International Journal of Engineering Education Vol. 34, No. 6, pp. 1876–1887, 2018
Printed in Great Britain
0949-149X/91 $3.00+0.00

A Comparison of Flipped and Traditional Classroom Learning: A Case Study in Mechanical Engineering*

JING YAN[1], LIN LI[2], JIANJUN YIN[3] and YUJING NIE[4]
[1] Foreign Language Institution, Nanjing Forestry University, Nanjing, Jiangsu, 210037, China. E-mail: jyan@njfu.edu.cn
[2] Department of Civil & Architectural Engineering, Tennessee State University, Nashville, TN 37209, USA. E-mail: lli1@tnstate.edu
[3] College of Education and Human Development, Jackson State University, Jackson, MS 39217, USA. E-mail: jianjun.yin@jsums.edu
[4] Foreign Language Institution, Nantong University, Nantong, Jiangsu, 226000, China. E-mail: jsmarionie@gmail.com

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 then "class 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 in order to establish an active flipped learning (AFL) model, aiming to promote active learning. Eighty sophomores 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 models were applied to five topics. All of the students attended these flipped models. Pre- and post-tests were conducted for the AFL. The survey results were analyzed to compare students' learning self-efficacy and satisfaction between the traditional and the active flipped classroom. Compared to the traditional classroom, students' learning motivation is obviously enhanced in the AFL classroom, with students' interest, curiosity and learning initiatives in curriculum promoted, intrinsic goal orientation further strengthened, in which students tend to have less extrinsic goal orientation and lower test anxiety than the students in the traditional classroom, but with improved control beliefs and self-efficacy for learning. In the traditional classroom, students use more rehearsal and elaboration strategies, while in the flipped classroom, students use more organization strategies and prefer to use critical thinking strategies to raise relative questions about teaching content and video materials. Students in the AFL model use more strategies of resource management, such as time and study environment, effort regulation, peer learning, and help seeking than in the traditional model. In comparison of different student groups, the AFL model effectively improves students' motivation in both long and short learning time groups, but the effects are not obvious on the low GPA students. From the perspective of gender, the AFL model helps to increase the male students' learning motivation, while female students use more learning strategies in task value, control belief and self efficacy in traditional model. Therefore, the instructors should pay more attention in improving the learning motivation and effectiveness of low GPA group and female students in the flipped classroom. In summary, 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.

Keywords: active flipped learning; engineering mechanics; the flipped classroom; the traditional classroom

1. Introduction

Upton and Tanenbaum [1] of American Institutes for Research reported the lack of diverse groups of individuals in STEM academic and work force fields and the need to foster the participation among African-Americans. Therefore, it is essential that African-Americans, being the underrepresented minorities in the STEM-related domains, should be provided with opportunities to increase their presence and achievements in STEM fields. The researches on how to foster effective active and deep learning to help African-American students maximize the students' potentials for academic success in STEM degree studies become the focus of STEM education.

To increase student retention rate and academic performance, many STEM researchers begin to investigate the flipped classroom in higher education [2]. The flipped classroom, also referred to as the inverted classroom [3, 4], which is a pedagogical model whereby the typical lecture and homework components of a course are reversed, was introduced to promote the use of technology as well as active and collaborative learning in the classroom to meet the goals of engineering education. Flipped Classroom consists of interactive group learning activities inside the classroom and direct computer-based individual instruction outside the classroom [5]. Exactly, in contrast to the traditional classroom, the flipped classroom has students watch prerecorded lecture videos before coming to class and then "class becomes the place to work through problems and advance concepts". The

* Accepted 8 July 2018.

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 [6–8]. The former president Obama announced a White House plan to make college more affordable, which includes flipped classrooms as part of the solution. This plan states, "A rising tide of innovation has the potential to shake up the higher education landscape. Promising approaches include three-year accelerated degrees, Massive Open Online Courses (MOOCs), and 'flipped' or 'hybrid' classrooms where students watch online lectures and faculty challenge them to solve problems and deepen their knowledge in class. Some of these approaches are still being developed, and too few students are seeing their benefits" [9]. To people's relief, the efficacy of this model has been proven [10]. In part, this is because in a flipped environment, instructors are able to engage one-on-one with students. Thus, "more students can be added to the classroom without sacrificing the 'student to valuable-human-time' that is traditionally only gained with low student to teacher ratios" [8].

