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Measuring the Impact of the Flipped Model in a Pre-Calculus Course

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Abstract. The flipped model of instruction has been championed as a method for increasing student engagement and enabling instructors to facilitate more active learning within the classroom. Research on the flipped model also suggests that it may also lead to better course outcomes than the traditional lecture approach. Given this potential for student success and engagement, faculty at California State University, Fullerton have adopted the model in many of their courses. In this preliminary report, we measure the impact of the flipped model on course outcomes of a Pre-Calculus course during the Spring 2024 semester. In addition, we compare student perceptions of the course elements that supported their learning between students enrolled in the flipped sections of the course and those in the non-flipped sections of the course.

Introduction

The flipped model of classroom instruction is a mode of active learning rooted in the constructivist theory of learning (Bishop & Verleger, 2013). In this model, students consume course content outside of the classroom through video lectures and/or course readings and spend in-person classroom time engaging in collaborative learning and problem solving (Lage et al., 2000; Salifu, 2017). Since gaining popularity during the early 2000's, various scholars have championed the model for its effect on student achievement (e.g., Caviglia-Harris, 2016; Connell et al., 2016; Day, 2018; Le & Ichinose, 2022) as well as attitudes towards learning and classroom engagement (Alebrahim & Ku, 2020; Stone, 2012).

Within the past decade, there has been a great shift towards active learning pedagogies (Stone-Johnstone et al., 2024) within the mathematics department at California State University, Fullerton (CSUF). One of the most popular active learning approaches used at CSUF is the flipped model, with many introductory mathematics courses (e.g., College Algebra, and the Calculus series) being flipped by certain professors. In this preliminary report, we evaluate the effect of the flipped model within the Pre-Calculus course at CSUF during the Spring 2024 semester by answering the following research questions:

1. Is there a statistically significant difference in course outcomes between the students in a flipped vs. non-flipped Pre-Calculus course at CSUF?
2. Are there differences in student perceptions of the course elements that supported their learning between the two groups?

Methods

Context. The flipped model, as employed at CSUF, is a three-part model that consists of online interactive content videos, pre-assessments (Ticket in the Door, TITD), and mathematics labs. Traditional lecture time is reconceptualized within this model as a mathematics lab, where students work collaboratively on activities in their course workbook during in-person class time. Data for this study was collected during the Spring 2024 semester, where there were eight coordinated sections of Pre-Calculus with an average of 35 students in each section. Out of the eight sections, four were flipped and the other four were non-flipped. In the non-flipped sections, students primarily learned course content within the classroom, with some instructors choosing to post optional resources for students to engage within the learning management system (Canvas). All students were assessed using common midterms and final exams.

Theoretical Framework. Given the emphasis on student classroom engagement within the flipped model at CSUF, we view the data through the lens of the Instructional Triangle (Cohen et al., 2003; Lampert, 2001). The instructional triangle is a framework for articulating the process of teaching and learning. This triangle consists of three primary nodes: student, teacher, and content (see Figure 1). The arrows represent the interactions between the nodes. As Cohen et al. (2003) explained, "instruction consists of interactions among teachers and students around content, in environments" (p. 122).

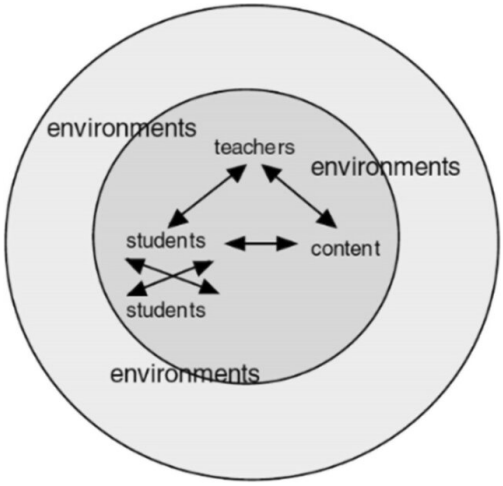

Figure 1. The Instructional Triangle (Cohen et al., 2003).

Student-student interactions may occur through in and out-of-class collaboration. Student-teacher interactions include teacher moves for engaging students and supporting their learning (Ball & Forzani, 2009). Student-content represents how students engage in course content, and this may be through course resources (e.g., homework, videos, textbook). Teacher-content interactions represent the instructional choices for content delivery. The concentric circles within Figure 1 represent the varying levels of the environment in which this learning transpires (in and outside the classroom). Given the differing pedagogical approaches within the flipped vs. non-flipped courses, the instructional triangle enables us to explore the student experience by examining the types of interactions that students identified as contributing to their learning.

Data Collection. This study was conducted with approval by CSUF's Institutional Review Board. There were two primary data sources employed to address the research objectives: student course outcome data for all Pre-Calculus students during the Spring 2024 semester and survey data. The authors constructed a Qualtrics survey, consisting of three parts. The first part consisted of Likert-type questions, gauging student perceptions about course structures (e.g., course workbooks, activities, and assessments). The second part consisted of three open-ended questions regarding their perceptions of support and barriers to their learning of course content. The final section consisted of demographic questions including information about previously attempted mathematics courses, placement scores (for entrance at CSUF), and their projected course grade.

