Flipped Classroom and its Impact on Student Engagement

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Abstract

This paper will provide the first-year results of the impact of implementing the flipped approach in lower level math and aerospace engineering courses. A quasi-experimental between-groups research design was used for assessing the effectiveness of this methodology. The control group consisted of students who were in the same course but in sections with traditional teaching delivery while the intervention group consisted of students who were registered in the sections with the flipped approach. All students were from underrepresented groups. A positive impact on the students' attitudes and learning strategies was observed as a result of the flipped classroom with active learning. Data pertaining to the effectiveness of the flipped classroom pedagogy is shared in this paper. Analysis of students' cognitive engagement and their attitudes towards flipped classroom is discussed. The paper also includes best practices, their impact on student performance, and challenges in implementing a flipped classroom pedagogy.

Keywords

HBCU, Flipped Classroom, Student Engagement, Mathematics, Aerospace Engineering,

Introduction

Persistence, retention and academic achievement in higher education are influenced by a complex interaction between self-efficacy, motivation and engagement. 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". Bandura and Locke [2] observed a strong relation between self-efficacy and performance in general. A meta-analysis of 114 studies by Stajkovic and Luthans [3] found a strong correlation between self-efficacy and work-related performance. A review of literature [4] on self-efficacy and academic performance published between 2003-15 indicated a moderate correlation between self-efficacy and academic performance. A statistically significant correlation was observed between self-efficacy and academic achievement of adult learners in an online environment as well [5].

A number of studies have looked at the correlation between self-efficacy, effort regulation, and learning strategies. Motlagh et al. [6] reported that in their study of 250 high school students, 10% of the variance in their regression model of academic achievement was explained by self-evaluation and self-regulation. Yusuf [7] found a strong correlation between self-efficacy, achievement-motivation and self-learning strategies in his study of 300 undergraduate students. A study of 310 university students by Ozan et al. [8] showed the influence of gender with females registering higher on the self-efficacy and self-regulated learning strategies. Koseoglu [9] suggested focusing on strengthening self-efficacy and effort regulation to influence academic achievement. Several mediating and moderating factors such as effort regulation, learning

strategies and goals were identified in this study which noted that effort-regulation, self-efficacy, and help-seeking explained 21% of the variance in GPA.

The effect of self-efficacy on behavioral, cognitive and motivational engagement has been reported by Linnenbrink and Pintrich [10]. Motivation and students' perception of progress and learning have also been observed to be correlated [11]. Self-efficacy has been identified by Schunk and Mullen [12] as a key variable that influences motivation and engagement in the classroom. Several dimensions of student engagement that impact academic success have been identified. Skinner and Belmont [13] noted that teacher behavior (involvement, structure and autonomy support) impacts students' behavioral and emotional engagement. Kahu [14] investigated student engagement from the behavioral, psychological, socio-culture and holistic perspectives in the context of how these behavioral perspectives are related to effective teaching practices [13]. Kuh et al. [15] studied the effect of engagement in meaningful academic activities on retention of first year students and 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. In this regard, Carini, Kuh, and Klein [16] conducted a survey of over 1000 students and determined a positive impact of engagement on critical thinking skills and grades.

Empirical evidence resulting from research on strategies for engagement indicates that active learning such as problem-based learning, project-based learning are effective approaches. The 'chalk and talk' transmittal method in the classroom is being replaced by the constructivist approach that has some of its basis in the 'zone of proximal development' construct [17]. In this approach, students are given the opportunity to construct their own knowledge through e.g. cooperative learning opportunities. Team-based learning which promotes cooperative learning improves student achievement by increasing student reasoning, problem-solving and critical thinking skills, encouraging more scientific thinking, and developing a deeper understanding of course content [18]-[24]. A team learning environment that promotes interdependence of the team members has been shown to positively impact student learning outcomes [25].

Furthermore, problem-based learning and project-driven learning, which are also examples of cooperative learning, are replacing the traditional lecture method and the teacher is moving away from being the 'sage on the stage' and assuming the role of a 'guide on the side' [26]. Active learning has also been identified as an effective pedagogical approach to develop critical thinking skills of students that lead to metacognitive behaviors in learning [27]-[30]. In a review of research on active learning Prince [29] determined that among other things, active learning resulted in positive student attitudes, and suggested that it could increase a student's score on an exam from 75 to 85. It was further noted in [29] that active learning as a pedagogy has broad support.