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. In addition, 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 important 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? Aiming to examine the effects of flipped classroom in STEM education at Jackson State University (JSU, an HBCU) and promote active learning, stress deep learning, encourage student engagement and highlight data-driven personalized learning. In this paper, an Active Flipped Learning (AFL) model was proposed and applied in engineering mechanics class by combining flipped classroom with active learning in order to provide individualized learning opportunities. Eighty engineering students, most of them are African American students, registered to participate the AFL study of engineering mechanics. The AFL model includes aspects of what engineers will encounter in their work: inter-disciplinary, group project based word on real-world, ill-structured problems [11, 12]. Students no longer learn passively in traditional classrooms, but actively and collaboratively through the AFL model. 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 successful career. This could lead to promising outcomes in an HBCU given the social-economic characteristics of African-American students.

2. Theoretical and methodological background

Flipped Classroom is an educational technique that consists of interactive group learning activities inside the classroom and direct computer-based individual instruction outside the classroom [5]. Different from the traditional classroom, the flipped classroom has students watch prerecorded lecture videos before coming to class and then "class becomes the place to work through problems, advance concepts, and engage in collaborative learning" [13]. The flipped classroom also switches the instructor's availability to students. Instead of being present during the lecture, the instructor walks around to answer questions during class time. By monitoring students' learning process and identifying their individual needs and difficulties, instructors can formulate a custom-tailored plan to fit each student in STEM, realizing data-driven personalized learning and active learning.

Active learning is a process whereby students engage in activities, such as reading, writing, discussion, or problem solving that promote analysis, synthesis, and evaluation of class contents. Active learning requires students to take on the responsibility of learning, encouraging students to experiment with ideas, to develop concepts, and to integrate concepts into systems. Research shows that active learning seeks to engage a greater range of students in effective learning. Based on a meta-analysis of 225 studies of undergraduate STEM teaching methods, Freeman et al. [14] found that when teachers use approaches that transformed students into active participants rather than passive learners, failure rates reduced and students' academic performances were boosted to a larger extent. Students no longer learn passively in traditional classrooms, but actively and collaboratively through the active flipped learning model. The active flipped learning model requires students to utilize higher-order thinking skills such as analysis, synthesis, and evaluation [6]. With internet access, students may view web-based instruction on their own time, at their own pace. The focus of the flipped classroom is on giving students the freedom to interact with the content more freely. This provides opportunities to utilize the classroom for the application and other high-order skills. Because students have watched the lecture prior to class, contact hours can be devoted to problem solving, and gaining a deeper understanding of the subject matter [15]. The teacher is able to provide students with a wide range of learner-centered opportunities in class for greater mentoring and collaboration, increasing the possibility to engage students [16].

A multitude of previous studies have examined students' perceptions toward flipped classroom and found that students enjoyed and were successful in the flipped classroom [3, 5, 10, 17]. In a study at Texas Tech University, a single semester of a microeconomics course was flipped. Not only did 76% of responding students indicate that the "flipped learning helped them learn," but also that the "students performed slightly better on average on midterm tests compared to previous semesters taught by the same instructor" [8]. An observation based on flipping a class at Villanova University's College of Engineering indicated that "the bottom third of students' grades were more than 10 percent higher than in a traditional classroom (the difference between a D+ and a C) and more than 3 percent higher for the class as a whole (moving from a C+ to a B–)" [7]. Similarly, a study at Seattle University found? "(1) the instructor covered more material; (2) students performed better on comparable quiz questions and on open-ended design problems; and (3) while students initially struggled with the new format, they adapted quickly and found the inverted classroom format to be satisfactory and effective" [4].

Recently, some researchers partially flipped their classroom to examine the effect of flipped learning on student performance [15, 18, 19, 20]. In an introductory biology course some researchers required students to watch narrated videos and complete a worksheet before class time [21]. In class, students participated in alternating mini-lectures and active learning exercises, which led to a performance increase of 21% on exam questions related to the topics introduced outside class with videos. Other studies went a step further and fully flipped their classrooms even with control group designs [10, 22]. Hotle and Garrow [10] conducted their study in a civil engineering system course and found that students in the flipped environment scored higher on all homework assignments, projects, and tests. Another example, Students at the University of Michigan do their math reading before class. The instructor gives a brief lecture, asks them about the reading, and goes through an example from the textbook. Students take turns going to the board to present their answers or working in groups. The instructors can hear and correct misunderstandings as they arise. Research at Michigan's teaching methods have led to greater gains in conceptual understanding. The techniques have been applauded by the Association of American Universities, among others.

