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# Introducing a Flipped Classroom to Engineering Students: A Case Study in Mechanics of Materials Course

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**Abstract.** Flipped classroom is basically a reversed way of learning in classroom. Lecture is brought outside classroom and available online in many forms such as video lecture and e-books. In-class time is focused more on discussions and practices such as exercises and projects. Flipped classroom was introduced to Mechanical Engineering students in Mechanics of Materials course in 2016 academic year at Maharakham University, Thailand. The course was still taught in traditional way and series of video lecture were used as additional class materials outside classroom. There were 2 groups of students that enrolled in the course in 2 different semesters. Students in 1<sup>st</sup> semester were taught in traditional way (control group) and students in 2<sup>nd</sup> semester were used flipped classroom (experiment group). Students' grades between 2 groups were compared and analyzed. Satisfaction survey of using flipped classroom was carried out and evaluated. There were 3 aspects of evaluation which were content, varieties of activity, and functions. Results showed that the course's GPA of experiment group was 1.92 which was greater than the control group of 1.68. The greatly reduction of failed students in experiment group was noticeable. The percentages of failed students of control and experiment groups were 17% and 6%. Satisfaction survey evaluation results showed that the students satisfied in high level in every aspect. The comments pointed out that flipped classroom were easy to use and promoted self-study outside classroom. Those qualities would help students develop more skills in lifelong learning and learning to learn.

## INTRODUCTION

Traditional way of teaching in the classroom is a teacher lectures while students take notes in the same room. The teacher interacts with students through instructional media and uses varieties of teaching technique to engage students to the class. Typically, teacher would give more time to lecture than discuss exercise problems. Students are expected to spend time in doing homeworks and other assignments outside classroom. At the digital age, internet opens so many doors to create innovation. An internet-connected device is considered as a powerful tool of learning. People can learn anything from anywhere at any time. A flipped classroom is a new teaching technique that moves lecture out of classrooms and lets students spend more time in discussing problems in classrooms. Students could study at their own paces and repeat it anytime when needed.

There were many studies that investigated how flipped classroom would be used or replaced the traditional classroom. In general, video lectures were provided online and assigned students to study before coming to class. Group discussions, problem solving demonstrations and other activities were taken place during in-class period. O'Flaherty and Phillips<sup>1</sup> reviewed many researches that studied the use of flipped classroom in higher education. With the use of flipped classroom method, in-class time was used for other benefits than lecturing. Findings showed that there were 2 main technologies that were used to engage students in the flipped classroom, i.e., pre-class asynchronous activities (pre-recorded lectures, interactive video, case-based presentations, and simulation) and face-to-face synchronous activities (team-based discussions, panel discussions, role-plays, and debates). DeLozier and Rhodes<sup>2</sup> also reviewed many studies about using flipped classroom. They discussed the range of approaches and focused on activities. They categorized activities to be out-of-class activities (e.g., video lectures) and in-class activities (e.g., quizzes and student discussions).

He et al.<sup>3</sup> investigated the impact of flipped classroom on student's performances and behaviors. They found that flipped classroom slightly increased final exam performance but not increased student motivation. However, students gave positive comments about benefits of using flipped classroom, including learning at one's own time and pace. These results were in good agreement with Boeve et al.<sup>4</sup>. Marks et al.<sup>5</sup> and Lai et al.<sup>6</sup> gave different results regarding to student's performances. They found that the flipped classroom helped student perform better and concluded that it encouraged students to become independent self-learners and be more confident.

The flipped classroom was used in many Engineering courses<sup>7-15</sup>. Kerr<sup>7</sup> reviewed many researches and found that the flipped classroom was used in all years of program study. Subjects were range from fundamental courses to advanced design courses. The majority of studies looked at student perceptions of their flipped classroom experience and comparisons of student performance in the flipped classroom model with the traditional face to face classroom approach. Many studies used video lectures and related resources and in-class activities to investigate student's performances<sup>9, 12-14</sup> and perceptions<sup>8-11, 13-15</sup>. Toto and Nguyen<sup>8</sup> showed that students suggested video lecture time length should be less than 30 minutes and they preferred attending face-to-face lecture. Blair et al.<sup>9</sup> compared students' performances and perceptions between 2 studied groups, traditional and flipped classrooms. They found that the flipped classroom led to slight improvement in how students perceived that course but there was no significant change in exam performance. On the other hand, results of<sup>13-14</sup> showed that flipped classroom helped students perform better. Mason et al.<sup>14</sup> found that students were struggled with the new format at the beginning but they adapted quickly and found the flipped classroom to be satisfactory and effective.