It has been recognized 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 [29]. Project-based learning and problem-based learning are two approaches to move STEM education from a deductive to an inductive learning environment through active learning opportunities [31].

From the aforementioned discussion, it can be observed that active learning has a positive impact on student engagement resulting in higher self-efficacy, enhanced learning and increased academic success. The question then arises as to why the traditional classroom which is a catalyst for student disengagement [32]-[34] still is the prevalent pedagogical model. Of the several challenges that dissuade instructors from implementing active learning is the time constraint of a typical class period [35]-[38]. One solution to the time constraint that has gained notoriety is the 'flipped classroom'. In this approach, the 'lecture' is moved out of the classroom in the form of engaging audio-video enhanced learning materials for students to study before coming to class. Levels of network connectivity, coupled with the plethora of online learning materials, and the relative ease in developing digital learning materials by faculty, are clearly rendering the 'flipped' learning environment more practical [39]-[41]. Research literature is increasingly pointing to the effectiveness of the flipped classroom [42]-[45]. Greater gains in conceptual understanding and engagement have been reported as a result of the flipped method [40], [46]-[48]. There is also an indirect research base supporting the effectiveness of properly designed blended learning that improved student-teacher interaction, provided opportunities for real-time feedback, increased student engagement, and allowed self-paced learning [49]. It was also reported by Deslauriers et al. [50] that blended instruction increased class attendance, improved engagement and enhanced the learning outcomes.

This paper provides the results of the first year of the three-year National Science Foundation (NSF) funded project "Strategies for Student Engagement". The project objectives include (1) improving student attitudes towards learning, and (2) enhancing student learning and academic success through the implementation of flipped pedagogy in lower level mathematics and aerospace engineering courses. The research questions are as follows:

1) Does the approach impact student learning strategies?

2) Does the teaching method impact student attitudes towards learning?

Method

The flipped classroom was implemented in several lower level mathematics and aerospace engineering courses at a Historically Black College (HBCU). The design of the flipped classroom utilized Bloom's Taxonomy [51] where the 'knowledge (or remembering)' and 'comprehension' components of learning were moved out of the classroom. Students were provided the learning materials as either a series of short 5 to 12-minute videos, annotated PowerPoints, or/and PDF notes on the Learning Management System. However, the biggest challenge of implementing a successful flipped class pedagogy is motivating students to come prepared to class so that they can participate in the active-learning activities designed at the higher levels of Bloom's Taxonomy. Usually, few students have an intrinsic motivation and therefore have to be extrinsically motivated [52-54]. Thus, the short videos over one concept were followed by a short online graded quiz that assessed primarily if students had watched the videos. The other objective of these online quizzes was to determine if the students had some conceptual challenges with the learning at the knowledge and comprehension levels. These identified challenges were clarified in the class. The students were then involved in active learning activities during class time. These activities were designed at the 'application' and 'analysis' levels of Bloom's Taxonomy [51]. The activities promoted peer-to-peer learning (group learning), communicating their understanding through explaining their

thought processes on the white board, working out problems, using "Jeopardy" style games for reviewing the concepts, etc. The post-class work included graded homework problems to strengthen the concepts.

The Motivation Strategies for Learning Questionnaire (MSLQ) [55] was administered to the students of the intervention and control groups to measure the five dimensions (a) Self efficacy, (b) Intrinsic value, (c) Test anxiety, (d) Cognitive strategy use, and (e) Self-regulation. Students' perceptions of the flipped classroom were determined with a Flipped Classroom survey. These instruments had a 5-point Likert response scale. The content performance data was used to determine the correlation between the various flipped classroom elements i.e. pre-class quizzes, in-class quizzes, graded homework and students' overall class performance through the in-class exams. This data was also used to identify the best practices and the effectiveness of the flipped classroom.

The data analysis for Math 107 (4-credit hours Pre-Calculus and Algebra course) and AENG 200 (a 1-credit hour Introduction to Aerospace Engineering Lab course) is shared in this paper. All the students in these flipped courses were from underrepresented groups and the majority of them were freshmen.

Results and Discussion

A total of 18 out of 20 students enrolled in the aerospace engineering course and 22 out of 50 students enrolled in the math course responded to the flipped survey and the MSLQ. A total of 37 out of 50 students in the math control group responded to the MSLQ. Both questionnaires (the flipped survey and the MSLQ) were anonymous.