Many educators also believe that STEM courses are an especially good fit for flipping. The difficulty and complexity of the subject matter lends itself to in-class activities that allow students to apply what they have learned. Through classroom activities, the instructor has the ability to obtain the data concerning what students have actually learned. Dr. Roger Freedman at the University of California asks his students to watch a video lecture before class and to answer a few questions based on that and some assigned reading. He discovered that students are engaged in class because they are hearing the things they want to know. Dr. Lorena Barba at Boston University uses class time not for a lecture, but for a series of STEM "dates" where students meet up at each workstation, compare notes, and select who has the most impressive solution. The winning solution becomes the topic of a class discussion. Dr. Barba claimed students performed much better, since they had more time to work out the kinks in class. Dr. Eric Mazur, a professor at Harvard University, flipped his classroom and noted that was the key that led students to the right answer—not his lecture. This form of active learning fits with the flipped classroom model because class time is not consumed by the lecture.

3. AFL design of engineering mechanics I

The Engineering Mechanics I in Fall 2017 is a core engineering course for sophomore year students. The computer, civil, electrical, and biomedical engineering students are required to take this course. In order 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 models were introduced for five topics, which needed all of students to attend. The teaching contents and assessment tools of each instructional model are shown in Table 1. During each flipped model, students watched a lecture video prior to 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 discussions were led by the assigned group leaders. Pre- and post-tests were conducted for the AFL.

4. AFL settings of engineering mechanics I

Each flipped class corresponded to a single topic. As shown in Table 1, the contents of second half semester cover five topics: the concept of Moment of a Force, Moment of a Couple, Distributed Load; Force System Resultants; Equilibrium of a Rigid Body; Structural Analysis for Truss; Friction. The teaching of the topic was broken down into four phases as shown in Fig. 1, phases1, 2 and 4 occur outside the classroom.

Phase 1: *Information gathering*—students watch an instructional video, or read the learning materials through CANVAS, which are mainly designed for remembering and understanding of the content. Students are required to keep notes of the learning materials following the requirements of Cornell notes.

Phase 2: *Preliminary assessment*—students do the online quiz (due the evening before the flipped class). The quiz includes 5 to 8 questions, and students are given two attempts. Individual feedback is given after the first submission, and the second attempt pulls a new set of randomized questions from a pool of similar questions. Students will receive a percentage of their final grade solely for participation. The instructor will review the results of each question and use this to determine what concepts to focus on in the classroom the next day.

Phase 3: *Assimilation of information*—in class, students work through problems individually and in groups to develop high-order skills. Using the data from the Canvas, the instructor comes to class with carefully-prepared questions centered on the parts that students are still struggling. The instructor presents a question and asks the students to work on the problem individually. Students have several minutes before submitting their responses. The results of this first polling session will be presented immediately, but the answer may not be revealed. At this point, the instructor will ask students to convince their partners of their choice. During the discussion, the instructor moves around monitoring and facilitating. After several minutes, students submit their responses and results are shown. The active learning and peer instruction can help the convergence of the class to the correct answer with less imposed input from the instructor. Once the solution to the question is worked out, a follow up question for students will be assigned.

Phase 4: *Homework*—students continue to make sense of information by working through questions on the weekly online assignment. It is designed to reinforce the content of the instructional video and the classroom practice. Students can discuss the homework in the BBS forum within the CANVAS. At the end of the week, students will take an in-class hand-written quiz, which assesses their understanding of the assigned homework.

At this stage, during the initial period some students who fail to complete Phase 1 and 2 will be allowed to complete during class time, while other students continue their learning activities (Phase 3). When most of them are accustomed, all of them are

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 • Mid-term 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 for Truss • Friction **Teaching materials:** • Video • Textbook • Reading references **Assessment Tool:** • AFL questionnaires • Homework • Interview participating students • CANVAS records • Exams • Quiz

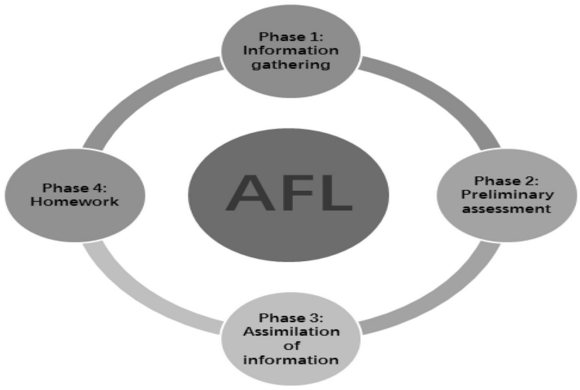

Fig. 1. The format of active flipped learning model.

Table 2. Demographic Characteristics of Students

Characteristic variable	
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	5
GPA	
• Average transcript GPA	3.16
• Average course GPA	3.08

required to complete the required Phase 1 and 2 beforehand.

