

The Effects of the Flipped Classroom and Peer Instructional Models on Learning Calculus

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Abstract: This study investigated the effects of the flipped classroom and peer instructional pedagogical models on students' achievements in Calculus for Business courses. One hundred eight students participated in the study and were divided into three groups. The Control group (35) was taught according to the traditional model; the first experimental group was taught according to the flipped classroom model (36); and the second experimental group was taught according to both the flipped classroom and the peer instruction models (37). Students in the experimental groups watched recorded lecture videos on Blackboard and solved an online pre-assignment before coming to class. A quasi-experimental design was implemented and two research instruments were designed and used; a pre- and post-tests. All the participants took a pre- test during the first week of the semester and completed a post-test after the treatment during the fourteenth week. The results of this study showed that students' achievements in the peer instructional classroom surpassed those of students in the other two sections.

Keywords: Flipped classroom, Peer instructional classroom, Calculus, Mathematics education

Introduction

Calculus is an entry topic for all students at the college of business and economics in the United Arab Emirates University (UAEU). The importance of Calculus in a wide range of disciplines promoted researchers to develop and use several teaching techniques and tools to improve the learning process including concept maps, graphing technologies, mathematics software and iPads (Al-Refai, Alshannag & Syam, 2014; Batista, Behar & Passerino, 2013; Ellison, 1993; Estela Carbonell & Saà Seoane, 2009; Hohenwarter, Hohenwarter, Kreis, & Lavicza, 2008; Kadry & El Shalkamy, 2012; Serhan & Syam, 2011).

Student engagement is one of the most important factors in effective learning. For this reason, researchers used different techniques to achieve this goal. The flipped classroom model is one of these techniques. It is a form of blended learning in which students learn content online by watching video lectures, usually at home, while work is done in class where instructors and students discuss and solve problems. The model offers a personalized student-instructor interaction as the roles of instructors shift more toward guidance than giving lectures.

Another model is the Peer Instruction Model which is an interactive student-centered learning technique developed by Harvard Physics Professor Eric Mazur (1997, 2012) in the early 1990s to enhance students' conceptual learning through small group discussions. In Mazur's technique, students answer conceptual questions independently, then they are asked to discuss their answers with their neighbors to convince them of their answer. This technique works best if students prepare before class and then test their application of knowledge in class. Peer instruction has proven to be an effective instrument for improving student learning in different scientific fields (Deslauriers, Schelew & Wieman, 2011; Gok, 2012; Lucas, 2009; Pilzer, 2001). Peer

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instruction emphasizes in-class interactions between instructor and students and students and peers. The peer instruction flipped learning model blends the concepts of flipped classroom and peer instruction in order to maximize the strengths of both models.

There are many varied models of flipped classrooms that were used by researchers including: entrance quizzes, in-class clicker questions, using mobile response devices, just-in-time teaching, problem-solving in groups, peer discussion and student presentations (Bates & Galloway, 2012; Demetry, 2010; Deslauriers, Schelew & Wieman, 2011; Frydenberg, 2012; Gannod, Burge & Helmick, 2008; Lage, Platt & Treglia, 2000; Moravec, Williams, Aguilar-Roca, & O'Dowd, 2010; Strayer, 2007; Strayer, 2012; Talbert, 2012; Toto & Nguyen, 2009). In addition, some research studies focused on the benefits of flipping college physics, engineering, mathematics and technology courses. They found out that the students who used the flipped classroom model were more engaged in learning class content outside of class, they felt more challenged and more eager to learn, they were also more involved and more open to cooperative learning. In addition, students indicated that the instructional videos helped them in learning the class content and pointed out that they liked the time they spent working on different activities in the classroom (Carlisle, 2010; Demetry, 2010; Frydenberg 2012; Strayer, 2007).

In a flipped introductory programming course, Carter (2012) used both peer instruction and JiTT. Before class, students viewed screenshots and then at the beginning of class, student comprehension was assessed using Clicker questions. When there was significant disagreement on the correct answer to a clicker question, mini lectures and peer instruction were used. The remaining class time was spent in active-learning group activities. The researcher found that students strongly favored the flipped approach over a traditional lecture style of instruction.

Given the growing interest in flipping pedagogy, in this paper, we discuss the effects of using the flipped classroom and peer instructional models on the learning process in a Calculus for Business and Economics course.

Purpose of the Study

The purpose of the study was to investigate the effects of using the flipped classroom and peer instructional approaches on students' achievements in a business calculus course.

The main research questions were the following:

- What is the effect of the flipped classroom as well as both the flipped classroom and peer instructional models on student achievement in a business calculus course?
- Is there a significant difference between student achievement in the flipped classroom vs the flipped and peer instructional classroom vs the traditional classroom?

Method

Participants

The students who participated in this study were enrolled in a Calculus for Business and Economics course at a major university in the United Arab Emirates. One hundred eight students participated in this study. The participants were enrolled in three sections: The traditional classroom (control group, 35 students), the flipped classroom (Experimental group 1, the flipped classroom group, 36 students) and the flipped classroom and peer instruction group (Experimental group 2, the peer group, 37 students). The students in this course used the textbook "*Calculus for Business, Economics, and the Social and Life Sciences*" (Hoffmann, Bradley, Sobecki & Price, 2013). The textbook emphasized the real-life applications in business of the different calculus concepts.