Aerospace Question	Always	Most of the Time	Sometimes	Rarely	Never
Do you watch the videos and do the corresponding quizzes by the deadline?	30%	60%	10%		
Do you take notes when you watch the videos?	30%	30%	30%	10%	
Do you find the discussion at the beginning of the class helpful?	50%	40%	10%		

Table 1a: Responses to flipped survey of students enrolled in aerospace engineering courses

Mathematics Question	Always	Most of the Time	Sometimes	Rarely	Never
Do you watch the videos and do the corresponding quizzes by the deadline?	40%	25%	30%	5%	
Do you take notes when you watch the videos?	30%	35%	25%	5%	5%
Do you find the discussion at the beginning of the class helpful?	30%	40%	25%		5%

Table 1b: Responses to flipped survey of students enrolled in mathematics courses

The flipped survey indicated that a majority of the students were engaged in pre-class preparation e.g. watching the videos, taking notes (Table 1a, 1b). The discussion at the beginning of the class

about the concept learned from the videos was helpful for almost all students in aerospace engineering (90%) and for the majority of students in math students (70%).

The following two questions were asked to determine the effectiveness of the pre-class learning materials and the in-class active learning:

(a) How confident do you feel about the material AFTER watching the videos but BEFORE coming to class?

(b) How confident do you feel about the material AFTER watching the videos and AFTER coming to class?

