Enhancing Students' Achievement and Investigating Students' Satisfaction in Learning Mathematics By using a Flipped Classroom

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Abstract: The objectives of this classroom action research were to enhance students' mathematical achievement and to survey students' satisfaction with learning by using a flipped classroom. The participants were 32 grade 11 students who enrolled in the second semester of the academic year 2019 at a secondary school in Bangkok, Thailand. The topic used in this study was Vectors in Three Dimensions. The instruments were 7 lesson plans using flipped classrooms and a satisfaction survey. Before class, students studied online learning through video clips, handouts, homework, and quizzes. During class, students discussed the contents that they had studied from home, solved harder problems, and got individual help from the teacher. Learning lasted 14 periods with 50 minutes in each period. There were three cycles of action plans. Data were collected from pretest, posttest, and satisfaction surveys. Data were analyzed by using the Effectiveness Index. The results showed that: 1) the Effectiveness Index of the flipped classroom was 0.80 which revealed that students' achievement increased by 80 percent from the beginning; and 2) students' satisfaction in three categories: students' understanding category, learning activities category, and learning atmosphere category by using flipped classroom were at least satisfied, satisfied, and very satisfied, respectively.

1. Introduction

Mathematics is a school subject that stimulates student's thinking. It enhances reasoning, creative thinking, planning, deciding, and solving problems. Mathematics is a tool for studying science and technology. Therefore, mathematics is useful for living and developing the quality of life (Academic and Educational Standards Affairs, 2005).

The Basic Education Core Curriculum implemented in B.E. 2551 (A.D. 2008) aimed to enable all children and youths to continuously learn mathematics with their potential. This aim was applied from Grade 1 to Grade 12 while the contents extended wider as students moved up to higher levels. The contents comprised six strands: Strand 1 Number and Operation, Strand 2 Measurement, Strand 3 Geometry, Strand 4 Algebra, Strand 5 Data Analysis and Probability, and Strand 6 Mathematical skills and processes. Today, The Basic Education Core Curriculum implemented in B.E. 2551 (Revision B.E. 2560) was developed by the Institute for the Promotion of Teaching Science and Technology (IPST) delegated authority from the Ministry of Education which prescribed the contents in three strands: Strand 1 Number and Algebra, Strand 2 Measurement and Geometry, and Strand 3 Statistics and Probability [1]. Schools can make their own decision from the National Curriculum to produce a school-based curriculum in which schools can choose contents and sequence to teach on their own.

For Thailand, the educational reform has introduced decentralization and delegated authority to schools as a school-based management system. Schools are supposed to develop a school-based

curriculum based on learning outcomes and indicators illustrated in the Basic Education Core Curriculum in the Mathematics Area. IPST has promoted a new method of teaching science, technology, engineering, and mathematics to foster students for standards of learning outcomes, indicators, and 21st-century skills by emphasizing knowledge and skills that are suitable to real life and careers. Moreover, the Institute for the Promotion of Teaching Science and Technology (IPST) developed an additional mathematics curriculum for high school mathematics to provide mathematical knowledge and skills to students studying science programs such as complex numbers, matrices, vectors in three dimensions, analytic geometry, trigonometric functions, and basic calculus.

By the reform and by the government setting of specialized IPST, it should be expected that student's achievement in science and mathematics was at a satisfactory level. However, the average mathematics O-NET (Ordinary National Education Test) scores in Grade 12 were 24.88%, 24.53%, and 37.50% in 2016, 2017, and 2018 respectively [2]. The low average scores clearly indicated that high school students in Thailand need improvement and higher quality of mathematics instruction. Students should have an opportunity to increase their mathematics scores at both national and international levels. In order to achieve this, mathematics instruction needs reform by changing from the traditional approach to a new approach.

The same situation of unsatisfactory student achievement happened in the school that the researcher had worked with. From discussion with teachers in the mathematics department, it could be concluded that the causes were: 1) limited class time, 2) school activities and events reduce class time and 3) insufficient time allocated to the discussion about important mathematical concepts and engaging in problem-solving.