5. DATA collection and analysis

This research uses Motivated Strategies for Learning Questionnaire (MSLQ), which is released online through Survey Monkey. Students answer the questionnaire by clicking on the invitation link and choosing the suitable answers. In order to enhance the enthusiasm of student's involvement in the survey, a prize is awarded to the top ten students who completed the questionnaires independently and completely. After all the students completed the online questionnaire, Survey Monkey conducts preliminary screening and sorting of the data. The researchers exported and downloaded questionnaire data and further calculated and analyze it with the help of statistical software SPSS 20.0.

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 5% for other races. The Grade Point Average (GPA) 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 courses in the whole curriculum and students has a weaker foundation for STEM courses, especially African-American students.

Table 3 shows the relationship between the six components of motivation scale in MSLQ questionnaire and related variables in traditional classroom, such as concept inventory, GPA, traditional grade, final grade, and so on. As can be seen from the table, among the variables studied, the student's CI is significantly related to the gender variable, indicating that girls tend to grasp better basic concepts than boys. This is mainly due to the fact that girls are more likely to focus on what teacher teach in class than boys in traditional classrooms and has better mastery of basic concepts. Therefore, girls have better concept inventory scores than boys. Among the six components of Motivation, IGO correlates with concept inventory and gender; EGO is highly correlated with concept inventory; CB is highly correlated with final grade, and SE is also related to final grade.

The Table 4 is used to investigate student's motivation in flipped classroom. As can be seen from the table, the quiz score correlated with gender, with a negative value –0.490. Because the female is coded as 1 and the male coded as 2 in SPSS, the negative score indicates that the female students tend to have higher quiz scores than the male students. It shows that the female students in flipped classroom have achieved better preparation results after watching the video before class. Intrinsic goal orientation correlates with gender and GPA. Control beliefs about learning correlates with final grade. Self-efficacy correlates with final grand and GPA.

Correlation of the nine strategies used by students in traditional classrooms and the variables is studied in this paper as given in Table 5. As can be seen from the table, metacognitive self-restraint strategy (MSR) is associated with cognitive inventory in traditional classroom learning. Obviously, the use of self-restraint strategies helps to enhance students' mastery of basic concepts such as basic concepts, Relevance of Time and Environment Learning Strategies (TSE) to student academic achievement. Gender is correlated with both Elaboration strategy (ELA) and Metacognitive Self-Regulation strategy (MSR).

The Table 6 is used to investigate Correlation of

Table 3. Correlation of Motivation Components in Traditional Classroom

	CI Tra	Tra G	Final G	Gender	Leader	GPA	IGO	EGO	TV	CB	SE	TA
CI Tra	1.000											
Tra G	0.386	1.000										
	0.126											
Final G	-0.319	-.635**	1.000									
	0.212	0.001										
Gender	-.539*	0.001	-0.098	1.000								
	0.025	0.996	0.655									
Leader	-0.009	-0.153	0.184	-0.203	1.000							
	0.973	0.496	0.413	0.366								
GPA	0.432	0.367	-0.451	-0.004	0.013	1.000						
	0.123	0.123	0.053	0.987	0.958							
IGO	.551*	0.397	-0.102	-.423*	0.258	-0.071	1.000					
	0.022	0.061	0.643	0.044	0.246	0.772						
EGO	-.697**	-0.246	-0.077	0.128	0.215	-0.258	-0.218	1.000				
	0.002	0.258	0.727	0.560	0.337	0.287	0.318					
TV	0.464	-0.080	-0.010	-0.360	0.258	0.117	.534**	0.040	1.000			
	0.061	0.717	0.963	0.092	0.246	0.635	0.009	0.858				
CB	-0.019	0.193	-.495*	0.010	0.106	-0.093	0.249	0.357	0.306	1.000		
	0.942	0.378	0.016	0.966	0.640	0.706	0.252	0.094	0.155			
SE	0.298	0.048	-.443*	-0.285	0.115	0.287	0.350	0.123	.618**	.715**	1.000	
	0.246	0.828	0.034	0.187	0.611	0.234	0.102	0.576	0.002	0.000		
TA	-0.398	-0.282	0.143	0.204	0.131	-0.348	-.600**	.465*	-.454*	-0.167	-.465*	1.000
	0.113	0.193	0.514	0.350	0.560	0.144	0.002	0.025	0.030	0.447	0.026	

CI means concept inventory; Tra means traditional; G means grade; 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. * means significantly correlated, ** means very significantly correlated.

