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Original Article

A Pedagogical Model on Engineering Students' Learning of Mathematics during the COVID-19 Pandemic

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Abstract *- This study investigated the effects of using the flipped classroom pedagogical model in teaching Calculus II during COVID-19 at UAEU in Fall 2021. In addition, it investigated students' perceptions of their learning and engagement in the flipped classroom. Thirty-four students from the college of Engineering participated in the study. The research aimed at investigating the impact of using the flipped classroom model on students' achievements in the experimental groups (14 students) and comparing the results with those of the traditional group (20 students), which followed traditional teaching methods. The focus of the study was the double and triple integrals and their applications. A quasi-experimental design was implemented, and two research instruments were designed and used; a pre-and post-tests in addition to a survey. The study showed that students in the experimental group had a significant improvement compared with the traditional group. In addition, most students in the experimental group had a positive attitude toward the use of the flipped classroom.*

Keywords *- Flipping classroom, Pre-test, Post-test, Survey, quasi-experimental design.*

1. Introduction

Over the past two years, many departments had adjusted to new teaching and learning modalities because of the COVID-19 pandemic. At the beginning of the pandemic, some schools moved their face-t0-face instruction to remote instruction. This could have been challenging for students and faculty alike. Many challenges arose, such as the need to learn how to use new technologies, develop new instructional materials, provided interactive teaching techniques, etc. Many studies investigated remote learning during the pandemic were conducted such as Abbasi et al. [1], Adnan & Anwar [2], Agarwal and Kaushik [3], Basilaia, et al. [4], Bao [5], Demuyakor [6], Giovannella [7], Al Rwawashdeh [8], Angelova [9], Murphy [10], Bates [11], Carisle[12], and Özer [13]. Many researches focus on the pedagogical models during this pandemic such as Demetry [14], Deslauriers [15], Frydenberg [16], Gannod [17], Hamilton [18], Hebebci [19], Larg [21], Marpa [22], McGivney [23], Moravec [24], and Naciri [25].

Agarwal and Kaushik [3] found that students had a positive perception of online teaching. Similar results were obtained by Al Rawashdeh [8]. United Arab Emirates University (UAEU) was among the universities that adjusted their teaching modalities during this pandemic. The flipped classroom model was one of the techniques that were used. In this model, the duties of students and teachers in this model differ from those in a regular classroom. Students study online by watching video lectures outside of class and participating in learning activities and discussions in class. Because education takes the form of counseling rather than lectures, instructors interact with students in a more customized way. Instead of the conventional focus on delivery and review of knowledge in the traditional classroom, class time is used to solve issues and practice.

Over the past few years, instructors have used different models of the flipped classroom including entrance quizzes, in-class clicker questions, mobile response devices, just-in-time teaching, problem-solving in groups, peer discussion, and student presentations, see Bates & Galloway [11], Demetry [14], Deslauriers, Schelew & Wieman [15]; Frydenberg [16], Gannod, Burge & Helmick [17], Lage, Platt & Treglia [20], Moravec et al. [24], Talbert [26], and Toto & Nguyen [27]. Some researchers explored the benefits of the use of the flipped classroom models on students' learning and engagement in different college-level courses such as Carlisle [12], Demetry [14], and Frydenberg [16].Love, Hodge, Grandgenett, and Swift [21] investigated students' understanding and perceptions of an applied linear algebra course. Students were divided into two groups: the traditional group and the experimental group. In the experimental group, students were expected to prepare for the class by doing any of the following: watching videos and watching instructor-prepared screencasts. The flipped classroom was structured as follows: the first 15 minutes at the beginning of the class, and then students worked on problems from the textbook. The researchers found that students in the experimental group performed significantly better on the last two exams compared to the students in the traditional group. There was no significant difference in the final exam.

The goal of this research was to see how employing a hybrid flipped classroom affected students' achievement and impressions of a Calculus II course at UAEU during the pandemic in the first semester of 2021

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2. Method

2.1. Participants

The participants in this research are 34 students registered in a Calculus II for engineering course at UAEU in Fall 2021/2022. Twenty students were part of the traditional group, and 14 students were part of the experimental group (the blended flipped classroom). The experimental group is students who registered in one section taught by the first author. The course covered several topics but for this study's purposes, the focus was on the following topics: double and triple integrals using different coordinates. All participants volunteered to participate in this study and took both the pre-test and the post-tests. In addition, this group of students completed a survey about the blended flipped classroom.

2.2. Treatment

In the ninth week of the semester, the experimental group received instructions about the blended flipped classroom model using face-to-face and distance learning. The Blended flipped classroom model was used for four weeks, the first two weeks students came to the university (face-to-face) and for the second two weeks, they worked online. The blended flipped pedagogical model was implemented between the tenth and the thirteenth week of the semester. Students were the center of the learning process during these four weeks. The following technological applications were used in these four weeks: Blackboard; Wolfram Alpha; Dropbox; the publisher's textbook platform, and the YouTube channel.

The tools that were mostly used in the first four weeks were animations, movies, and drawing. Students also completed worksheets before class. This allowed instructors to analyze student work and feedback to design level-appropriate tasks for each student in the class.

The blended flipped classroom model was constructed as follows:
Before class: The instructor provided students with lecture videos to watch. Students completed worksheets before coming to class. The goal was to allow the instructor to differentiate between students' levels and to know which concepts they had difficulties with.

During a class: The instructor gave a brief presentation covering the concepts that student had difficulties with based on their worksheet responses. During class time, students solved questions and worked on projects. Each student received a different in-class worksheet based on their answers on the worksheet that they submitted before class. For the traditional group, students received instruction using the traditional method of teaching using in-class lectures.