2. Flipped Classroom

Nowadays, technology has made great advances. Online activities such as online conferences, online marketing, Google Classroom, and online learning are rapidly growing. Two American secondary school teachers, Bergmann J. and Sams A. [3] used the advantages of online learning to help their students who had to leave the classes during sports competition events. This practice gradually developed into a new teaching and learning method called flipped classroom. The method was adopted by many practitioners and institutions in various fields such as mathematics, science, engineering, and languages [4], [5]. The results from applying flipped classrooms were positive to students' achievement [6].

The flipped classroom can extend class time. In online learning, students can replay video clips as many times as they want and work on some parts of the lessons in advance. So, it allows more time for class discussion which can lead to a deeper understanding of the contents and encourage students to engage in learning. Therefore, many teachers, in recent years, have adopted flipped classrooms and expanded class time to develop students' understanding. Students have more time to think critically about mathematical concepts and ideas through collaboration, justifying, and explaining their processes while the teacher facilitates and guides them [7].

In teaching mathematics, the researcher has been assigned to teach vectors in three dimensions for Grade 11. The idea of vectors is important in applied mathematics because many quantities used in physics such as force, motion, the flow of fluid electric current, light, and sound are concerned with vectors. The researcher studied various textbooks to be used as a basis for the instruction of vectors in three dimensions. Those textbooks were Vectors and Related Topics in Schaum's Outline Series in Vector Analysis Second Edition [8], [9], Cambridge Additional Mathematics [10], New Additional Mathematics [11], and Calculus textbook [12]. Moreover, the

researcher has studied textbooks about the teaching of vectors such as Teaching of Vectors [13] and Handbook for Grade 11 Mathematics Teachers developed by IPST [1].

In addition, the flipped classroom was a new approach to learning and teaching methods for students. By this method, the participants had to adjust themselves to the new method. Before class time, they must control themselves by watching online video clips, reading math handouts, and doing worksheets and quizzes. During class time, key concepts would be revealed, and students studied and discussed more contents, examples, problem-solving, and knowledge extension. These activities needed time and concentration. It might cause tension to them. So, the researcher wanted to know whether they were satisfied with this method.

From the above problems and the benefits of flipped classrooms as mentioned, this study aimed to use flipped classrooms to enhance mathematics achievement and to survey students' satisfaction in learning mathematics.

3. Conceptual Framework

Action research is conducted by the researcher to solve a specific problem(s) in a specified area or by practitioners to improve their practices. Classroom action research is also conducted by teachers as researchers to solve the problem(s) in the classroom or to improve their own teaching. It sometimes creates ideas for grounded theory which are bases for the main theory. Actually, in action research, the researcher neither identifies the sample nor the population because the researcher aims to solve problems in a specific area and also does not aim to generalize the research results. In teaching mathematics, the problems fixed with students' low achievement are related to understanding, reasoning, proving, and problem-solving. Now, teachers can extend class time for more discussion and problem-solving by using the internet which gradually developed to be a new method of teaching and learning called a flipped classroom. The flipped classroom is composed of three steps: 1) before class, 2) during class, and 3) extending skills or knowledge. Before class teacher assigns students to study basic concepts online through video clips, study handouts, and quizzes in advance. During class time, the teacher reviews important concepts, discusses more examples, and problem-solving. From various studies and ideas from flipped classrooms, this classroom action research aimed to enhance students' achievement by using flipped classrooms and to investigate students' satisfaction in learning mathematics by using flipped classrooms. The researcher adopted the action research model presented by Kemmis and McTaggart [14] which involves spiral and recursive steps of: 1) planning a change, 2) acting and observing the processes, 3) reflecting on these processes, and 4) revising the plan.

4. Research Methodology

This research took the model of classroom action research with three cycles to enhance students' mathematical achievement and to investigate students' satisfaction in learning mathematics by using flipped classrooms. Participants in this research were 32 Grade 11 students studying in the second semester, of the academic year 2019 at a secondary school in Bangkok, Thailand.