In Mechanical Engineering program at Mahasarakham University, Mechanics of Materials course is a core course that every student has to pass. Since there are many topics to be covered, only a few examples are discussed and showed how to solve step-by-step. Moreover, the size of the class is always big, sometimes students have difficulty to catch up the lecture and to ask questions. There were a lot of failed students every semester and there were many students who had to register for this course more than 1 time. In academic year of 2016, the flipped-classroom was introduced to the class as an additional resource of the course which aimed to reduce number of failed students. The course was opened to register for 2 semesters and the flipped classroom was used in the 2<sup>nd</sup> semester only. Comparison of courses' GPA between 2 studied groups was carried out. Satisfaction analysis of using the flipped classroom was reported and discussed.

## METHODOLOGY

There were 2 groups of student in this study. The control group was a group of students who registered in the 1<sup>st</sup> semester and the course was taught in traditional way. The experiment group was a group of students who registered in the 2<sup>nd</sup> semester and a flipped classroom method was introduced and used.

### Case Study: Mechanics of Materials Course

The Mechanics of Materials course was selected to be a case study for introducing flipped classroom to Engineering students. The course is about stresses and strains relationship, failure criterion, behavior of materials, and material selection. After completing the course, students are expected to be able to calculate stresses and strain, predict failure, and select proper material to meet design conditions. Typically, there were about 20-30% of students who failed in this course and the instructor has tried different ways of teaching and course evaluations to fix the problems. In academic year of 2016, this course was opened to register for 2 semesters. In the 1<sup>st</sup> semester, the course was taught in traditional way which was in-class lecture. In the 2<sup>nd</sup> semester, lectures were given both in traditional way (in-class) and online (flipped classroom). Examples and discussions were still taken place in-class for both semesters. The assessments were the same for those semesters, which were midterm, final, tests, homeworks, and attendances. The courses' GPA and number of failed students were compared and discussed.

### Flipped Classroom

Flipped classroom is a new learning method that move lecture session to outside classroom. Class materials are explained in series of clip video and available online. Exercise and problems are assigned prior to the in-class session. Those assignments are solved and discussed in the class. Other learning activities are encouraged during the class as well. With this method, students would engage more in the class activities, i.e., solving problems and discussing solutions, instead of listening to the lecture during in-class sessions.

In this research, flipped classroom was introduced to students in 2<sup>nd</sup> semester. Lectures were taped and uploaded online. Since this method has never been used in any Engineering classes at Faculty of Engineering, Mahasarakham University, the traditional way of lecturing was still in place in order to make students feel comfortable to learn and adapt to new learning style. Flipped classroom was applied to the course and used as a helping tool. Students could watch lectures before coming to the class or watch them again after the class. It was expected to help students learn in their own paces and be able to pass the course.

### Course's GPA Evaluation

The GPA of the course was calculated from students' grades. Total score of 100% was consisted of 5 parts. Midterm, final, tests, homeworks, and attendances were weighted 36%, 36%, 13%, 5%, and 10%, respectively. Grading scale was the same for control and experiment groups and normative based grading method was used. Grading criterion and score range were shown in Table 1. To calculate course's GPA, each grade has different scale from 0 to 4 as shown in Table 1. Scale of each grade was multiplied by number of students associated with the grade received. Then those totals were added up and divided by the total number of registered students. The course's GPA would represent the average performance of registered students. The maximum and the minimum values were 4 (grade A) and 0 (grade F).

TABLE 1. Grading criterion and grading scale

Grade	Score range (%)	Scale
A	> 80	4.0
B+	70 - 79	3.5
B	65 - 69	3.0
C+	60 - 64	2.5
C	50 - 59	2.0
D+	40 - 49	1.5
D	30 - 39	1.0
F	< 30	0

### Satisfaction Survey

The satisfaction survey was used to measure how the flipped classroom helped the experiment group learn. There were 3 aspects to be evaluated, i.e., content, varieties of activity, and functions. Rating scale was used and ranked from 1 to 5 in which 1 indicated the lowest level of satisfaction and 5 indicated the highest level of satisfaction. Details of each aspect were presented in Table 2.