Table 4. Correlation of Motivation Components in Flipped Classroom

	CI Fli	CI Imp	Fli G	Quiz G	Final G	Gender	Leader	GPA	IGO	EGO	TV	CB	SE	TA
CI Fli	1.000													
CI Imp	.666*	1.000												
	0.018													
Fli G	0.530	0.540	1.000											
	0.076	0.070												
Quiz G	-0.156	-0.553	-0.126	1.000										
	0.628	0.062	0.577											
Final G	-.654*	-0.482	-.621**	-0.159	1.000									
	0.021	0.113	0.002	0.480										
Gender	-0.075	0.553	0.169	-.490*	-0.098	1.000								
	0.818	0.062	0.441	0.020	0.655									
Leader	0.233	0.244	-0.078	-0.046	0.184	-0.203	1.000							
	0.467	0.444	0.730	0.845	0.413	0.366								
GPA	0.123	-0.101	0.079	0.323	-0.451	-0.004	0.013	1.000						
	0.736	0.780	0.748	0.191	0.053	0.987	0.958							
IGO	0.364	0.012	-0.011	0.093	-0.311	-.447*	0.312	.515*	1.000					
	0.245	0.970	0.961	0.681	0.148	0.032	0.157	0.024						
EGO	-0.082	0.120	0.305	-0.031	-0.223	0.021	-0.018	-0.057	0.005	1.000				
	0.799	0.711	0.157	0.892	0.306	0.924	0.937	0.818	0.983					
TV	-0.029	-0.139	0.135	-0.206	-0.305	-0.023	0.035	0.409	.503*	0.391	1.000			
	0.930	0.666	0.539	0.359	0.156	0.916	0.878	0.082	0.014	0.065				
CB	0.518	0.365	0.360	-0.352	-.534**	0.251	0.071	0.407	0.373	0.262	.700**	1.000		
	0.085	0.243	0.092	0.109	0.009	0.248	0.752	0.084	0.080	0.227	0.000			
SE	0.141	-0.199	0.098	-0.060	-.509*	-0.110	-0.088	.529*	.667**	0.161	.707**	.739**	1.000	
	0.663	0.535	0.655	0.791	0.013	0.618	0.697	0.020	0.001	0.464	0.000	0.000		
TA	-0.056	0.402	0.090	0.124	-0.100	0.167	0.009	-0.345	-0.377	0.397	-0.167	-0.188	-0.379	1.000
	0.863	0.195	0.684	0.581	0.649	0.446	0.968	0.148	0.076	0.061	0.446	0.390	0.074	

Table 5. Correlation of Learning Strategy Components in Traditional Classroom

	CI Tra	Tra G	Final G	Gender	Leader	GPA	REH	ELA	ORG	CT	MSR	TSE	ER	PL	HS
CI Tra	1														
Tra G	.386	1													
	.126														
Final G	-.319	-.635**	1												
	.212	.001													
Gender	-.539*	.001	-.098	1											
	.025	.996	.655												
Leader	-.009	-.153	.184	-.203	1										
	.973	.496	.413	.366											
GPA	.432	.367	-.451	-.004	.013	1									
	.123	.123	.053	.987	.958										
REH	.267	.137	-.129	-.221	-.023	-.017	1								
	.301	.534	.559	.311	.919	.944									
ELA	.329	.234	-.251	-.467*	.048	.135	.486*	1							
	.197	.282	.249	.025	.833	.581	.019								
ORG	.261	-.012	-.128	-.348	.185	.170	.361	.422*	1						
	.311	.955	.560	.104	.410	.485	.090	.045							
CT	.476	-.031	-.088	-.402	.231	.308	.280	.689**	.516*	1					
	.053	.888	.689	.057	.301	.200	.195	.000	.012						
MSR	.601*	.016	-.114	-.495*	.170	-.054	.554**	.732**	.599**	.736**	1				
	.011	.941	.605	.016	.451	.825	.006	.000	.003	.000					
TSE	.178	-.480*	.184	-.309	.380	-.051	.192	.138	.551**	.413*	.466*	1			
	.493	.021	.400	.151	.081	.836	.381	.529	.006	.050	.025				
ER	-.287	.088	-.012	-.098	-.080	-.335	.281	-.090	-.173	-.417*	-.122	-.290	1		
	.263	.689	.955	.658	.725	.161	.194	.684	.431	.048	.579	.179			
PL	.268	-.062	-.192	-.398	-.083	.119	.363	.706**	.375	.614**	.520*	.018	.025	1	
	.297	.780	.379	.060	.715	.628	.089	.000	.077	.002	.011	.935	.910		
HS	.227	-.338	.044	-.393	-.017	-.221	.443*	.650**	.421*	.605**	.724**	.496*	-.045	.676**	1
	.381	.115	.841	.063	.940	.363	.034	.001	.046	.002	.000	.016	.838	.000	

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 helping seeking.

