Flipping College Algebra: Effects on Student Engagement and Achievement

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Abstract

This study compared student engagement and achievement levels between students enrolled in a traditional college algebra lecture course and students enrolled in a "flipped" course. Results showed that students in the flipped class had consistently higher levels of achievement throughout the course than did students in the traditional course, despite no differences in demographics. Moreover, students in the flipped course reported greater gains in affective variables related to mathematics than did students in traditional courses. In addition, this study found evidence that the flipped course experience was especially impactful for Hispanic women.

Introduction

Colleges and universities have increasingly been concerned with "bottleneck" or "gateway" courses: that is, entry-level courses with high-level enrollment but low success. Failure of these courses to effectively serve students can have a severely detrimental effect on both the student and the institution. At the forefront of identified bottleneck courses is college algebra, a one-semester mathematics course that can either be taken for general education credit or as a prerequisite for further mathematics courses. Each year more than 1,000,000 students take college algebra or a related course (Lutzer et. al, 2007). Moreover, studies have placed the non-success/withdrawal rate for these courses nationally in the 40-50% range (Herriot, 2006).

In April 2013, California State University Chancellor Timothy P. White's budget proposal included funding to reduce the negative impact of bottleneck courses through the use of innovative online technologies. One such type of course redesign is the initiative to "flip" the classroom. In a flipped class, students watch online video lectures before coming to class, complete a pre-assessment assignment, and then engage in a classroom discussion of the material facilitated by the instructor. This is in contrast to the traditional lecture model, where students independently take lecture notes and then attempt to complete homework problems on their own.

In this paper, we present the results of flipping a college algebra class using online technologies. Our conceptual model addresses the following two research questions:

1. How does the academic achievement of students in a flipped college algebra class compare with that of students in a traditional lecture model college algebra class?
2. What variables may serve as predictors for student achievement in a flipped college algebra class?

This paper presents a current literature review and theoretical model; the methodology used in the study with regard to questionnaire design and data collection; the data analysis; and the results and implications of this research.

Literature Review and Theoretical Model

Review of Recent Studies

The struggle that students face to pass college algebra is well documented. In 2010, a national U.S. Department of Education study found that 80 percent of high school dropouts cited their inability to pass Algebra I as the primary reason for leaving school (Schachter, 2013). Problems common to algebra students include the student's previous knowledge of the subject, the effectiveness of the instruction, and their motivation to work hard enough to succeed (Thiel, Peterman, & Brown, 2008). Many college students, not just those in college algebra, have misconceptions about their "math ability" and have since given up on the notion that they could ever truly succeed in math (Boaler, 2013). These types of perceptions, coupled with the difficulty of the material and its reliance on prerequisite math skills from K-12 math classes, lead to many students failing college algebra, often multiple times.

Intervention strategies have been implemented to try and increase student pass rates in college algebra with varying degrees of success. Examples leveraging the use of modern technology include Carla Thompson and Patricia McCann's study to redesign college algebra to improve student retention (2010); Sherry Herron's study on the use of computer algebra systems in the classroom to improve pass rates (2012); and Neil Hatem's study on the use of graphing calculators (2010). Other types of technology used in college algebra have included online homework, online tutoring services, and multimedia technology (Kersaint, Dogbey, Barber, & Kephart, 2011). Approaches such as tutoring and supplemental instruction have also been found to be helpful for increasing both academic performance and improving attitudes towards math (Corey Legge, 2010; Ugo, 2010).

While college alebra professors share one major goal, to increase pass rates, it is also important to consider the affective component of student success. The term "affect" in mathematics, while not strictly well-defined, generally relates to a student's beliefs and attitudes towards studying math (Di Martino & Zan, 2010). Studies have shown that a college student's positive attitude towards mathematics tends to be correlated to higher achievement in a math courses (Hemmings & Kay, 2010; Hodges & Kim, 2013).

Although studies have been conducted on improving both achievement and affect in traditional college algebra settings, few explore flipped class college algebra courses. Several recent studies on general flipped-class strategies have been conducted, including Kathleen Fulton's study (2012) of flipping high school classrooms (2012); Maloy's study of flipping a college community engagement course (2014); and Demski's "expert tips" article (2013). However, few studies focus on a college mathematics courses in general, let alone for college algebra specifically (Wilson, 2013; Sparks, 2011). With this study, we hope to address a gap in the literature to examine the effects on student achievement of flipping college algebra in a university setting.

The learning process can be analyzed with Anderson and Krathwohl's revision of Bloom's Taxonomy in Figure 1(Krathwohl & Anderson, 2010).