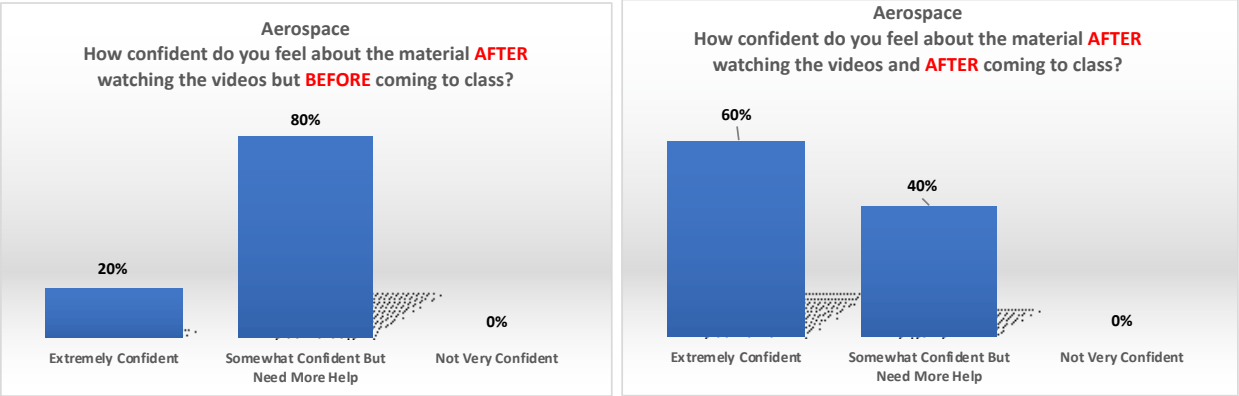

Figure 1a: Content confidence of students enrolled in aerospace class

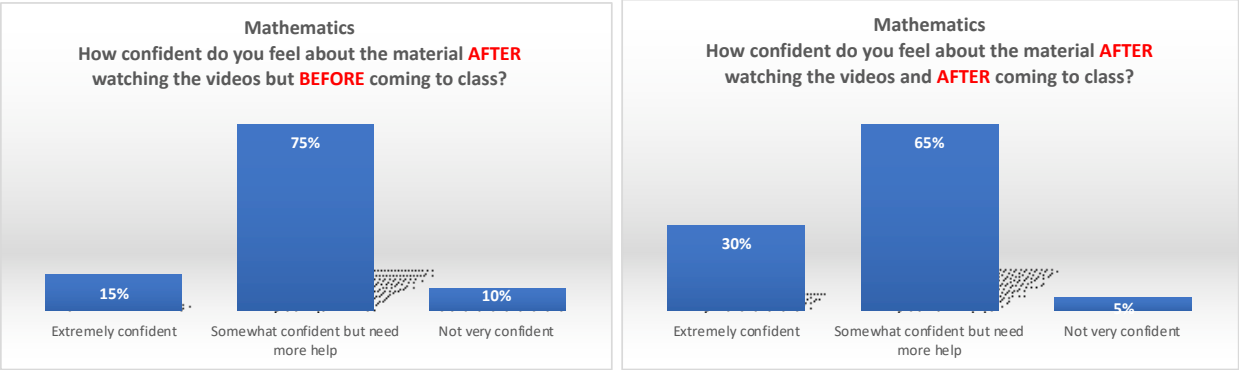

Figure 1b: Content confidence of students enrolled in mathematics class

The students found that watching the videos before coming to class is useful and their confidence about the materials increased after class discussion and active-learning. In each of the flipped classes, data (Fig. 1a-aerospace and 1b-math) showed a statistically significant ($p < 0.05$) increase in students' confidence about the content after watching videos and attending class compared to only watching the videos. This result indicates the effectiveness of utilizing the class time for active learning. Even though the pre-class materials/videos and the in-class active-learning helped both aerospace engineering students and math students, the data showed a higher impact on the aerospace engineering students. This observation can be explained by the fact that the AENG 200 is a major course for the aerospace engineering students while Math 107 is a preparatory course

for students from various science and engineering majors. Therefore, the aerospace engineering students perhaps were more motivated to learn compared to the students enrolled in Math 107 course.

The responses to the MSLQ survey administered at the end of the semester to students enrolled in the Pre-Calculus (Math 107) and Intro to Aerospace Eng. Lab. (AENG 200) flipped classes, and to the control group (students registered in MATH 107 but taught in the traditional format) were compared. There was no control group for the aerospace engineering course since only one section was offered during the semester. The averages of the responses are given in Table 2.

Dimension		Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree	
Self-Efficacy		SA	A	U	D	SD	Group
I am sure I did an excellent job on the problems and tasks assigned for this class.	MATH 107	36%	50%	7%	7%		Flipped
	MATH 107	20%	40%	20%	20%		Control
	AENG 200	39%	50%	6%	5%		Flipped
I know that I was able to learn the material for this class.	MATH 107	29%	50%	14%		7%	Flipped
	MATH 107	30%	40%	30%			Control
	AENG 200	28%	67%	5%			Flipped
Intrinsic Value							
I think I will be able to use what I learned in this class in other classes.	MATH 107	22%	50%		14%	14%	Flipped
	MATH 107	30%	10%	30%	30%		Control
	AENG 200	11%	50%	33%		6%	Flipped
Understanding this subject is important to me.	MATH 107	57%	36%	7%			Flipped
	MATH 107	30%	60%	10%			Control
	AENG 200	44%	44%	6%	6%		Flipped
Test Anxiety							
I have an uneasy, upset feeling when I take a test.	MATH 107	29%	14%	21%	14%	22%	Flipped
	MATH 107	30%	20%	30%	20%		Control
	AENG 200	11%	17%	22%	28%	22%	Flipped
I worry a great deal about tests.	MATH 107	43%	29%		14%	14%	Flipped
	MATH 107	40%	30%	30%			Control
	AENG 200	6%	43%	28%	6%	17%	Flipped
Cognitive Strategy Use							
It is hard for me to decide what the main ideas are in what I read.	MATH 107	7%	29%	21%	29%	14%	Flipped
	MATH 107	10%	50%	30%	10%		Control
	AENG 200	6%	11%	22%	50%	11%	Flipped
When reading, I try to connect the things I am reading about with what I already know.	MATH 107	57%	43%				Flipped
	MATH 107	20%	50%	30%			Control
	AENG 200	39%	56%		5%		Flipped
Self-Regulation							
When work is hard I either give up or study only the easy parts.	MATH 107	7%	21%	57%		15%	Flipped
	MATH 107	30%	30%	40%			Control
	AENG 200		17%	28%	44%	11%	Flipped
I find that when the teacher is talking, I think of other things and don't really listen to what is being said.	MATH 107	7%	29%	7%	36%	21%	Flipped
	MATH 107	30%	30%	10%	30%		Control
	AENG 200		17%	17%	61%	5%	Flipped

Table 2: MSLQ Responses

The MSLQ contains several questions for each dimension. However, only two representative questions from each dimension are included in Table 2. The preferred direction of the answers is in highlighted in yellow color. The data indicates that the self-efficacy of the students enrolled in the flipped classes was higher than the control group. The students in both the intervention group and control group recognized the importance and utility of the courses. The students enrolled in the flipped classes (intervention group) reported lower test anxiety as compared to the control group. Similarly, the responses of students in the flipped classes indicated better cognitive strategies for learning. The data suggests that students in the flipped classes had effective self-regulation (persistence, and engagement in the classroom). In addition, the data helped identify the aspects needed to be improved based on the undecided responses, e.g. the responses (33%) in the intrinsic value dimension in the AENG 200 course.