Table 6. Correlation of Learning Strategy Components in Flipped Classroom

	CI Fli	CI Imp	Fli G	Quiz G	Final G	Gender	Leader	GPA	REH	ELA	ORG	CT	MSR	TSE	ER	PL	HS
CI Fli	1.000																
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	0.467	0.444	0.730	0.845	0.413	0.366											
GPA	0.123	-0.101	0.079	0.323	-0.451	-0.004	0.013	1.000									
	0.736	0.780	0.748	0.191	0.053	0.987	0.958										
REH	-0.075	-0.332	-0.027	0.136	-0.308	-0.289	0.019	0.123	1.000								
	0.816	0.292	0.902	0.547	0.152	0.181	0.933	0.616									
ELA	0.083	-0.124	0.097	-0.079	-0.373	-0.243	0.211	.514*	.796**	1.000							
	0.798	0.701	0.660	0.728	0.080	0.265	0.347	0.024	0.000								
ORG	0.527	0.051	0.164	-0.044	-.477*	-0.248	0.185	0.261	.734**	.766**	1.000						
	0.078	0.874	0.453	0.847	0.021	0.255	0.410	0.281	0.000	0.000							
CT	0.037	-0.358	0.345	0.190	-.555**	-0.194	0.113	0.426	.675**	.737**	.709**	1.000					
	0.910	0.253	0.107	0.397	0.006	0.375	0.616	0.069	0.000	0.000	0.000						
MSR	0.220	-0.003	0.250	0.041	-.492*	-0.138	0.212	0.292	.765**	.793**	.791**	.822**	1.000				
	0.492	0.992	0.250	0.857	0.017	0.530	0.343	0.225	0.000	0.000	0.000	0.000					
TSE	0.069	0.208	0.067	0.076	-0.322	-0.049	0.329	0.076	0.403	.480*	.426*	0.377	.707**	1.000			
	0.830	0.517	0.760	0.738	0.134	0.823	0.134	0.758	0.057	0.020	0.043	0.076	0.000				
ER	0.109	0.217	.432*	0.368	-.585**	0.049	-0.030	0.056	0.249	0.159	0.102	0.380	.419*	.598**	1.000		
	0.737	0.498	0.040	0.092	0.003	0.823	0.896	0.821	0.252	0.468	0.642	0.074	0.046	0.003			
PL	-0.065	-0.323	0.409	0.178	-0.383	-0.198	-0.060	0.177	.576**	.513*	.482*	.865**	.696**	0.231	.414*	1.000	
	0.840	0.306	0.052	0.428	0.071	0.364	0.790	0.468	0.004	0.012	0.020	0.000	0.000	0.290	0.049		
HS	-0.224	-0.476	0.292	0.206	-.431*	-0.306	-0.146	0.124	.670**	.613**	.513*	.840**	.656**	0.351	.475*	.866**	1.000
	0.485	0.118	0.176	0.358	0.040	0.156	0.517	0.614	0.000	0.002	0.012	0.000	0.001	0.100	0.022	0.000	

student's strategies and related variables in traditional classroom used in the flipped classroom. Elaboration strategy correlates with GPA and rehearsal strategy. Organization correlates with final grade, rehearsal and elaboration. Final grade correlates with five strategies, such as organization, critical thinking, metacognitive self-regulation, effort regulation, and help seeking strategies. Both of peer learning and help seeking closely correlate with most of the other strategies.

The Table 7 shows the comparison of concept inventory test scores and test scores of all students under two different teaching models. As can be seen from the table, the average score 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 statistical 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 score in the traditional classroom. The main reason for that is as follows: although the traditional teaching model 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 flipped model, teaching chapters cover 70% contents of the teaching plan. Because of the flipped model, the video content uses fragmented form under a 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.

It can be learned from correlation analysis of Table 3 to Table 6 that students' concept inventory and test grade are correlated with their GPA, gender and other factors. 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 8. In comparison of 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

Table 7. Comparison of Performance in Traditional and Flipped Classroom

	Traditional		**Flipped**					
Measurement	**Mean**	**SD**	**Mean**	**SD**	**Growth**	**T**	**P**	**Effect Size**
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

Table 8. 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.

model has a greater role in improving male students' achievement in concept inventory. However, the improvement in the female students 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 that 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 model, 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 in the flipped classroom.