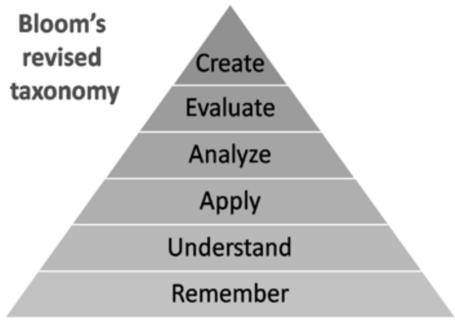

Figure 1. Revised Bloom's Taxonomy

In the traditional classroom model, the first two levels, "remember and understand," are presented during classroom time. The student is responsible for the higher levels of comprehension on her or his own. By comparison, the flipped class is structured to allow in-class time for higher levels of comprehension. Since students watch pre-recorded lecture videos on the material before coming to class, class time can incorporate a problem-solving workshop format where students can work independently or in groups to solve more difficult problems. This allows the first two levels of Bloom's taxonomy to take place before class, and allows the instructor and students to build the upper levels of comprehension together during class time.

Flipped Class Structure

The flipped class used in this study is based on a three-step process. The student is expected to watch a 7-12 minute online module for each section of the text prior to coming to class. These modules include explanation of main ideas, examples, and embedded comprehension questions that the student answers as he or she watches and completes a pre-assessment ("Ticket in the Door") prior to coming to class. He or she then brings the completed Ticket in the Door to class the next day; this serves as the basis for the class discussion and work. Students present their solutions to Ticket in the Door problems and then spend the rest of the class period engaged in problem solving of more difficult problems that would traditionally be assigned as homework (Figure 2).

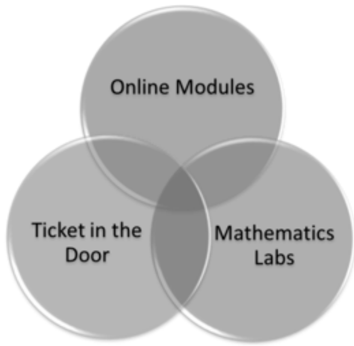

Figure 2. Three-Part Flipped Class Model

Theoretical Model

This study aims to measure differences in achievement between students in a flipped college algebra class and students in a traditional lecture class. In addition to the standard marker variables of ethnicity and gender, we consider how being in a flipped class as well as previous attempts at college algebra may predict a student's affective response to college algebra. We use this set of variables, along with the student's affective responses, to predict academic achievement in college algebra (Figure 3).

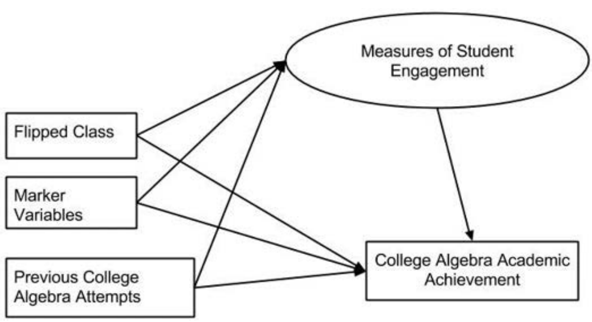

Figure 3. Theoretical Prediction Model

Method

This study was based on students at California State University Fullerton (CSUF) who completed Math 115: College Algebra, during the spring 2014 semester. CSUF is a large, urban, 4-year public university in Southern California, with approximately 38,000 students. The 669 students who completed the Math 115 course in Spring 2014 were included in this study. Information regarding ethnicity, gender, number of college algebra attempts, and grades was reported via university records for all participants.

For the population of 669 students, 40.1% of the students self-identified as male and 59.9% of the students as female. Approximately 18.1% of students self-identified as Asian/ Asian American; 19.1% as White/Caucasian; 49.9% as Hispanic/Latino/a; 3.0% as Black/African American; 6.3% as multiracial; 0.6% as "other"; and 3% as unknown/decline to state.

Since this was a spring semester, we considered the number of times the student had attempted college algebra. First-time students accounted for 49.9% of the population; students who had taken the class once previously accounted for 46.9% of the population, and students who had taken the class two or more times accounted for 3.1%. Thus, half of the students had either previously failed or withdrawn from college algebra at CSUF. Because the flipped program was a pilot, the flipped group was smaller than the traditional lecture group. There were 19 sections of college algebra, with 3 flipped sections and 16 traditional lecture sections. Of the three instructors who taught flipped classes, two of them also taught traditional lecture classes. The flipped classes accounted for 19.9% (133) of the students, while 80.1% (536) of the students were in a traditional lecture class.

