two types of surveys: one small survey must be submitted after each video and another detailed one must be submitted after the exams. The results of both surveys showed the following:

- The new way of lecture by watching the video before coming to the class required some adjustment to their schedule and way of studying.
- Over the semester, students felt that the flipped classroom model was a better use of class time
- Students evaluated videos and class time as better contributors to their learning than the assignment.
- During the in-class discussion, students reported that they enjoyed being able to replay parts of the videos that were unclear on the first watching.
- Most of the students stated the videos helped them understand the concepts, as well as allowed them to learn at their own pace.
- Half of the students desired to be able to ask questions while watching the videos.

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.

C. Course Syllabus Coverage Rate

Course syllabus coverage rate was compared in the flipped classroom model and in the traditional lecture model. At the end of the semester, the flipped classroom was in advance of one week and half of the traditional classroom in terms of syllabus progress.

D. Course Completion Rate

The Course completion rates are evaluated by the percentage of initially enrolled students completing the mid-term and final examinations. In our study, the proportions of students completing the mid-term and final examination were numerically lower for the flipped classroom (83.2% vs. 84%).

E. Student Memory Retention

We study the efficiency of the students' memorization by asking the feedback of the instructors who teach courses were Calculus II is prerequisite. In our research, we check the grades of the student in one of the quiz in the Probability course (Calculus II is prerequisite), that offered in last summer term, were students asked to find the mean and the standard deviation by using integration. The average of the student that has taken the flipped classroom is higher than the students of the traditional course. The word "data" is plural, not singular.

4. Conclusions

In this article, we implemented a modified and enhanced model of flipped classrooms for one semester of calculus II course in order to assess student performance, student perception, course syllabus coverage rate, completion rate and students' memorization efficiency. Students generally perceived the flipped classroom model as a positive experience, and especially appreciated the benefits of viewing lectures on their own time and at their own pace. Generally, students in the flipped classrooms performed better than students in traditional classrooms, although the performance gains were not high enough to be statistically significant but promised. More study is required to further discover the influence of this model on students' learning outcomes and to recognize best practices of a flipped classroom. Research should also focus on the impact of this model on the mixed classes, students of different majors and with students with different class level (sophomore, Junior…).

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