As mentioned previously, the flipped pedagogy implementation has three important elements, namely pre-class work, e.g. watching of lecture videos and taking quizzes on the Learning Management System before class time, in-class activities, and post-class work. In-class content performance of the students enrolled in the flipped classes was compared with their pre-class preparation and post-class reinforcing work.

The overall performance of each student in the class assessments was plotted against the elements of a flipped class room to determine the effectiveness of these elements. A typical data set of students enrolled in Math107 flipped class is shown in Fig. 2.

Analysis of the data indicated a strong correlation between these elements of the flipped pedagogy and student academic performance. After in-class discussion and active-learning activities, students reinforced the concepts by doing their after-class work. This statement is clearly demonstrated by these data. Students who did their homework, had a good class average (r = 0.9156). In-class quizzes also had a strong positive influence on student end of course performance. Students who scored high on the in-class quizzes which indicated that they came to class prepared for the activities, performed well in the overall course (r = 0.8508). The Blackboard pre-class quizzes which were mainly for the instructor to check that students watched the videos, also

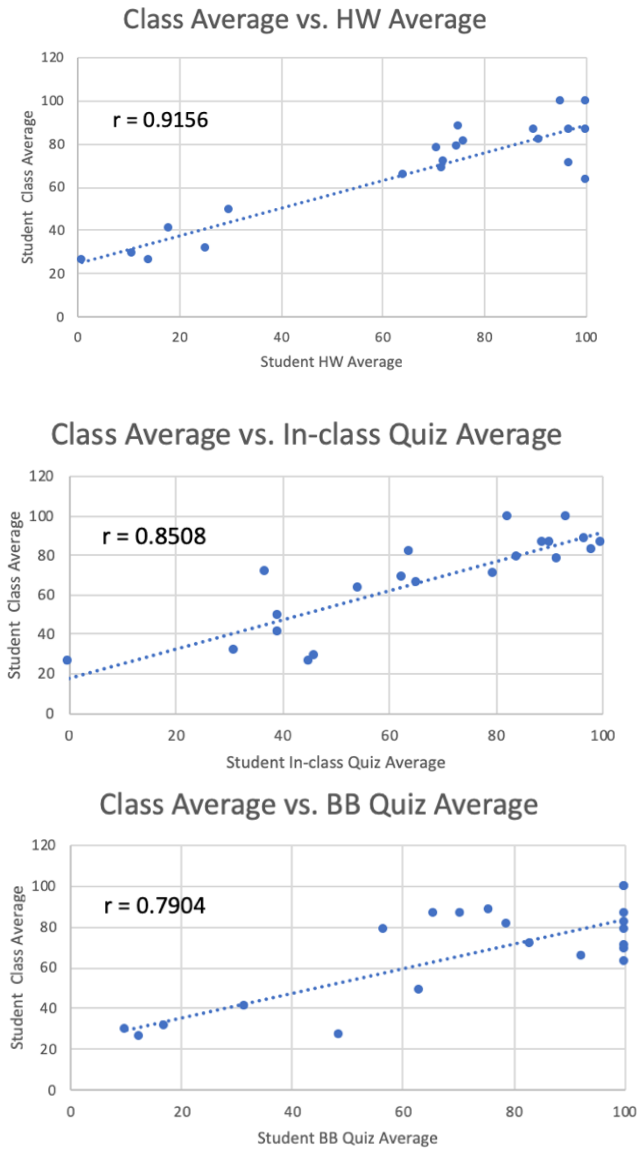

Figure 2: Correlation of student class average with the elements of the flipped class

indicated a good correlation (r = 0.7909) with the student overall performance in the class.

As noted above, the aerospace engineering course AENG 200 is a one-credit hour course. Therefore, students were not assigned many pre-class activities and in-class quizzes so a comparison with the overall class average could not be done.

Conclusions and Future Work

The data analysis indicated that the implementation of the flipped pedagogy with the integration of in-class active learning had a positive impact on student engagement, self-efficacy and content knowledge. The strategies to motivate students to come prepared to class were observed to be effective. Students improved their critical thinking skills and cognitive strategies, reduced test anxiety and were engaged in learning in the classroom. These results show that the approach had a positive influence on students' attitudes toward learning. The effectiveness of a properly designed implementation was demonstrated.

Additional courses in mathematics and aerospace engineering are being prepared for delivery using the flipped class approach with active-learning strategies. The learning materials are being developed to incorporate the lessons learned from the data analysis discussed in this paper.

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