Table 9 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 traditional classroom, the motivation of students is significantly increased in flipped classroom. Looking into the six components in learning motivation, the mean of students' intrinsic goal orientation (IGO) increased from 3.63 in traditional classroom to 3.70 in flipped classroom, while extrinsic goal orientation (EGO) has decreased from 4.13 in traditional 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 student's interests in curricula, curiosity and learning initiatives are improved with their intrinsic goal orientation further strengthened. 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

Table 9. Comparison of Components in MSLQ in Traditional and Flipped Classroom

		Traditional		Flipped					
Scale	**Component**	**Mean**	**SD**	**Mean**	**SD**	**Growth**	**T**	**P**	**Effect Size**
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 pre-test.

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.

In order to find out the learning motivation and learning strategies of different student groups in two teaching models, the researcher divided students into different groups based on their GPA (high and low), study time (long and short) and gender (male and female) respectively. Table 10 shows the difference between pre- and post-test of student's motivation and learning strategy in different groups. It can be seen from the table that the performance of students' learning motivation in

Table 10. Comparison of Components in MSLQ in Different Groups

Scale	Component	GPA	Mean	SD	Time	Mean	SD	Gender	Mean	SD
Motivation	IGO	Low	-0.31	0.47	Short	0.06	0.81	Female	0.03	0.49
		High	0.54	0.60	Long	0.07	0.45	Male	0.10	0.77
	EGO	Low	-0.37	0.95	Short	-0.35	0.91	Female	-0.15	0.63
		High	0.07	0.19	Long	-0.11	0.61	Male	-0.31	0.88
	TV	Low	-0.28	0.78	Short	-0.17	0.46	Female	-0.37	0.63
		High	0.09	0.38	Long	-0.04	0.84	Male	0.09	0.63
	CB	Low	0.04	0.80	Short	0.00	0.69	Female	-0.03	0.75
		High	0.29	0.57	Long	0.27	0.67	Male	0.25	0.62
	SE	Low	0.09	0.86	Short	-0.22	0.48	Female	-0.09	0.62
		High	0.18	0.30	Long	0.35	0.78	Male	0.16	0.74
	TA	Low	0.00	0.83	Short	0.03	0.93	Female	-0.06	0.81
		High	-0.06	0.80	Long	-0.18	0.57	Male	-0.08	0.77
Learning Strategy	REH	Low	-0.15	0.45	Short	-0.04	0.35	Female	-0.08	0.43
		High	-0.07	0.37	Long	-0.27	0.48	Male	-0.21	0.43
	ELA	Low	-0.24	0.48	Short	-0.13	0.47	Female	-0.28	0.49
		High	0.07	0.36	Long	-0.12	0.41	Male	0.00	0.36
	ORG	Low	0.25	0.68	Short	0.04	0.46	Female	0.08	0.49
		High	0.29	0.39	Long	0.36	0.73	Male	0.29	0.70
	CT	Low	-0.05	0.64	Short	0.12	0.50	Female	-0.04	0.51
		High	0.37	0.24	Long	0.09	0.63	Male	0.22	0.59
	MSR	Low	-0.11	0.46	Short	0.06	0.42	Female	-0.13	0.50
		High	0.27	0.51	Long	0.01	0.54	Male	0.17	0.42
	TSE	Low	0.05	0.78	Short	0.16	0.51	Female	-0.04	0.70
		High	0.27	0.56	Long	0.02	0.83	Male	0.19	0.66
	ER	Low	0.10	0.45	Short	0.31	0.57	Female	0.18	0.33
		High	0.46	0.67	Long	0.20	0.57	Male	0.33	0.69
	PL	Low	0.05	0.38	Short	0.14	0.48	Female	-0.03	0.29
		High	0.24	0.46	Long	0.15	0.31	Male	0.28	0.43
	HS	Low	-0.21	0.55	Short	-0.10	0.55	Female	-0.15	0.39
		High	0.21	0.49	Long	-0.09	0.57	Male	-0.06	0.65

different groups is not the same. For low GPA students, both intrinsic goal orientation (IGO) and extrinsic goal orientation (EGO) are decreased, changes in self-efficacy (SE) are small, and test anxiety does not change. All those changes indicate that current flipped model cannot effectively improve the low GPA student's learning motivation, and further optimization of the flipped model and video content are needed. For the long and short study time groups, the flipped model improves both two groups student's motivations. For the gender groups, the flipped model improves male's learning motivation more effectively. The probable reason for female student's decrease in task value, control belief and self-efficacy is that female students prefer traditional classroom model, accustomed to the teacher-teaching and student-listening model. Therefore, they meet problem in adapting to the student-centered active flipped classroom. As a result, female student's learning motivation shows a downward trend as a whole.