Students were asked to participate in a voluntary, confidential pre- and post- survey regarding their opinions about mathematics. The same questionnaire was given for both the pre- and post- survey. Students who completed both the pre- and post- survey were awarded ten extra credit points at the end of the semester (1.0 % of the course grade). The pre-survey was available during the first two weeks of the semester, and the post-survey was available during weeks 13 and 14 of the sixteen-week semester. Of the students who responded to the survey, 310 students answered at least 70% of the questionnaire items. This resulted in a 46.3% response rate. Data considered in these analyses came from a series of Likert-scale questions taken from the PISA survey (2012) as well as several questions written by researchers.

We explored whether the variables about mathematical beliefs and in college algebra could be reduced to a smaller set of factors, or latent variables, using an exploratory factor analysis from the post-survey questionnaire (left column of Table 1). A principal components analysis with a varimax rotation was conducted in order to identify latent variables; missing data were deleted pairwise; and factor loadings below 0.300 were suppressed.

Table 1

Survey Factor Loads

	Component				
	1	2	3	4	5
I enjoy reading about mathematics.	0.668				
I look forward to my mathematics lessons.	0.577				0.364
I get very tense when I have to do mathematics homework.			0.720		
In mathematics I enjoy working with other students in groups.				0.914	
In mathematics I learn most when I work with other students in my class.				0.891	
I do mathematics because I enjoy it.	0.828				
I get good grades in mathematics.	0.633	0.307			
I get very nervous doing math problems.			0.865		
I learn mathematics quickly.	0.726				
I have always believed that math is one of my best subjects.	0.828				
I feel helpless when doing math problems.			0.814		

How confident do you feel about calculating how many square feet of tile you would need to cover a floor?		0.737			
How confident do you feel about calculating how much cheaper a TV would be after a 30% discount?		0.827			
How confident do you feel about calculating the gas mileage of a car?		0.772			
How confident do you feel solving an equation like 3x+5=17.		0.618			
Learning mathematics is worthwhile for me because it will improve my career prospects.					0.872
Math is important to me because I need it for what I want to study later.					0.853
I would like to spend my life doing advanced mathematics.	0.737				0.300

Five principal factors were identified based on the individual variables present with the highest loadings (Table 2).

Table 2

Five Principal Factors Linked to Course Achievement

1. Math enjoyment	2. Confidence in problem-solving	3. Math anxiety	4. Peer preference	5. Perceived importance of math

Identical course assessment/grading tools were used in the flipped and traditional classes. A course coordinator for all college algebra classes determined the textbook, course material, use of online homework, and syllabus for all college algebra courses. Most of the student's grade (about 80 %) was based on in-class real-time examinations (four exams and a final). The exams and final given to the traditional classes were identical to those given in the flipped classes. Moreover, the conditions of the exams (calculator use, time allowed, formulas given, etc.) were identical as well. In neither type of class were students provided an exam "review sheet."

During enrollment, when choosing a college algebra course section, there was no indicator to the student what type of class he or she was choosing. Students in the flipped classes were not aware of the different model until the semester began and they were asked to watch an introductory video explaining how their class would be different from the traditional lecture class. Although students could change course sections, fewer than 1% of those enrolled made such a change.

Results

Demographic Information

There were no statistically significant differences between the flipped group and the traditional lecture group in gender or ethnicity; there was a significant difference of the number of course attempts with more repeaters in the flipped classes ($t = 2.242$, $df = 665$, $p = .025$). In the flipped group, nearly three-fifths (59.4%) of students were repeating the course, compared with half (50.1%) of the students in the traditional group. As flipped classes were not previously available for college algebra, all of the students who were repeating the course had failed or withdrawn from a traditional lecture class.

Course Achievement

There were statistically significant differences between treatment (flipped) and control (traditional) groups on scores for exams 1, 3, 4, and the final exam, in each case favoring the treatment group (Table 1). There was also a significant difference in final percent earned in the course, with students in the flipped class earning a mean course grade 7 % higher than that in the traditional class. The passing rate in the flipped group was 66% compared with 57% in the traditional group ($t = .063$). The statistical techniques used to obtain these results accounted for the unequal sample sizes between the flipped and traditional group.

Table 3

t-tests for Equality of Means

	t	*df*	Significance	Mean diff.	St. error diff.
Exam 1	5.72*	221	.001	8.79	1.54
Exam 2	0.69	214	0.49	1.15	1.61
Exam 3	4.50*	190	.001	10.2	2.27
Exam 4	2.79*	192	.006	7.08	2.53
Final Exam	2.78*	206	.006	12.9	4.66
% in Course	4.18*	230	.001	7.0	2.0
Pass Rate	1.91	209	.063	9.0	18.0

* denotes statistically significant difference

Survey Results

Survey analysis was done to explore possible interaction that affective variables may have had on academic achievement. Survey analysis was based on the sample of 310 students who completed at least 70% of both the pre- and post-survey questionnaires. In this sample there were 69 students in the flipped group (22% of the sample) and 241 in the traditional group (78%). Descriptive statistics showed that this sample was reflective of the original 669 students, with no significant differences between groups in terms of gender, ethnicity, or number of times attempting the course. Seventeen of the eighteen affective variable questionnaire items on the pre-survey showed no significant difference in responses between the flipped group and traditional group; given an alpha level of .05 with nearly 20 items, the one significant difference may have been due to chance.

