Preliminary Study of Active Flipped Learning in Engineering Mechanics

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Abstract

The flipped classroom has been introduced to promote collaborative learning and higher-order learning objectives. In contrast to the traditional classroom, the flipped classroom has students watch prerecorded lecture videos before coming to class, and the classroom becomes the place to work through problems, advance concepts, and engage in collaborative learning. In this paper, the active flipped learning was applied in engineering mechanics class to combine flipped classroom with active learning to establish an active flipped learning (AFL) model, aiming to promote active learning. Eighty sophomore engineering students, most of whom are African-American students, participated the active flipped learning. To compare the effect of AFL, the traditional teaching was applied in the first half semester and pre- and post-tests were used to evaluate their learning performance. After the mid-term exams, five flipped modules were applied to five topics. All of the students attended these flipped modules. During each of the flipped models, students watched lecture videos before class and conducted a quiz after the video as well as raised and discussed unclear questions in the course management system CANVAS. The instructor analyzed the students' quiz results and developed the in-class exercises. In the lecture time, the instructor focused on the subjects that were problems to students from their quiz results and questions raised after group discussion. Then the instructor used question sets for group activities and discussions. The student group discussion was led by the assigned group leaders. Pre- and post-tests were conducted for the AFL. The survey results were analyzed to compare students' learning engagement, empowerment, self-efficacy, and satisfaction between the traditional classroom and with the AFL. It was found that the AFL model, by taking advantage of advanced technology, is a convenient and professional avenue for engineering students to strengthen their academic confidence and self-efficacy in Engineering Mechanics by actively participating in learning and fostering their deep understanding of engineering statics and dynamics.

Key words: The flipped classroom, collaborative learning, active flipped learning, AFL

Introduction

To increase student retention rate and academic performance，many STEM researchers begin to investigate the flipped classroom in higher education[1]. The flipped classroom has students watch prerecorded lecture videos before coming to class, and the classroom becomes the place to solve problems and advance concepts. The fundamental idea behind flipping the classroom is that more classroom time should be dedicated to active learning where the teacher can provide immediate feedback and assistance[2][3][4]. While flipped classroom appears promising in its ability to meet the requirement of engineering education, there are several shortcomings to these studies. First, the duration of the treatment was limited to one semester, and most in-class activities still carried a lecture component. Second, students learning process data was not valued for improvement. Also, scant research has ever been conducted in Historically Black Colleges and Universities (HBCUs) to examine whether it will improve African-American students' STEM performance. It is essential to assess whether flipped methods are indeed better than traditional methods in HBCUs. Do flipped classrooms improve learning outcomes of HBCUs? Do African-American students in flipped classrooms master course concepts better? Do African-American students like flipped classrooms? In this paper, an Active Flipped Learning (AFL) model was proposed and applied in engineering mechanics class by combining flipped classroom with active learning to provide individualized learning opportunities. It aims to examine the effects of the flipped classroom in STEM education at JSU, a HBCU, promoting active learning, stressing deep learning, encouraging student engagement and highlight data-driven personalized learning applied in engineering mechanics class by combining flipped classroom with active learning in order to provide individualized learning opportunities. The goal of AFL model is committed to enhancing the quality of undergraduate STEM education at HBCUs, providing student academic development in their STEM vision establishment, learning strategies improvement and motivation for a successful career, which could lead to promising outcomes in an HBCU given the social-economic characteristics of African-American students.

AFL Design of Engineering Mechanics I

The Engineering Mechanics I in Fall 2017 is an engineering course for sophomore year students. The computer, civil, electrical, and biomedical engineering students are required to take this course. To compare the effect of AFL, the traditional teaching was applied in the first half semester and pre- and post-tests were used to evaluate their learning performance. In the conventional classroom format, all of the class time was spent lecturing to students with no active learning activities. After the mid-term exams, five flipped modules were introduced for five topics, which needed all of the students to attend. The teaching contents and assessment tools of each instructional module are shown in Table 1.

