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Board 183: A Case Study of AFL Models on Factors of Engaged Learning in STEM Education

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Abstract

With Active Flipped Learning (AFL) model, some STEM instructors and education instructors at HBCUs provided instructional video, audio, lecture notes, and reading materials while initiating active learning activities in class to engage students in active flipped learning. By monitoring students' engagement, instructors formulated a custom-tailored plan to fit each under-representative student in STEM. After practicing the longitudinal research for three years, some results were found during the procedure. The AFL model effectively promotes under-representative students performance in various science disciplines such as engineering, physics, and mathematics, such as help to foster under-representative students' deep understanding of STEM disciplines, becoming more engaged in STEM learning, and eventually realizing students' data-driven personalized learning in STEM education.

Keywords: Active Flipped Learning (AFL), STEM education, Engaged learning, under-represented students

1. Introduction

National Science Board announced that the STEM (Science, technology, engineering, and mathematics) knowledge and skills that educated graduates possess are vital to a significant part of the US workforce and contribute to the national economic competitiveness and innovation [1]. A study made by Livinstone and Bovil [2] found that American students are digital-centered, tend to learn visually and socially, and enjoy interaction and connectivity with others and expect to learn in the virtual context. AFL (Active Flipped Learning) is a customer-tailored design attempting to take students' characteristics into account, reflecting the embodiment of active learning so that STEM students were immensely motivated to reflect, evaluate, create, and make connections between ideas [3][4]. The positive influence of active learning has been confirmed in a lot research. For example, Freeman et al. [5] stated that the average exam scores were improved by about 6% in active learning sections. Esmaeili and Eydgahi [6] provided that active motivation and learning strategies like perceived usefulness, self-efficacy, and attitude, influence under-representative students' STEM course registration and learning.

Engagement is the attention and efforts that students devote to their learning. In practice, when students are engaged, they can initiate action and exert intense effort in the learning tasks, and show positive emotions during an ongoing action [7]. Strayhorn et al.[8] reported that STEM students with more engaged learning have more satisfaction and better academic performance. Student engagement reflects not only behavioral engagement but also psychological engagement in learning. Specifically, three kinds of engagement are involved: behavioral, cognitive, and emotional [9].

Engaged Learning Index (ELI) is a useful tool in evaluating the AFL efficiency on under-representative STEM students, which is designed to assess the emotional, insightful and behavioral engagement of students under the guide of Active Flipped Learning.

2. **Research design**

The longitudinal research has been executed for three years, from 2016 to 2018, with comprehensive plans. A faculty team of selected STEM instructors and education instructors at Jackson State University (JSU, an HBCU) integrated active learning with flipped classroom instruction. By monitoring students' learning process and identifying their individual needs and difficulties, instructors formulated a custom-tailored plan to fit each under-representative student in STEM, realizing data-driven personalized learning.
Structurally, the AFL development plan consists of four core components: 1) promoting active learning; 2) stressing deep learning; 3) encouraging student engagement; 4) highlighting the data-driven personalized learning.

3. Methodology

Participants

One hundred and three students from three stem courses (Engineering, Physics, and Calculus) at JSU participated in the study. Variables include gender, grade, race, major, GPA, course, study hours, and whether the student has leadership experiences, because of the potential relationship that each has to student engagement and student motivation and learning strategy, based on previous studies [10]. Furthermore, students are divided into high, middle, and low learning groups by GPAs. Long, middle, and short study-hour groups are divided according to their weekly study hours.

Measures

Two sets of well-developed instruments were employed to determine student engagement in the context of AFL, which are valued as two significant indicators for student achievement. *Engaged Learning Index* (ELI), developed by Schreiner and Louis [11], was used to measure the affective, behavioral, and cognitive components of a student's level of engagement. Three components are measured in the Engaged Learning Index: meaningful processing, focused attention, and active participation.

In terms of the subject arrangement, *Calculus I*, *General Physics I*, and *Engineering Mechanics I* were chosen as AFL subjects. Calculus and Physics courses are core courses for all STEM students in most North American colleges and universities in first-year students' year. All assessment tools were developed and utilized to assure that the activities conducted were well aligned with the project goals, determining if AFL-guided learning design helped improve student and academic performance in STEM. All participating students engaged themselves throughout the assessment and evaluation process.

4. Results and discussion

From the previous research of the author, students had greater improvement in their academic achievements in AFL than in traditional setting [4] . The current study is a follow-up research, which explored whether students would have different properties in engagement. Several one-way analyses of variance (ANOVA) tests were done to compare differences between students in three STEM courses applied active flipped learning.

Statistical analyses were conducted to determine the psychometric properties of the Engaged Learning Index (ELI). There are three variables in ELI, such as meaningful processing representing cognitive processing of new information and efforts to relate the new material to preexisting knowledge or determine its relevance; focused attention associated with mental attentiveness during class; and active participation representing student learning through active involvement and contribution to classroom discussions.

ANOVA tests were conducted on the Engaged Learning Index scale in different groups, divided according to their genders, GPAs, study times, and different courses. MSLQ questionnaires were also conducted to study their motivations and learning strategies within the groups mentioned above. A correlation analysis was made between all the variables.