5. Research Instruments

The instruments used in this study consisted of lesson plans, achievement tests, satisfaction surveys, and teacher's reflections.

(1) Lesson plans: There were 7 lesson plans on vectors in two dimensions and three dimensions integrated with the flipped classroom. The contents were 1) Introduction of geometric

vectors, 2) Coordinate systems in two dimensions and three dimensions, 3) Vectors in two dimensions and three dimensions, 4) Addition, subtraction, scalar multiplication of vectors, and their properties, 5) Unit vectors and direction cosines, 6) Dot products, cross products, and their properties, and 7) Application and problem-solving. At the end of periods 3, 5, and 7, the researcher reflected on teaching results for improvement in the following periods. All lesson plans were commented on by an expert. Then, they were revised according to the comment.

(2) Achievement test: The researcher developed the mathematical achievement test. It was composed of 10 multiple-choice items for 10 points and 3 written tests for 10 points. This test covered all the topics used in this study. The Index of Item Objective Congruence (IOC) was used to measure the congruence between learning objectives and the test items. The IOC of this test was measured by three experts. For this achievement test, the value of IOC in multiple-choice items was 0.97, but IOC in written tests was 0.89.

From 6 cognitive domains presented by Anderson and Krathwohl [15] who presented the revised Bloom's taxonomy, the researcher considered testing students only 4 cognitive domains (remember, understand, application, and analysis) presented by Anderson and Krathwohl.

(3) Satisfaction survey: The rating scale was a 5-point Likert scale to survey student satisfaction in learning using a flipped classroom. There were 20 items that can be categorized into three (3) groups: students' understanding, learning activities, and learning atmosphere. This survey had Cronbach's internal confidence of 0.89. The questions used in this research were shown as follows:

Category 1: Students' understanding

Item 1: I understand the content more because I do it alone, not only listen to teachers.
Item 2: I can remember the content longer.
Item 3: I can understand the content by myself.
Item 4: I can apply this learning process to other subjects.
Item 5: I'm proud of myself when I can understand the hard content.
Item 6: I can decide by using reasoning.
Item 7: I can understand my friends more.
Item 8: I can work with others.
Item 9: I think this learning process makes me learn more than only listening to teachers in the classroom.

Category 2: Learning activities

Item10: Learning management suits the content.
Item11: Learning management helps me to exchange knowledge with others in the classroom.
Item12: Learning management helps my thinking and decision.
Item13: Learning management makes me brave when questioning or answering.
Item14: Learning management helps me to comment in the classroom.
Item15: Learning management makes me understand the content more.
Item16: Learning management helps me and my friends learn together.

Category 3: Learning Atmosphere

Item17: The learning atmosphere makes me participate in learning management.
Item18: The learning atmosphere makes me responsible for myself and others.
Item19: The learning atmosphere makes me studious.
Item20: The learning atmosphere makes it easier to talk and to ask questions with the teacher.

The data were collected from the following sources: pretest, posttest, and satisfaction survey and analyzed by using the effectiveness index: mean, mode, and standard deviations.

6. Research Results

Results on the enhancement of achievement

Table 1: Students' scores from pretest, posttest, and Effectiveness index.

Student's score from the pretest		Student's score from the posttest		Effectiveness Index
Mean	S.D.	Mean	S.D.	
8.88	2.47	21	1.48	0.8

From Table 1, there was a large gap between the mean of the pretest and that of the posttest. It showed the enhancement of students' achievement. On the other hand, the standard deviation of posttest scores was smaller than that of the pretest. It showed the narrowed distribution of the posttest scores. The effectiveness index was 0.8 which is higher than the accepted effectiveness index (0.5). The effectiveness index of 0.8 meant that the student's achievement was improved by 0.8 compared to that at the beginning. It could be concluded that using flipped classrooms could be able to enhance students' achievement.

