A Comparison of Teaching Modalities for Student Success

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Abstract

This paper provides a case study comparing the effectiveness of traditional face-to-face, flipped classroom, hybrid and asynchronous fully online teaching and learning environments. An analysis of the collected data is discussed for student success rates in three lower level courses in mathematics including College Algebra, Pre-Calculus, and Calculus and an introductory aerospace engineering course that were taught with these different teaching delivery modes. The gender base difference in performance is analyzed for the math courses. The students enrolled in these courses were from under-represented groups at a historically black university. In addition, this paper identifies the strengths and weaknesses of each pedagogical approach.

Keywords

Online teaching; face-to-face; flipped classroom; hybrid; mathematics and aerospace engineering

Introduction

Persistence, retention and learning in higher education are influenced by a complex interaction between self-efficacy, motivation and engagement. Research by educators and cognitive scientists have identified several approaches that have been empirically shown to impact self-efficacy, motivation and engagement resulting in enhanced learning. More recent research is exploring these constructs in context of online learning in general and in an asynchronous environment in particular. This paper will first provide a brief literature overview on self-efficacy and engagement impacting student academic success, followed by a short literature review on face-to-face, flipped classroom, hybrid, and fully online teaching modalities. A case study exploring these four different teaching environments at a historically black university will then be presented.

Self-efficacy and Engagement Related to Active Learning

Student engagement, self-efficacy and motivation are influenced by several factors including inadequate preparation and institutional elements that are structural in nature. A. Bandura[1] defined perceived self-efficacy as "belief in one's capabilities to organize, and execute the courses of action required to produce given attainments, the perception to do tasks and achieve goals". P. Hsieh, et al.[2] suggested that students with low self-efficacy should be identified, and that those students with performance-avoidance attitudes need to be recognized and guided appropriately. M. M. Handelsman, et al.[3] identified four reliable dimensions of student engagement at the course level as skills, participation/interaction, emotional, and achievement. G. D. Kuh, et al.[4] studied the effect of engagement in meaningful academic activities on retention of first year students. This engagement showed statistically significant impacts on GPA and persistence. They also noted a proportionally higher impact of educationally engaging activities on students from underserved groups. A common theme in the literature on engagement is academic challenge, faculty-student interactions, and peer interactions. R. M. Carini, et al.[5] also investigated the impact of engagement on critical thinking skills and found positive correlation.

Research literature[6-8] indicates that active learning promotes engagement, motivation, self-efficacy and metacognitive behaviors in learning. It has been recognized[9] that while STEM students are often inductive learners, the learning environment is still designed around a deductive approach; this includes both learning materials (books) as well as the methods of delivery of the information. Project-based learning and problem-based learning are two such approaches to move STEM education from a deductive to an inductive learning environment through active learning opportunities.

The research cited above, clearly supports a learning model that is firmly anchored in the active learning approach. Therefore, the question that arises is: Which of the four pedagogical methods (face-to-face traditional, hybrid, flipped, and asynchronous online) promotes the best active learning environment? The self-efficacy and the engagement were not directly measured in this study. However, improved academic performance indicates high self-efficacy and engagement of the students.

Traditional Classroom Teaching Environment (Face-to-Face, F2F)

In the majority of higher education institutions around the globe, the classroom environment is still that of 'chalk and talk'. And, the instructors still admirably perform the role of the 'sage on the stage'. One of the advantages of this traditional F2F class is adapting the lecture during the delivery to respond to students' needs. The F2F classroom is free from external interruptions (such as phone calls, emails pop-ups, visitors etc) so students are dedicating that time for learning. However, most of the class time in this passive learning style is spent in lecturing and the instructor might not recognize the challenges that students might face to understand the material. Consequently, these students might struggle completing their assigned work outside the classroom. In the last decade, STEM education has seen a positive move from a teaching to a learning paradigm where the focus is the student and not the teacher. This paradigm shift has been informed by compelling empirical evidence, the result of extensive collaborative research by educators, and cognitive and educational psychologists. The major reason for this shift has been the effectiveness of the active learning approach as summarized above. Several approaches such as problem-based learning, project-based learning have been used to infuse the traditional classroom with active learning. However, the traditional F2F classroom may not allow sufficient opportunities for active learning due to time constraints.