Table 1 showed a significant difference between male and female students in one of the variables: active participation, but with small effect sizes. Male students have higher means in meaningful processing and active participation, while male and female students are almost equal in focused attention. The results indicated a significant difference between male and female students in active participation. The Male students showed more activeness in the class, and they also tended to do more meaningful processing matters.

Table 1 ANOVA Comparison of Gender on ELI

Variable	Gender	Mean	SD	F	P	Cohen's	Effect size
Meaningful Processing	Male	3.70	0.51	3.020	0.085	0.322	0.159
	Female	3.48	0.82				
Focused Attention	Male	3.32	0.45	0.280	0.597	0.111	0.055
	Female	3.37	0.45				
Active Participation	Male	3.74	0.54	8.59	0.004**	0.557	0.268
	Female	3.35	0.83				

Note: Male n=62; Female n=41; **refers to P<0.01，

Table 2 shows that the high GPA group students had the highest means in meaningful processing and focused attention variables among high, middle, and low GPA groups. It is easy to understand that the high GPA group students tend to have close attention in the class, and they always have clear aims and meaningful methods during the learning process. Middle GPA group students participated most actively in the class, and the active flipped classroom phenomenon is possible suitable for middle students actively participating in the classroom activities.

Table 2 ANOVA Comparison of GPA on ELI

Variable	GPA	Mean	SD	F	P
Meaningful Processing	High	3.69	0.84	0.229	0.796
	Middle	3.57	0.57		
	Low	3.61	0.64		
Focused Attention	High	3.45	0.37	0.849	0.431
	Middle	3.32	0.44		
	Low	3.3	0.5		
Active Participation	High	3.57	0.78	0.414	0.662
	Middle	3.66	0.67		
	Low	3.51	0.67		

Note: High n=22; Middle n=42, Low n=39

In Table 3, study time differences are also compared within three groups with different lengths of study time weekly. No significant differences are found. While from the means, we know that students with long study time tend to have more meaningful processing and active participation in the class. Focus attention is an exception, with all groups having similar results, which implies that no matter how many hours they studied after class, an active flipped classroom attracted the students' attention equally.

Table 3 ANOVA Comparison of study time on ELI

Variable	Study time	Mean	SD	F	P
Meaningful Processing	Long	3.73	0.81	1.356	0.262
	Middle	3.66	0.59		
	Short	3.43	0.7		
Focused Attention	Long	3.32	0.54	0.047	0.954
	Middle	3.35	0.41		
	Short	3.33	0.51		
Active Participation	Long	3.68	0.64	0.66	0.519
	Middle	3.61	0.65		
	Short	3.45	0.83		

Note: Long n=16; Middle n=63, Short n=24

Table 4 compared students from three different courses: Engineering, Calculus, and Physics. A statistically significant difference was found in meaningful processing, with a P-value of 0.021. The mean of Engineering group is the highest among the three. The probable reasons for this might be that Engineering groups were the earliest group that participated in the active flipped learning model in the courses. They were more experienced and knew how to achieve the best results in learning and communicate well with classmates and professors. In focused attention, the Calculus and Physics groups had similar means and were only slightly higher than the Engineering group. While in active participation, the Physics group had the lowest mean, and the probable reason for that is that the content of Physics was complex for students to participate actively.

Table 4 ANOVA Comparison of courses on ELI

Variable	Course	Mean	SD	F	P
Meaningful Processing	Engineering	3.82	0.60	4.028	0.021*
	Calculus	3.47	0.67		
	Physics	3.45	0.66		
Focused Attention	Engineering	3.29	0.47	0.474	0.624
	Calculus	3.37	0.39		

	Physics	3.38	0.48		
Active Participation	Engineering	3.61	0.68	0.557	0.575
	Calculus	3.66	0.76		
	Physics	3.48	0.65		

Note: Engineering n=43; Calculus n=30, Physics n=30, * refers to p<0.05

5. Conclusions

This analysis illustrates some crucial findings. First, male students tended to be more active while learning in the class, and they felt more energized and worthwhile in the learning process. Second, high GPA students tended to have more close attention in the class, having clear aims and meaningful methods during the learning process. Thirdly, students with long study time tend to have more meaningful processing and active participation in the class. Fourthly, Engineering group students did the most meaningful processing matters among three stem courses, partly because they were more experienced than other groups in the active flipped learning model.

Therefore, it concluded that some factors in the AFL model affect students' awareness of the STEM research results in student engagement, problem-solving and creative thinking skills. Faculty members involved in this research reaped many benefits and expertise in fostering active learning by communicating with students and colleagues in the AFL. Therefore, the AFL can be potentially expanded to other institutions to help all students succeed in STEM classrooms and careers, crucial to academic and social growth. Hopefully, the AFL will help increase the national STEM literacy and be applied to non-STEM majors.

Abbreviations

STEM: Science, technology, engineering, and mathematics; AFL: Active Flipped Learning; HBCU: Historical Black Colleges and University; JSU: Jackson State University; ELI: Engaged Learning Index; ANOVA: analyses of variance; SD: standard deviation; MP: meaningful processing; FA: focused attention; AP: active participation

Statements and Declarations

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm

that the order of authors listed in the manuscript has been approved by all of us. Thanks for the support from the National Science Foundation (NSF S-STEM #2029907; NSF Implementation Project #2306341). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors.

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