Results from the satisfaction survey

Table 2 Results from students' satisfaction survey

Question No.	**Number of Students**					**Satisfaction level**
	Very Satisfied	**Satisfied**	**Neutral**	**Dissatisfied**	**Very Dissatisfied**	
Category 1: Students' understanding						
1	7	14	11	0	0	Satisfied
2	5	19	8	0	0	Satisfied
3	13	19	0	0	0	Satisfied
4	18	14	0	0	0	Satisfied
5	28	4	0	0	0	Satisfied
6	9	18	5	0	0	Satisfied
7	2	18	12	0	0	Satisfied
8	3	18	11	0	0	Satisfied
9	21	11	0	0	0	Very Satisfied
Summary of this category						Satisfied

Question No.	Number of Students					Satisfaction level
	Very Satisfied	Satisfied	Neutral	Dissatisfied	Very Dissatisfied	
Category 2: Learning Activities						
10	2	22	8	0	0	Satisfied
11	5	18	9	0	0	Satisfied
12	13	19	0	0	0	Satisfied
13	11	21	0	0	0	Satisfied
14	17	14	1	0	0	Very Satisfied
15	6	16	10	0	0	Satisfied
16	6	21	5	0	0	Satisfied
Summary of this category						Satisfied
Category 3: Learning Atmosphere						
17	24	8	0	0	0	Very Satisfied
18	9	16	7	0	0	Satisfied
19	17	10	5	0	0	Very Satisfied
20	12	14	6	0	0	Satisfied
Summary of this category						At least Satisfied
Summary of all categories						Satisfied

From Table 2, the results showed that students were satisfied with the understanding category and learning activity category while they were at least satisfied with the learning atmosphere category. In summary, students were satisfied with all categories of learning by using a flipped classroom**.**

Additional results from students' Internet access

The number of online devices and the time used by students for internet access. Before the experiment, the researcher investigated online devices used by students and the time used for internet access. The results are shown in Table 3 and Figure 1 below.

Table 3: The number of students who had online devices

Online devices	Number of students	
	Have	Don't have
Cell phone	31	1
Computer	29	3
Tablet	15	17

Table 3 revealed that the number of students who had a cell phone, a computer, and a tablet were 31, 29, and 15 respectively. One student didn't have a cell phone but he had a computer at home, so every student could access the online learning.

The time used by students for internet access per day is shown in Figure 1 below.

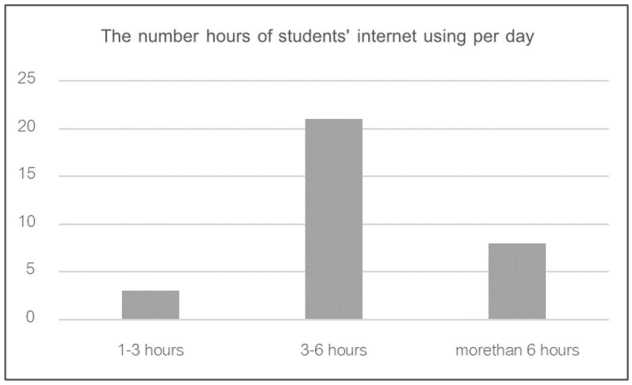

Figure 1: Number of Hours Students used the Internet per Day.

Figure 1: shows that students spent at least 1-3 hours on internet access. Most students (21 students) accessed 3-6 hours a day. So, each student was accustomed to internet access.

7. Conclusion

For students' achievement, the effectiveness index from this study was 0.80 which was higher than that of the accepted index 0.50. This indicated that students' achievement was enhanced after using flipped classrooms. The index of 0.80 meant that students' achievement was enhanced by 0.80 compared to that from the beginning of the pretest. For students' satisfaction, the results revealed that by using a flipped classroom, students were satisfied with math learning in all three categories: students' understanding, learning activities, and learning atmosphere.