Table 1. Course Design of Engineering Mechanics I

Traditional classroom section: the first half of Engineering Mechanics I	**Flipped classroom section: the second half of Engineering Mechanics I**
Contents: ● Force Vectors ● Equilibrium of a Particle Teaching Materials: ● Textbook ● Reading references Assessment Tool: ● Quiz ● Homework ● Midterm examination ● Concept inventory	Contents: ● Concept of Moment of a Force, Moment of a Couple, Distributed Load ● Force System Resultants ● Equilibrium of a Rigid Body ● Structural Analysis of Truss ● Friction Teaching materials： ● Video ● Textbook ● Reading references Assessment Tool: ● AFL questionnaires ● Homework ● Interview participating students ● Blackboard records ● Exams ● Quiz

During each flipped module, students watched lecture videos before class and conducted a quiz after the video. They also raised and discussed unclear questions in the course management system CANVAS. The instructor analyzed the students' quiz results and developed the in-class exercises. In the lecture time, the instructor focused on the subjects that were problems to students from their quiz results and questions raised after group discussion. Then the instructor used question sets for group activities and discussions. The student group discussion was led by the assigned group leaders. Pre- and post-tests were conducted for the AFL.

DATA Collection and Analysis

This research used MSLQ (Motivated Strategies for Learning Questionnaire), which is released online through Survey Monkey. Students answered the questionnaire by clicking on the invitation link and choosing the suitable answers. To enhance the enthusiasm of students' involvement, a prize was awarded to the top ten students who completed the questionnaires wholly and independently. After all the students completed the online questionnaire, Survey Monkey conducted preliminary screening and sorting of the data. The researchers exported and downloaded questionnaire data and further calculated and analyzed it with the help of statistical software SPSS 20.0.

Table 2. Demographic Characteristics of Students

Characteristic variable	Value
Total number of students	86
● Valid Questionnaire	80
● Incomplete	6
Gender,%	
● Male	56.2
● Female	43.8
Ethnicity, %	
● African-American	82.5
● White	12.5
● Other	4
GPA	
● Average transcript GPA	3.16
● Average course GPA	3.08

As shown in Table 2, there are 86 students who participated in the survey, in which there are 80 valid and 6 incomplete data. Among the 80 valid questionnaires, the gender ratio is 43.8% for female students and 56.2% for males. Ethnicity statistics are 82.5% for African-American, 12.5% for Whites and 4% for other races. The GPA (Grade Point Average) of students before the start of the course is 3.16. At the end of the course, the average course grade of Engineering Mechanics is 3.08. The main reason for the comparatively lower grade point average of the course is that Engineering Mechanics is a core STEM curriculum that is more difficult than most of the other classes in the whole curriculum, and students have a weaker foundation for STEM courses, especially African-American students.

Table 3 shows the comparison of concept inventory test scores and test scores of all students under two different teaching modules. As can be seen from the table, the mean of concept inventory changed from 43.75 in the traditional classroom to 61.25 in the flipped classroom, with an absolute increase of 17.5. After applying Paired Samples T-test, the difference of concept inventory in two models is statistically significant, with P-value 0.045, as well as a high effect size value of 0.76. Besides, the average score of exams in flipped mode is slightly lower than the average rating in the traditional classroom. The main reason for that is as follows: Although the conventional teaching module is adopted in the first stage (the first six weeks), the teaching contents are smaller but with a more comprehensive teaching syllabus than the flipped one. Therefore, students have better commanding and application of the knowledge taught in the traditional classroom. In the flipped module, teaching chapters cover 70% contents of the teaching plan. Because of the flipped module, the video content uses the fragmented form under dispersed teaching, leading to students' relatively weaker mastering of knowledge than in the first stage, which explains the second phase of the test scores showing a slightly decreasing trend.

Table 3. Comparison of Performance in Traditional and Flipped Classroom

Measurement	Traditional		Flipped		Growth	T	P	Effect Size
	Mean	SD	Mean	SD				
Concept Inventory	43.75	22.97	61.25	29.16	17.5	2.27	0.045*	0.80
Grade	80.52	16.42	78.61	14.93	-1.91	0.39	0.700	0.12

To study the specific impact of GPA, gender, and the length of study time on student achievement, the researchers divided the students into two groups according to their GPA, greater than 3.0 and less than or equal to 3.0, named High and Low respectively. According to the length of study, students were divided into two groups, with study time more than 150 minutes was named Long, and less than or equal to 150 minutes was named Short. All students were also divided into two groups by gender. Under the traditional and flipped classroom model, the statistical results of different contrast groups are shown in Table 4.