Data Analysis. Employing a mixed-methods approach to data analysis (Creswell, 2012), we answer the first research question by conducting a quantitative analysis. Specifically, we performed a two- sample $t-$test to determine whether there was a statistically significant difference in the course outcomes between flipped and non-flipped courses. Students who withdrew from the course ($n = 25$) were removed from the analysis since no point value was assigned to a grade of W.

We answer the second research question regarding student perception of the support for their learning of Pre-Calculus, by conducting a qualitative analysis. All Pre-Calculus students were asked to complete the Qualtrics survey during the ninth and tenth week of the semester. Of the 276 enrolled students, 173 completed the survey (approximately 63% response rate): 88 students in the flipped course and 85 in the non-flipped course. For the purpose of this investigation, we focused on students' responses to the open-ended question, "What are two or three components of the course that have supported your learning?"

All student responses were coded using a coding scheme adopted from the Instructional Triangle framework (Cohen et al., 2003). Since students discussed aspects of the course that they found beneficial to their learning, we limited our coding to focus on the Student-Student, Student-Teacher, and Student-Content interactions within the Instructional Triangle. The dataset did not allow for us to explore the Teacher-Content interactions, nor teacher motivations for their instructional choices (i.e., Herbst & Chazan, 2012). Throughout the coding process, a subcode of the Student-Content interaction was created, "External Resources," to describe instances where students relied on learning resources separate from the ones provided by the instructor. A second subcode, "Office Hours," was generated to differentiate between in-class teacher support and outside-class teacher support, given the additional effort required for the latter.

There were 132 complete student responses to this open-ended question. The first author coded the entire dataset, and 30% of the dataset was double-coded by two other members of the research team. Instances of disagreement were discussed and negotiated, with only two instances of disagreement (95% agreement).

Preliminary Findings

Course Outcomes. The result of the two-tailed independent samples $t-$test was not significant based on an alpha value of .05, $t(248) = 1.53$, $p = .126$, indicating there was no significant difference in the course performance (course grade point value) between the flipped

and non-flipped classrooms. The results are presented in Table 1. While the difference in performance was not statistically significant, the overall mean score in the flipped classrooms was slightly higher. In particular, the mean value of course grades is 0.27 points higher for the flipped modality compared to the non-flipped modality ($\tilde{1}$3.6% difference).

Table 1. Two-Tailed Independent Samples t-Test for Final Grade Point Value by Modality

	Flipped			*Non-Flipped*				
Variable	M	SD	n	M	SD	n	t	p
Point Value	2.25	1.31	114	1.98	1.36	136	1.53	.126

Perceived Supports for Learning

When comparing the students in the flipped course to those in the non-flipped course, we did not observe meaningful differences in the course components that students identified as supporting their learning. Table 2 illustrates the frequency of the different codes across the two groups of students.

Table 2. Distribution of Code Frequencies between Students in Flipped and Non-Flipped Courses

	Flipped	*Non-Flipped*
Student-Student	11	5
Student-Teacher	27	22
Office Hours	1	8
Student-Content	57	50
External Resources	2	5

More of the flipped students mentioned Student-Student coded elements as supporting their learning, with one student commenting: "We help out what questions we have to answer as a group while working on the workbook and worksheet." Some students in the non-flipped course also expressed valuing group collaboration, explicitly naming "in class group activities" as supporting their learning.

Students in both groups credited their instructor's in-class explanations and lectures for supporting their learning. However, it is worth noting that eight students from the non-flipped group (compared to just one from the flipped group) specifically mentioned attending their instructor's office hours as a course element that supported their learning.

The majority of the dataset was coded as "Student-Content," with both groups of students identifying the workbook, the online homework, and, for the flipped classroom students, the Ticket in the Doors as valuable to their learning. The primary differences that arose between the two groups were with respect to the types of external resources students credited. Two flipped students mentioned workshops (Supplemental Instruction) as a support, while the five non-flipped students mentioned resources such as YouTube and Khan Academy.

Discussion

The preliminary findings revealed no statistically significant difference in course outcomes between the students in a flipped vs. non-flipped course; however, the data does suggest the flipped model may still have potential benefits for course outcomes. The observed 13.6% higher mean point value of letter grades between the flipped and non-flipped students is promising.

Similarly, we did not observe notable differences when comparing the student's perceptions of course supports between the flipped and non-flipped modalities. Students from both modalities primarily credited their learning to course elements such as homework assignments and in-class workbook activities.

Considering the active teaching culture within the mathematics department at CSUF, one could speculate that the non-flipped model might have incorporated more interactive elements compared to a traditional lecture-based course. If so, this could account for the similarities in student perceptions regarding the course elements that supported their learning between both modalities. The only notable difference in students' perceptions was that non-flipped students reported using Khan Academy and YouTube for video lecture support whereas the flipped students already had instructor-provided videos embedded within the course.

As we continue to explore this data, and the flipped classroom model in general, we invite the audience to consider the following questions:

1. Though we found no significant or noticeable differences between flipped and non-flipped modalities of instruction, how does this finding contend with the current teaching and learning climate?
2. What specific aspects of the flipped and non-flipped course formats might have led to the observed lack of statistically significant difference in student outcomes?

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