The 'Flipped' Environment

The 'flipped' classroom is fast becoming the choice learning environment. In this approach, the 'lecture' is moved out of the classroom in the form of engaging audio-video enhanced learning material for students to study before coming to class. The classroom time would then be effectively dedicated to carefully design hands-on activities that strengthen the concepts and provide opportunities to enhance critical thinking skills. With this method, the instructor would be able to identify and help the students who are struggling to understand the concepts. The flipped approach is considered to be an effective approach for undergraduate students as it retains the important face-to-face contact with the instructor as well as the essential aspect of the social interactions to develop teamwork abilities and enhance communication skills. Increased student involvement in learning has been reported by S. McCallum, et al.[10]. Significant improvement in learning and motivation was noted by K. K. Bhagat, et al.[11]. It was also observed by A. Sahin[12] that the underclassmen had a preference for the flipped classroom. However, the implementation of a flipped environment is not without its challenges. For example, N. K. Lape, et al.[13] and J. Welker, et al.[14] reported a negative attitude of students towards the 'distracting' environment of flipped classroom. The biggest challenge with this delivery mode is to ensure students' viewing of online materials/lectures so they would be ready for the active-learning activities in the class. However, the flipped classroom should not be overwhelming for students. Effective design of the active-learning opportunities in the classroom is therefore the key to student engagement.

The 'Hybrid' Environment

Like the flipped classroom, the hybrid environment combines face-to-face and online teaching and learning. In the hybrid model, in-class meetings are reduced compared to F2F and flipped classes. Part of the instruction takes place through an asynchronous online delivery as discussed below. Varied effectiveness of the hybrid model has been reported in literature. For example, J. H. Westover, et al.[15] investigated the effectiveness of the hybrid model for a lower and upper level algebra courses and observed challenges with student preparation using the out-of-class materials. G. Hensley[16] reported no differences in learning between the hybrid and F2F environments while G. J. Senn[17] observed negative perceptions of the hybrid class associated with perceptions of additional work and lower achievement. B. El Mansour, et al.[18] reported the students' preference for the hybrid environment for its flexibility and convenience.

The 'Asynchronous Online' Environment

In the last five years, there is a surge in providing opportunities for learning in a virtual environment especially in an asynchronous mode. This approach empowers a large segment of learners to be included in the process to enhance their academic qualifications while not disrupting their other responsibilities. The challenges associated with undergraduate learning explained previously i.e. engagement, motivation, persistence and retention may become more significant in a fully online learning environment. J. H. Park, et al.[19] studied various factors including individual characteristics, external and internal factors of 147 adult online learners and noted that organizational support (external factor) and relevance (internal factor) predicted persistence. Lack of some sense of community, understanding the objectives of the course, interaction with faculty, the proper use of technology as reported in many studies[20-22] are some other challenges associated with online learning.

Method

In this study, the various teaching methodologies were investigated for several cohorts in the mathematics courses: College Algebra, Pre-Calculus and Trigonometry, and Calculus-I course using a quasi-experimental design. The flipped model was also implemented in an introductory Aerospace Engineering course. All the students were African-American. Comparisons were also made with a cohort that was a traditional F2F course. The College Algebra course was taught F2F (with Males, N=9; Females, N=20) and online (with Males, N=10; Females, N=12), Pre-Calculus course was taught using the F2F (with Males, N=13; Females, N=5), hybrid (with Males, N=9; Females, N=5) and flipped modes (with Males, N=7; Females, N=10), while Calculus-I course was taught using the F2F(with Males, N=9; Females, N=5), hybrid (with Males, N=10; Females, N=8) and a F2F supported by out-of-class video lecture materials (with Males, N=13; Females, N=10). For the aerospace engineering course, there were 40 male students and 12 female students in the F2F class and there were 32 males and 6 females in the flipped class.

College Algebra is the lowest level mathematics course offered at the university where the study was conducted. The Pre-Calculus and Trigonometry course is offered to freshmen students with higher mathematics SAT/ACT score than the required minimum score to be accepted at the university. All these lower level mathematics courses including Calculus-I are each four credit hours. For the F2F or flipped courses, the instructor meets with students four times a week. For the hybrid class, the instructor meets with students only two times a week. All students who were not in F2F class were required to watch the instructor's recorded short video lectures, read posted notes, and do graded homework online. Each recorded video not exceeding 12 minutes long, covers either the explanation of one mathematical concept or covers one or more examples (depending on the difficulty of the concept). Therefore, each lecture material contains five to eight video lectures. The links to the lecture videos were then posted in advance for students. The class time was used for practice, discussion and clarification of difficult topic, group activities, and word-problem solving. Several online and in class quizzes were provided to keep track on students' performance. Four exams and a comprehensive final exam were scheduled in class. One Calculus class "F2F with out-of-class videos lectures" was taught in a traditional F2F environment. The lecture videos were available online but students were not required to watch them.

The Introduction to Aerospace Engineering was a one credit hour course and met weekly. The F2F cohort (N = 35, F = 8, M = 27) was taught in the traditional lecture mode. For the flipped course, videos on 10 major concepts were developed. These video lectures were typically 10-15min long. The video lectures consisted of narrated white board solutions as well as with embedded animations and videos. Students in the flipped course (N = 35, F = 8, M = 27) were required to watch a particular video before coming to class. The class time was used for further discussion of the concept and solving problems. The students were tested at the end of the semester for their learning of the concepts.