Table 4. Comparison of Performance in Different Groups

Variable	Module	GPA	Mean	SD	Time	Mean	SD	Gender	Mean	SD
Concept Inventory	Traditional	Low	40.00	26.35	Short	38.89	30.80	Female	63.89	27.81
		High	67.00	34.39	Long	60.00	27.90	Male	31.88	25.06
	Flipped	Low	56.25	28.88	Short	46.43	23.75	Female	63.33	33.27
		High	65.00	35.00	Long	82.00	23.87	Male	59.17	27.46
Grade	Traditional	Low	78.46	17.11	Short	75.75	15.88	Female	80.50	15.79
		High	91.29	6.75	Long	85.73	16.08	Male	80.54	17.52
	Flipped	Low	75.62	16.56	Short	79.67	14.38	Female	75.80	16.79
		High	82.43	12.19	Long	77.45	16.12	Male	80.77	13.61

Low means GPA <=3.0; High means GPA>3.0
Long means study time >150 minutes; Short means study time <=150 minutes

In a comparison of the concept inventory section, students with a low or high GPA under both classroom models showed an obvious difference in the concept inventory test. Low GPA students have more visible progress than high GPA students in the flipped classroom. However, the difference in concept inventory test under two teaching models is not obvious for high GPA students. For long and short study times, students' concept inventory test scores have been significantly improved under flipped classroom model than in the traditional one. Indicating that under the same study time, the flipped classroom is more beneficial for improving students' study efficiency. For gender difference, flipped classroom model has a greater role in improving male students' achievement in concept inventory. However, the improvement in the females who participated in this study is not so obvious when compared to male students in the concept inventory. The possible reason for this phenomenon is those female students tend to be more accustomed to the traditional classroom, a teacher-teaching and student-listening model than male students. In the comparison of test mean section, it can be seen that flipped classroom model is more effective for low GPA students. In flipped classroom module, the length of times for students to test scores did not make big differences. It is because students have effectively deepened their understanding of knowledge and got their problems solved during flipped classroom time, and they do not need extra study time to improve academic performance outside classroom time besides watching the video and finishing a little quiz after class. Under the traditional classroom model, there was little difference between male and female students' course grade. However, there is a certain difference between male and female students in the flipped class, in that male students have higher scores than female students. Therefore, in the next stage of experiment teaching, the researcher needs to optimize the AFL model further to help female students to improve their study efficiency further in the flipped classroom.

Table 5 shows a comparison of learning motivation and learning strategy usage between the traditional and flipped classroom. As can be seen from the table, compared with the conventional class, the motivation of students is significantly increased in a flipped classroom. Looking into the six components in learning motivation, the mean of students' intrinsic goal orientation (IGO) increased from 3.63 in a traditional class to 3.70 in a flipped classroom, while extrinsic goal orientation (EGO) has decreased from 4.13 in the conventional model to 3.89 in flipped one. The result shows that in the flipped classroom, students pay more attention to the active acquisition of engineering mechanics rather than just paying attention to the achievement of scores, and students' interests in curricula, curiosity, and learning initiatives are improved with their intrinsic goal orientation further strengthened.

Table 5. Comparison of Components in MSLQ in Traditional and Flipped Classroom

Scale	Component	Traditional		Flipped		Growth	T	P	Effect Size
		Mean	SD	Mean	SD				
Motivation	IGO	3.63	0.84	3.70	0.71	0.07	0.48	0.64	0.08
	EGO	4.13	0.74	3.89	0.70	-0.24	-1.49	0.15	-0.32
	TV	4.11	0.68	4.00	0.62	-0.11	-0.79	0.44	-0.16
	CB	3.78	0.72	3.91	0.58	0.13	0.92	0.37	0.18
	SE	3.82	0.70	3.87	0.66	0.05	0.37	0.71	0.07
	TA	3.48	0.78	3.41	0.91	-0.07	-0.43	0.67	-0.09
Learning Strategy	REH	3.89	0.54	3.74	0.65	-0.15	-1.72	0.10	-0.28
	ELA	3.85	0.60	3.73	0.57	-0.12	-1.36	0.19	-0.20
	ORG	3.61	0.69	3.80	0.53	0.20	1.53	0.14	0.29
	CT	3.57	0.68	3.68	0.75	0.10	0.90	0.38	0.15
	MSR	3.63	0.46	3.67	0.54	0.04	0.38	0.71	0.09
	TSE	3.52	0.44	3.62	0.43	0.09	0.66	0.51	0.20
	ER	3.20	0.50	3.46	0.57	0.26	2.25	0.04*	0.52
	PL	3.59	0.84	3.74	0.88	0.14	1.74	0.10	0.17
	HS	3.76	0.63	3.86	0.61	0.10	0.86	0.40	-0.16