8. Discussions

Students' achievement was enhanced because of using flipped classrooms. This enhancement was the results of the following: 1) class time was extended from a before-class study such as watching video clips online, studying handouts, doing homework, and quizzes; 2) more class time for discussion and problem solving from worksheets; and 3) extending new skill/knowledge such as practice harder problems and more application. Reflection in each cycle helped the researcher to improve the teaching process and to talk to students who didn't do quizzes or didn't understand the contents. In addition, line groups supported students' learning. Participants could discuss problems, and solution processes and communicate through it. All of those activities encourage students to learn and to spend more time learning.

The enhancement was consistent with many studies. Karadag and Keskin [16] studied the effects of the flipped learning approach which revealed that it positively affected students' academic achievement and attitudes toward mathematics. Furthermore, for some components of flipped classrooms in mathematics, many studies showed that they could enhance students' mathematical achievement. Khairiree. K [17] found that students who studied in using flipped classroom were more

engaged than those in a traditional classroom. The flipped classroom helped students manage time in doing classroom activities more efficiently and improved their achievement. Unakorn and Klongkratoke [18] stated that flipped classrooms engaged students in self-learning and increased opportunities for students to achieve learning objectives of learning statistics topics in Grade 11. Poomorn, A. [19] also stated that for students' satisfaction with flipped classroom instruction, most of the students strongly agreed that they communicated with the teacher more often. They also agreed that they had greater opportunities to communicate with other students. They could apply out-of-class experiences with the lesson and could learn more from practical applications.

One crucial point to consider was about preparing teaching and learning materials such as handouts and quizzes. The researcher applied the practices and recommendations from experts and professional organizations for the benefit of students' understanding, computational skills, reasoning, and problem solving. The recommendations were about: 1) content selection and sequencing, and 2) teaching vector concepts, important points to be careful of, and some pitfalls to be avoided [13]. The following were some points integrated with teaching: 1) visualization of vectors, vector operations, negative and unit vectors by drawing directed line segments to represent them; 2) reasoning such as why $\frac{\vec{u}}{|\vec{u}|}$ is a unit vector in the direction of $\vec{u}$ or why $\left(\vec{u}\cdot\vec{v}\right)\cdot\vec{w}$ is meaningless; 3) computation in vector operations; 4) prove some theorems left for students; 5) prove harder problems; 6) applications in physics for dot product (the work done) and cross product (the torque); and 7) extended knowledge such as equations of spheres and lines in space. For students' satisfaction with flipped classrooms, the results showed that most students were satisfied with learning. These results were consistent with the studies of [20], [21], and [22].

From limitations in classroom action research, normally there will be no generalization of the results. Applying the practices must be done with great care. This study was concluded in a highly economical area. Students and parents were ready for high educational competition. Achievement enhanced and students' satisfaction resulting from applying flipped classrooms in different areas may or may not occurred.

9. Recommendations

Recommendations for teachers

Until now, teachers and students experienced online learning, so it was a good time to use flipped classrooms by extending from online learning. There were two parts to be considered, the teachers' part and the students' part. For the teacher's part, using flipped classrooms needed much time and effort in preparing lesson plans, video clips, handouts, homework, quizzes, learning activities, and problems. Part of students, needed class time, concentration, and self-study ability by watching video clips, studying handouts, and doing homework and quizzes. Considering both parts, teachers at the beginning of using flipped classrooms might try just one-fourth or one-half of a course and look back to evaluate both teachers' and students' parts and improve them. Then, teachers could develop and expand the whole course.

Recommendations for future research

Further repetitive research about using flipped classrooms was still needed to fulfill various points that were not answered in this study. Some of them were the following:

1) Effectiveness of flipped classrooms to high school students at normal or average ability.

Samples in this study were in leading high schools and were in high economic areas. They showed above-average learning abilities. What was the effectiveness of the average student?

2) Effectiveness of flipped classroom to lower-secondary school students (Grade 7 – Grade 9 students).

Many research and practices were performed with high-school or undergraduate students but rarely with lower-secondary students.

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