2.3. Procedure

The researchers explained the study's goal to the teachers at the start of the semester. In the ninth week, students took the pre-test. The pre-test covered the following topics which were not yet discussed in class: double and triple integrals in different coordinates. Students from both groups (34 students) students took the pretest. The test consisted of six questions distributed as follows (Table 1)

Table 1. Exam specifications

Content	Knowing	Applying	Reasoning
Double integrals in polar coordinates	Q1	Q3	Q2
spherical, cylindrical coordinates, and triple integrals	Q1	Q4	Q5, Q6

One question on the polar, cylindrical, or spherical coordinates to compute the double and triple integrals. Two questions on drawing regions in different coordinates and converting them from one coordinate to another. Three questions on converting integrals from one coordinate to another to make evaluating the integral easier. The learning outcomes for the study period were

- Know how to draw regions in different coordinates.
- Know how to convert integral from one coordinate to another.
- Analyze engineering challenges using critical thinking.
- Calculate areas, volumes, and centers of mass for various configurations using multiple integrals.

Outcome number 1 is measured by Q3 and Q4, outcome number 2 is measured by Q2 and Q5, outcome number 3 is measured by Q 6, while outcome number 4 was measured by Q2, Q5, and Q6.
For the experimental group, the treatment was divided into three main components:

- Before class: the instructor posted recorded videos for students to watch before class, explaining the concepts and the formulas and how to implement them. The instructor uploaded the videos on a YouTube channel. In addition, worksheets were sent to the students before they came to class. They completed the worksheets and submitted them to the instructor who analyzed students' responses. The instructor prepared worksheets, mini projects, and a short PowerPoint presentation for the class meeting (face-to-face and online).
- During class: the instructor gave a brief lesson to the students based on their responses on the worksheets. Students also worked on mini projects and other worksheets. They worked both in groups and individually on different tasks. The instructor facilitated students' discussions.
- After class: Students solve more problems and online quiz and send their answers to the instructor to ensure that they are aware of the principles
- On week fourteen, the two groups completed a post-test which is identical to the pre-test. In addition, students in the experimental group completed a survey about their experience with the blended flipping classroom model.

3. Results

The main purpose of this study was to learn whether using the flipped classroom pedagogical model (FCPM) in teaching Calculus II is effective in helping students learn Calculus for Engineering.; in particular, the concepts of double and triple integrals in different coordinates. In addition, the study investigated students' feedback of the blended FCPM.

The data from the pre- and post-tests were analyzed. Descriptive statistics for the two groups were provided, including the mean (±SD) and median values for continuous variables, and the number of patients in each group who had a change in score of at least ±1 on the measure. Statistical analyses were performed using IBM SPSS software with a 0.05 significance level. The mean of both groups improved between the pretest and the posttest (Table 2).

Table 2. Descriptive Statistics

	Experimental Group		**Traditional Group**		**P-value ***
	Mean	Standard Deviation	Mean	Standard Deviation	
Change in score	7.50	3.32	4.25	2.45	0.005

The independent t-test (Table 3) indicates that students in the experimental group showed significant improvement compared with the traditional group in the posttest.

Table 3. Independent t-test

	Experimental Group		**Traditional Group**	
	Median	**Mean**	**Median**	**Mean**
Pretest	1.00	1.21	2.00	1.95
Posttest	9.00	8.71	5.50	6.20

Regarding the experimental group students' perceptions of the blended flipped classroom, their responses in the survey were divided into five categories: advantages and disadvantages, interactivity and confidence, effectiveness, effort, preferences, and interactivity and confidence.

As indicated in (Table 4) most students (79%) indicated that they felt more confident about their learning using the blended flipped classrooms, and 71% of students perceived the flipping classroom environment to be more interactive.

Table 4. Experimental students' interactivity and confidence

	Yes	No	Not sure	Total
Interactivity	10	3	1	14
Confidence	11	2	1	14

In terms of effort, 93% of the students indicated that they put more effort into their learning when using the blended flipped classroom model while 7% of them reported that they put the same effort using the blended flipped classroom (Table 5).

Table 5. Experimental students' effort

	More	Less	same	Total
Effort	13	0	1	14

A majority of students (93%) found the blended flipped classroom modality effective, while 86% found it helpful. Only 7% found it easy to use.

Table 6. Effectiveness of the flipped classroom

	Yes	No	Not sure	Total
Easy	1	13	0	14
Effective	13	1	0	14
Helpful	12	1	1	14

Students mentioned two main advantages of the blended flipped classroom model: flexibility (93%) and a better understanding of the concepts (86%). The students (36%) overwhelmingly reported that the only disadvantage of attending the online course was the technical difficulties experienced.

Table 7. Advantages and disadvantages of the flipped classroom

	Yes	No
Technical problems	5	9
Understanding	12	2
Flexible	13	1

4. Discussion

The purpose of this study was to investigate whether using the flipped classroom pedagogical model for teaching Calculus II to engineering students improved their learning. The research aimed at investigating the impact of using the flipped classroom model on student achievement in the experimental groups (14 students), and comparing the results with those of the control group (20 students), which followed traditional teaching methods. Students' answers in both groups were analyzed using an independent t-test for both the pre-and posttests. The results indicated that students in the experimental group performance are better compared with the other group. Overall, though, students' achievements were below the expectations for both groups.

- Based on the results of this study, we recommend:
- Increase the sample size in both groups to be able to arrive at accurate results and conclusions
- More training for Faculty members and students on the use of the blended flipped model
- Have enriched infrastructure (for example wireless internet & software)
- Establish learning resources to enhance the teaching & learning process

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