The assessments consisted of a pretest and a post test. The pre- and posttests were identical and contained twelve essay questions (see (Table 1) for test specifications).

Table 1. Questions' Specifications

Content/Cognitive	Knowing	Applying	Problem solving and reasoning
Limits	Q1	Q2	Q3
Continuity	Q4	Q5	Q6
Differentiation	Q7	Q8	Q9
Integration	Q10	Q11	Q12

The learning outcomes for the period of study are:

1. Compute the limits and the discontinuity of several elementary functions.
2. Compute derivatives of several elementary functions.
3. Evaluate different types of definite and indefinite integrals.
4. Apply mathematical models and tools to various business and economics problems.

Treatment

In this study the quasi experimental design of the form was used:

$$\begin{array}{r}
 O_1 - X_1 - O_2 \\
 O_1 - X_2 - O_2 \\
 O_1 - \quad - O_2
 \end{array}$$

All participants agreed to participate in this study. One of the researchers gave both experimental groups a training session on the flipped classroom instructional approach (Experimental group 1) and on the flipped classroom and peer instructional approach (Experimental group 2). He explained these instructional approaches and gave examples. Blackboard was used during this study for both experimental groups.

The instruction for both experimental groups consisted of the following:

- I. Before class, students in both experimental groups watched recorded lecture videos on Blackboard and solved an online pre-assignment. In the meantime, instructors analyzed the feedback from the online pre-assignment, prepared worksheets for the next class and designed a short PowerPoint presentation. In addition, and for experimental group 2, instructors prepared multiple choice questions.
- II. During the class, students in Experimental group 1 worked on solving worksheets (independently), they also worked on team mini-projects, asked questions and participated in class discussions. In addition to doing similar tasks, students in Experimental group 2 solved a sequence of multiple-choice questions. The instructors gave short presentations based on the online pre-assignment feedback, they facilitated and supported students' individual inquiries and collaborative work. For experimental group 2, after the short presentation, the instructor asked the multiple questions one by one based on students' responses.

Procedure

During the first week of the semester, the researchers explained to the instructors the purpose of the study. Data were collected from a pre-test that was conducted during the first week of the semester, as well as from a post-test. The same questions were used for the post-treatment test which was given during the fourteenth week of the semester. Both tests were administered by one of the researchers and taken by students without any interference from the researcher. In the fifteenth week a survey was given to students in the two experimental groups.

Analysis

The aim of this study was to investigate the effects of using the flipped classroom and the flipped and peer instructional models on students' achievement in a math class, in addition to investigating their attitudes towards

these models. To answer the research questions, a detailed statistical analysis was conducted. The data collected from the pretest and posttest were analyzed using SAS (Version 9.4: SAS Institute Inc.) to check for any statistical differences between the three groups, thus providing answers to the first research question regarding the effects of using these models on students' achievement. Responses to the survey items were categorized as follows: Students' interactivity and confidence, Students' effort, and Students' perceptions.

Results

The mixed models procedure was used in the analysis to test the effects of the experimental groups' type, time point, and experimental groups' type x time interaction on the scores. Post hoc tests were done on least-squares means using Tukey adjustment for multiple comparisons. Statistical analyses were performed using SAS (Version 9.4: SAS Institute Inc.). (Table 2) shows that there was no significant difference between the means of the pretest between all the groups, while there was a significant difference between the peer group and the other two groups (the control and the flipped classrooms).

Table 2. Mean differences of Pre and Post-tests between the groups

Score	Difference (Peer to Control)*			P-value*	Difference (Flip to Control)*			P-value*	Difference (Peer to Flip)*			P-value*
	Mean	95% CI			Mean	95% CI			Mean	95% CI		
		Lower	Upper			Lower	Upper			Lower	Upper	
Pretest	0.02	-0.96	1.01	1.000	-0.04	-1.04	0.95	1.000	0.07	-0.91	1.05	1.000
Posttest	10.58	8.91	12.24	<0.001	1.80	0.12	3.47	0.029	8.78	7.12	10.44	<0.001

*Tukey adjusted post hoc test

(Table 3) gives the mean differences between the pretest and the posttest for each group, there is a significant difference between the posttest and the pretest for each group.

Table 3. Mean differences within each group

Score	Pretest			Posttest			Difference (Time 2 to Time 1)*			P-value*
	Mean	95% CI		Mean	95% CI		Mean	95% CI		
		Lower	Upper		Lower	Upper		Lower	Upper	
Peer	2.59	2.12	3.06	16.92	16.12	17.71	14.32	13.05	15.60	<0.001
Flip	2.53	2.05	3.00	8.14	7.33	8.94	5.61	4.32	6.90	<0.001
Control	2.57	2.09	3.05	6.34	5.53	7.16	3.77	2.46	5.08	<0.001

Discussion

This study aimed at investigating the effects of the flipped classroom as well as the peer instructional models on students' achievements in Calculus for Business and Economics courses. The 108 participants took a pre- test during the first week of the semester and completed a post-test after the treatment during the fourteenth week.

Results of this study indicated that students in the peer instructional group performed significantly better than the students in the other two groups. Further research investigating intensive use of flipping classroom and peer instructional approaches with modifications is needed to measure the effectiveness of their use in the classroom.

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