TABLE 2. Satisfaction aspects in using flipped classroom

Aspect	Detail
Content	<ol style="list-style-type: none"> <li>Cover all course objectives</li> <li>Cover all materials as state in course description</li> <li>Proper to knowledge and capability levels of students</li> <li>Video lecture series are similar to in-class lecture series</li> </ol>
Varieties of activity	<ol style="list-style-type: none"> <li>Encourage self-learning</li> <li>Activities are related between inside and outside classrooms</li> <li>Promote the use of new technology in the classroom</li> <li>Give enough time to do activities both inside and outside classroom</li> </ol>
Functions	<ol style="list-style-type: none"> <li>Simple and easy to use</li> <li>Similar lecture time length compare to in-class lecture</li> <li>Repeatability</li> <li>No need to be in the classroom</li> <li>Help gaining more confident in doing exam</li> <li>Could replace traditional classroom</li> <li>Could reduce time in lecture session if use along with traditional classroom</li> </ol>

## RESULTS AND DISCUSSIONS

The courses' GPA and number of failed student of the control group and the experiment group were compared. The differences of those results were discussed and pointed out the significances. The satisfaction survey was carried out only for the experiment group. The results were analyzed and reported.

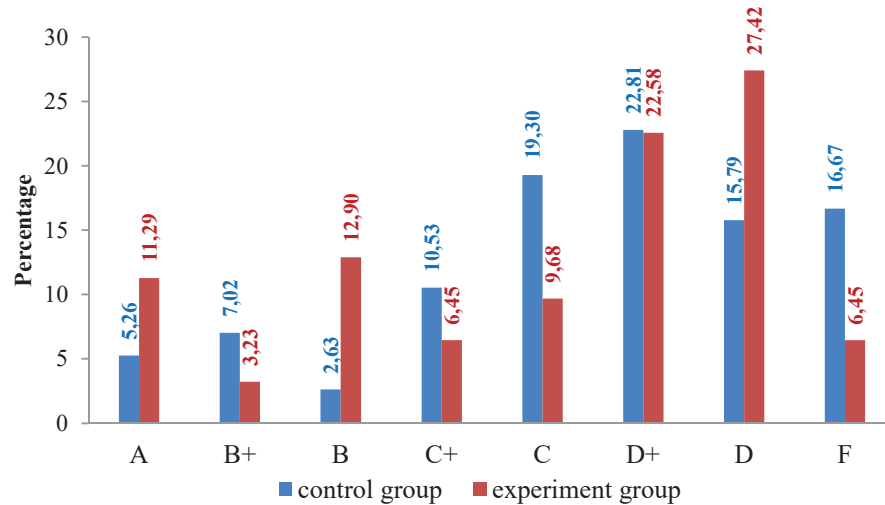
### Students' Performance

There were 114 students in control group and 62 students in experiment group. Assessments and grading system were the same for control and experiment groups. In Table 3, students' grades and courses' GPA of both studied groups were showed and compared.

**TABLE 3.** Students' grades

Grade (Scale)	Control Group	Experiment Group
A (4.0)	6	7
B+ (3.5)	8	2
B (3.0)	3	8
C+ (2.5)	12	4
C (2.0)	22	6
D+ (1.5)	26	14
D (1.0)	18	17
F (0)	19	4
Total	114	62
<b>Course's GPA</b>	<b>1.68</b>	<b>1.92</b>

Results showed that the course's GPA of the experiment group was higher than that of the control group. Those grading results were brought to compare individually in order to see the differences in Fig.1.



**FIGURE 1.** Comparison of students' grades between control and experiment groups

Results showed that the experiment group had lower number of failed students comparing to the control group. It was assumed that students' grade would move from F to D or other grades after applying flipped classroom to the course. With flipped classroom, students had a helping tool to use in studying the class materials. It could point out that the flipped classroom was more useful to weak students. They could improve their performance by studying with their paces outside classroom. They could prepare themselves and be ready before coming to the class. They could also re-study over and over after the class.

## Satisfaction Survey Evaluation

The satisfaction survey was done by the experiment group after the final exam. There were 56 out of 62 (90.32%) registered students who submitted the survey. There were 3 parts of survey; general information, satisfaction survey, and comments and suggestions.

**TABLE 4.** General information summary

Information	Summary
Gender	Male (71%)
	Female (29%)
Own computer	Yes (89%)
	No (11%)
Own internet-connected smart phone	Use data package (16%)
	Use WIFI (23%)
	Use both (61%)
Register the course	1 <sup>st</sup> time (70%)
	2 <sup>nd</sup> time (12%)
	3 <sup>rd</sup> time or more (18%)

Results showed that students could access the video lecture from anywhere and at anytime via their phones or computers. Only 70% of the class that registered for the 1<sup>st</sup> time and there were 30% of the class that this semester was their 2<sup>nd</sup> time or more. There are 2 reasons for registering the course more than 1 time; failed or withdraw.