To control for the impact of the variation of the teaching strategy by different instructors, all the math courses were taught by one instructor and the aerospace courses were taught by one instructor.

Results and Discussion

The success rate of students of the F2F College Algebra course was 59% as compared to 77% in the online delivery mode; the difference was not statistically significant. The percentage of females receiving A and B grades in the online class was 60% as compared to the F2F delivery (25%), a statistically significant difference ($p=0.05$) although the sample size is small. However, this result does point to the possibility that the online delivery of the lower level math courses may better support the self-efficacy of female students. An increase in A and B grades was noted for males in the online delivery mode as compared to the F2F but the difference was not statistically significant.

The percentage of students passing the Pre-Calculus course delivered in the traditional F2F was 85% (M=69%, F=100%). The pass-percentage for the Pre-Calculus hybrid cohort was 83% (M=67%. F=100%) and for the cohort that experienced the flipped mode was 88% (M=86%, F=90%). It was observed from these data that for the Pre-Calculus course, there was no statistically significant impact of the delivery mode for the cohorts. However, a closer look indicates the influence of gender. The pass-percentage of males who experienced the flipped mode (though not statistically significantly different) was higher than for those who took the course in a traditional F2F delivery or hybrid modes. There was a statistically significant ($p=0.05$) difference between the percentage of males obtaining an A or B grade in the flipped class (71%) as compared to the F2F class (31%), although the sample size is small.

There was no statistically significant difference in performance of cohorts in the F2F, hybrid and out-of-class videos supported F2F delivery modes in the Calculus-I course. The performance of females in the hybrid class was better as compared to those in the F2F. However, the difference was not statistically significant due to the small sample size. It was observed that some students had enrolled in the hybrid class with the expectation that reduced in-class meeting entailed reduced effort.

An analysis of the performance in the introductory Aerospace Engineering course revealed that there was no statistical difference between the pass percentages of the cohort in the F2F class (97%) and the flipped class (97%). However it was observed that the percentage of the students obtaining an A or B grade in the flipped class was higher (97%) as compared to the cohort in traditional F2F class (71%). This difference in performance was statistically significant ($p<0.01$). The gender impact couldn't be analyzed due to the low number of females enrolled in the Aerospace Engineering course.

A summary of the performance with demographic data is provided in Table I.

Conclusions and Future Work

The effectiveness of the traditional face to face, hybrid and flipped learning environments were compared for College Algebra, Pre-Calculus, Calculus-I and Introduction to Aerospace Engineering. Performance in the flipped and online course (compared to F2F and hybrid) indicated a positive influence though not statistically significant (possibly due to small sample sizes), on the performance of the students in the flipped hybrid, and online environments. It was observed that there is a statistically significant impact of the flipped environment on higher achievement of males in the Pre-Calculus course in comparison to the female students in that course.

The observations and results are based on a small sample size and therefore the results may not be generalizable. Additional data will be collected to strengthen the statistical analysis.

On the other hand, the effectiveness of a specific pedagogical method may be dependent on the academic environment including the content of the course and on the number of students enrolled in that course. For instance, the flipped classroom might not be a good learning method for a large class. Moreover, the flipped classroom may require teaching assistants to support and assist in the in-class activities. Therefore, the future work will include determining the optimum class size for an effective flipped classroom.

Course & Cohort	**Success Rate**			**Statistically Significant**
Algebra	**F2F (N=29;F=20, M =9)**		**Online(N=22;F=10,M=12)**	
All students	58.6%		77%	No, Online better %
Females	60%		80%	No, Online better %
Males	56%		75%	No, Online better %
Females with A & B	**25%**		**60%**	**YES; Online better %**
Males with A & B	33%		50%	No; Online better %
Pre Calculus	**F2F (N=18) (F=5, M=13)**	**Hybrid (N=14) (F=5, M=9)**	**Flipped (N=17) (F=10, M=7)**	
All students	78%	79%	88%	No; Online better %
Females	100%	100%	90%	No
Males	69%	67%	86%	No; Flipped better %
Females with A & B	100%	100%	90%	No
Males with A & B	**31%**	56%	**71%**	**YES; Flipped better %**
Calculus	**F2F (N=14) (F=5, M=9)**	**Hybrid (N=18) (F=8, M=10)**	**F2F +vid (N=23) (F=10, M=13)**	
All students	57%	78%	65%	No; Hybrid better %
Females	60%	88%	80%	No; Hybrid &+vid better %
Males	56%	70%	53%	No; Hybrid better %
Females with A & B	40%	75%	70%	No; Hybrid & +vid better
Males with A & B	44%	50%	15%	No, Hybrid better %
Intro Aerospace Engg	**F2F (N=35) (F=8, M=27)**		**Flipped (N=39) (F=4, M=35)**	
All students	97%		97%	
Students with A & B	77%		97%	**YES; Flipped better %**

Table I: Summary of Participant Demographics and Performance

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