Structural Equation Modeling

The theoretical model in Figure 3 was used to predict semester grade using gender, ethnicity, number of times taking the course, and type of class, together with the five factors in place of individual questionnaire items. The model implies that six regressions needed to be run. These six regressions were run using a stepwise method at an $\alpha = .05$ significance level. Missing data were handled by pairwise deletion with significant path coefficients obtained from stepwise regressions. The revised prediction model shown in Figure 4 shows that only female Hispanic/Latino/a identification and participation in the flipped class were statistically significant predictors for course achievement.

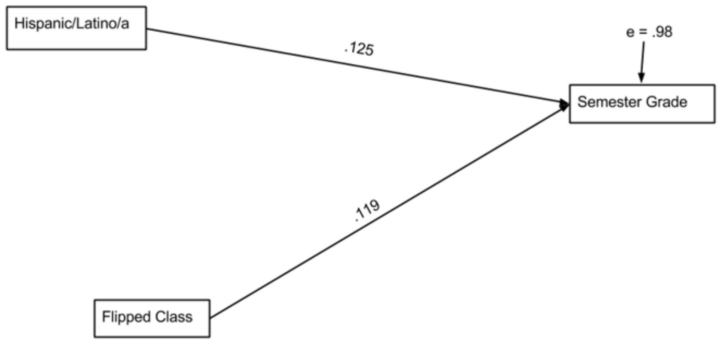

Figure 4. Revised Prediction Model

Discussion

Students in the flipped class model scored significantly higher on four of the five major assessments in the course, and on average earned a 7% higher grade in the course. Additionally, the pass rate for the flipped class was 66%, as compared with 57% in the traditional class. Moreover, all assessments were standardized and placement of students into a flipped or traditional class was random, limiting the effects due to self-selection or differences between instructors. This addresses the first research question regarding how academic achievement compared between class models.

Beliefs about math for each group were relatively static over the course of the semester. Factor analysis revealed five clusters relating to important constructs of various mathematical beliefs, the same categories considered in the PISA survey (2012). However, positive responses to these affective variables did not correlate with higher course achievement. In addition, the number of times the student had previously failed the course did not emerge as a predictor of success (or non-success).

While the original conceptual model showed various paths to higher semester grades by way of different background variables and affective factors, only female Hispanic/Latino/a identification combined with flipped class participation emerged as significant predictors of achievement. This addresses the second research question regarding what variables may serve as predictors for student achievement. This finding is important especially at CSU Fullerton, where the largest gender/ethnic group is comprised of female Hispanic/Latino/a.

This study was designed as a pilot to evaluate the flipped class model in college algebra at CSU Fullerton. The study had several limitations, including a usable survey response rate below 50% due in part to student error on self-identification of their assigned university ID; the unequal proportion of students between the control and experimental groups; and the limited set of variables considered. Repeating the study based on fall semester results may help inform this research, especially since more of the students would be taking the course for the first time, creating a more homogenous population. Samples taken from other institutions with different assessments and implementations of the flipped classroom might also be important to investigate the impact of the flipped model, although controls would need to be carefully considered. The composition of the institution may be relevant also. For students attending a large, urban commuter campus, the flipped model may have provided a vehicle for interactions with peers and instructors that may not have otherwise been available.

The flipped math class is not limited to college algebra. Currently, several CSU Fullerton faculty members are in the process of creating (or have already implemented) flipped modules for pre-calculus, first-semester calculus, and math for liberal arts. Evaluating the differences in student engagement and achievement in different types of classes may provide evidence for applications and scalability of the flipped model.

Conclusion

Leveraging online technology to increase student success has been an important consideration over the last ten years or so, and continues to grow in popularity among educators. The initial results are promising. However, an important consideration would be the longevity of these techniques. Some educational technology, like the pocket calculator, has become a staple of today's modern math classroom; others such as radio and TV saw an initial surge in popularity and then were mostly abandoned. In order to investigate the potential strength of the flipped classroom on a large scale, researchers must focus on data and evidence over time. In addition, it is important to remember that a strong commitment to education, high standards, and quality teaching are the most important considerations for student success. Flipping the class is potentially a way to strengthen and augment a healthy mathematics classroom, rather than a "cure-all" for poor student performance. By continuing to document evidence, we can critically evaluate the efficacy and staying power of the flipped class model.

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