**TABLE 5.** Satisfaction analysis

Aspect	Detail	Score
Content (Average <b>4.25</b> )	1. Cover all course objectives	4.25
	2. Cover all materials as state in course description	4.43
	3. Proper to knowledge and capability levels of students	4.05
	4. Video lecture series are similar to in-class lecture series	4.29
Varieties of activity (Average <b>4.19</b> )	1. Encourage self-learning	4.34
	2. Activities are related between inside and outside classroom	4.32
	3. Promote the use of new technology in the classroom	4.07
	4. Give enough time to do activities	4.04
Functions (Average <b>4.14</b> )	1. Simple and easy to use	4.04
	5. Similar lecture time compare to in-class	4.13
	6. Repeatability	4.41
	7. No need to be in the classroom	4.16
	8. Help gaining more confident in doing exam	3.98
	9. Could replace traditional classroom	3.95
	10. Could reduce lecture time if use with traditional classroom	4.29

In content aspect, “Cover all materials as state in course description” received the highest score of 4.43 while “Proper to knowledge and capability levels of students” had the lowest score of 4.05. In varieties of activity aspect, “Encourage self-learning” had the highest score of 4.34 and “Give enough time to do activities” had the lowest score of 4.04. In functions aspect, “Repeatability” had the highest score of 4.41 while “Could replace traditional classroom” received the lowest score of 3.95. Average scores showed that students satisfied with content the most and functions the least. The average scores of all aspects were above 4.00 which meant that students satisfied with using flipped classroom at high level.

Comments and suggestions were shown in Table 6. Students felt that the flipped classroom was easy to use and could be used anytime and anywhere. The strongest feature was students could study from the video lecture again and again until they understand the class materials. They could study with their own pace. Survey results were similar to others’ studies [3, 10, 13, 15-17]. It was obvious that the flipped classroom affected student’s performance and promoted self-study outside classroom.

**TABLE 6.** Comments and suggestions

<b>Subject</b>	<b>Detail</b>
Content	<ul style="list-style-type: none"> <li>• More examples and exercises</li> <li>• Should focus more on examples</li> <li>• Concise content</li> <li>• Could watch reruns after class</li> </ul>
Varieties of activity	<ul style="list-style-type: none"> <li>• Should use game in the class</li> <li>• Let students show how to solve problem to others in the class</li> <li>• Video series help students study class materials and get better understandings</li> </ul>
Functions	<ul style="list-style-type: none"> <li>• Easy to use</li> <li>• Could watch reruns over and over</li> <li>• Good way to use technology for education</li> </ul>
Strength	<ul style="list-style-type: none"> <li>• Could study from video lecture anytime</li> <li>• Could pause, rewind, and restart video lecture at anytime</li> <li>• Could reduce lecture time in the classroom</li> <li>• New experience</li> <li>• Good technique</li> </ul>
Weakness	<ul style="list-style-type: none"> <li>• Improve quality of video series</li> <li>• Instructor speaks too fast</li> <li>• Bigger handwriting</li> <li>• Should show step-by-step of solving problems</li> </ul>

## CONCLUSIONS

The flipped classroom was introduced to Engineering students of Mechanics of Materials course at Faculty of Engineering, Mahasarakham University, Maha Sarakham, Thailand. Video lecture series were uploaded to the internet and assigned as additional resource to students. There were 2 studied groups; control group and experiment group. The course's GPAs were compared between 2 groups and numbers of failed students were monitored. Results showed that students in experiment group obtained better course's GPA. The course's GPA of experiment group and the control group were 1.92 and 1.68. The greatly reduction of number of failed students in experiment groups was noticeable. The percentages of failed students of control and experiment groups were about 17% and 6%. It was assumed that the flipped classroom would help students study and it resulted in getting better grade. Satisfaction survey was carried out in 3 aspects; content, varieties of activity, and functions. Results of satisfaction survey evaluation showed that the average scores of all aspects were above 4.00 which meant that students satisfied in high level in every aspect. The comments pointed out that flipped classroom were easy to use and promoted self-study outside classroom. There were rooms for improvement that students suggested such as improving quality of video and providing more examples.

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