Effect Size = difference between means of post-test and pre-test divided by the Std. Deviation of the pre-test.
IGO means intrinsic goal orientation; EGO means extrinsic goal orientation; TV means task value; CB means control beliefs about learning; SE means self-efficacy for learning and performance; TA means test anxiety. REH means rehearsal; ELA means elaboration; ORG means organization; CT means critical thinking; MSR means metacognitive self-regulation; TSE means time and study environment; ER means effort regulation; PL means peer learning; HS means help-seeking.

However, due to this being the first time attempting to apply the flipped model in Engineering Mechanics, there is a specific gap between students' expectation of the learning materials and the video materials provided by the teacher. Fragments of learning materials in the flipped model are not beneficial to students to form a comprehensive knowledge system, which will lead to the slight decrease in the mean of students' task value (TV). Students' Control Beliefs about learning (CB) rose from 3.78 in the traditional classroom to 3.91, indicating that students love the flipped classroom teaching model in Engineering Mechanics, and their control beliefs about learning have been strengthened. Students' self-efficacy for learning and performance (SE) increased from 3.82 to 3.87, showing that students' self-efficacy has been enhanced in the flipped model. The decrease in text anxiety in the flipped model proves that students' test anxiety will naturally decrease after they discuss with peers in the same group and develop a deeper understanding of teaching contents in the flipped classroom.

In the comparison of learning strategies, the Rehearsal (REH) and Elaboration strategy (ELA) useless in the flipped model than in the traditional model. Organization strategy (ORG) has increased because students have solved their problems through discussion within groups and by using the teacher's answers to difficult questions in the flipped classroom. The students' knowledge got strengthened and applied, and their study efficiency has been improved after the flipped classroom model. Therefore, the rehearsal and elaboration strategy showed a decrease in the flipped model. In the traditional model, teachers often adopt a more detailed and systematic classroom instruction model according to their experience. Therefore, students form a more comprehensive knowledge system, based on the review of the teaching content and teachers' detailed description of the core knowledge, which explains the high score in rehearsal and elaboration in a traditional classroom. Students need to efficiently organize the fragmentation of understanding to form a complete knowledge system to improve the application of organization strategy in flipped than the traditional classroom model. From the perspective of critical thinking strategy (CT), students prefer to use critical thinking to question teaching content and video materials, raising relative questions in flipped model, which is inconsistent with the nature of flipped classroom learning, such as the procedure of watching the video, building the issue, solving the problems, and strengthening knowledge. Metacognitive self-regulation strategy (MSR) increased from 3.63 to 3.67, which further proves that students have improved in their learning initiative, awareness and cognitive abilities in the flipped classroom. The four resource management strategies such as time and study environment (TSE), effort regulation (EF), peer learning (PE) and help-seeking (HS), have different degrees of increase in the flipped model, indicating that students pay more attention to the time management and learning environment, conducting more peer learning and seeking help in the flipped classroom.

Conclusion

Overall, compared to the traditional classroom, students' learning motivation is obviously enhanced in the flipped classroom, with students' interest, curiosity and learning initiatives in curriculum promoted, intrinsic goal orientation further strengthened. However, students' extrinsic goal orientation, aimed at grade has an overall decline, their control beliefs, and self-efficacy for learning have been improved, and their test anxiety has been decreased. In flipped classroom, students use less rehearsal and elaboration strategies than in the traditional classroom. However, organization strategies are on the increase, and students prefer to use critical thinking strategies to raise relevant questions about teaching content and video materials. The four strategies of resource management (Time and Study Environment, Effort Regulation, Peer Learning, and Help-Seeking) are all increased to some extent in the flipped model, indicating that students pay more attention to the use of time and learning environment, conducting more peer learning and help-seeking.

Acknowledgements

The study is supported by the National Science Foundation, US (Grant No. NSF 1623031), partly supported by Fund of Philosophy and Social Science in Higher Education from Educational Commission of Jiangsu Province, China (Grant No. 2017SJB0136), and is part of the research results of 2017 Excellent Applied Social Sciences Project of Jiangsu Province, China (Grant No. 17jsyw-53). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors.

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