In comparison of usage of learning strategies in GPA groups, the main differences between low and high groups show on elaboration, critical thinking, meta-cognitive self-regulation and help seeking strategies. It is difficult for low GPA students to adapt to active flipped learning within one semester from traditional to flipped classroom, and their motivations have not got improved, which leads to the decrease in learning interests and strategies. In comparison of usage of learning strategies in study time groups, the long and short groups are similar in flipped classroom. In comparison of gender groups, female students show a decrease in using elaboration, critical thinking, meta-cognitive self-regulation strategies, time and study environment and peer learning. Combining the grade comparison of male and female students, the female's grade in flipped classroom is lower than that of male, which maybe due to the same reason that the female is difficult to adapt to the new teaching model from traditional to flipped classroom.

6. Conclusions

This paper develops an AFL model, which combines the flipped classroom and active learning, applied in Engineering Mechanics I. In order to better study the effects of AFL model, the current research is carried out among 80 college students in a HBCU. The researcher uses traditional teaching model in the first half of semester, and flipped classroom model in the second half of semester, without changing the teaching objects and courses. 80 students answered the MSLQ questionnaires, and SPSS 20.0 software is used for data statistics and processing.

In summary, 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, in which students tend to have less extrinsic goal orientation and lower test anxiety than the students in the traditional classroom, but with improved control beliefs and self-efficacy for learning. In the traditional classroom, students use more rehearsal and elaboration strategies, while in the flipped classroom, students use more organization strategies and prefer to use critical thinking strategies to raise relative questions about teaching content and video materials.

Students in the AFL model use more strategies of resource management, such as time and study environment, effort regulation, peer learning, and help seeking than in the traditional model, indicating that students pay more attention to the use of time and learning environment, conducting more peer learning and help seeking.

In comparison of different student groups, the AFL model effectively improves students' motivation in both long and short learning time groups, but the effects are not obvious on the low GPA students. From the perspective of gender, the AFL model helps to increase the male students' learning motivation, while female students use more learning strategies in task value, control belief and self efficacy in traditional model. Therefore, the instructors should pay more attention in improving the learning motivation and effectiveness of low GPA group and female students in the flipped classroom.

The current study has many limitations such as it has just practiced on one subject Engineering Mechanics and only learning motivation and learning strategies has been studies in comparison of the traditional and the AFL models. Other STEM subjects such as Physics and Mathematics should be studied in future studies to achieve more objective and valuable results from more perspectives, such as students' engaged learning and learner's empowerment. In all, researchers should explore from various aspects in the comparison of AFL classroom and traditional classroom in subsequent studies, further improving students' motivation and effectiveness in STEM learning.

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) as well as Youth Science and Technology Innovation Project of NFU, China (CX2016033). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors.

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Jing Yan graduated in 2005 with a BA in English Teaching in Yangzhou University. From 2005 to 2008 she attended Graduate School at Yangzhou University, where she obtained a M.A. degree in Linguistics. She received a PhD from Jackson State University in April 2018. She joined Foreign Language Institute at Nanjing Forestry University in 2008 and now is an assistant professor. She teaches College English to STEM majors and has been PI of three major research grants from Jiangsu province and her university. She is currently interested in developing and implementing best practices in STEM education and language acquisition.

Lin Li is a Professor and Department Head of the Department of Civil and Architectural Engineering at Tennessee State University. He teaches geotechnical engineering courses, including foundation engineering, unsaturated soil mechanics, geo-environmental engineering, advanced soil mechanics, and soil dynamics. His expertise is in innovative levee testing and protection, biomediated ground improvement, sustainable infrastructure and geo-environmental area. He has been PI of more than fourteen major research grants from federal and state agencies with total funding amounts of $3.6 Million. Dr. Li is the author or co-author of more than 87 peer-reviewed published articles. He got numerous faculty excellence award and Richard S. Ladd Standards Development Award from ASTM.

Jianjun Yin, PhD Professor of Education at the Department of Elementary and Early Childhood Education, has extensive experiences and expertise working with both pre-service and in-service teachers, elementary and middle school students and their parents. As a certified evaluator of Mississippi teacher performance, Dr. Yin has worked as a clinical supervisor for more than twelve years and his work surrounds largely around promoting teacher quality and instructional effectiveness. He has directed three NSF grants, a service learning grant to assist CSET students getting into math and engineering fields. Dr. Yin has worked as liaison between Yahoo Public Schools, Jackson Public Schools and Jackson State University and facilitated efforts among the participating organizations. During the past 15 years, Dr. Yin has published amply in international and professional peer referred journals in the areas of engineering education, reading, elementary and early childhood education and education for minority children and youth. As a doctoral adviser, Dr. Yin has directed numerous dissertations, theses and Education Specialist projects and published with both junior faculty and graduate students.

Yujing Nie is an associate professor of Foreign Language Institute at Nantong University in China.