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THE EFFECTIVENESS OF FLIPPED CLASSROOM STRATEGY ON SELF-DIRECTED LEARNING AMONG UNDERGRADUATE MATHEMATICS STUDENTS

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ABSTRACT

The purpose of this study is to measure the effectiveness of the flipped classroom strategy for self-directed learning among undergraduate students in Mathematics courses. A forty-six (46) students of Actuarial Mathematics course from one university were participated to measure their academic performance during-the-class. A six number of students were randomly selected for a survey with open-ended questions via google form to explore their experiences using this approach. For this study, there was a pre-experimental research design with a group of students in one class. There were two ways of teaching techniques to make a comparison in this study. First, the undergraduate students were taught using a traditional teaching method to provide a baseline, where the instructor showed and explained all the steps to solve mathematical problems, and the understanding of the students will be assessed by conducting a pre-assessment quiz. Second, the students were taught using flipped classroom strategy, where the students

were given the solutions including all the steps to solve mathematical problems without guidance or explanation from the instructor, then the students were given similar mathematical problems to be solved by themselves by referring to the example given, then the understandings of students will be assessed by conducting a post-assessment quiz. Third, reimplementing the flipped classroom strategy by conducting the third quiz. Finally, the effectiveness of the flipped classroom strategy is measured by comparing the results from all assessment performance. Also, teacher reflection and students' feedback were gathered to assess self-directed learning effectiveness. The result showed that the post-assessment performance from a flipped classroom strategy was significantly higher than the pre-assessment performance from traditional teaching methods. The lowest score of the pre-assessment using the traditional teaching method was less than one (1) score. On the contrary, the lowest score of the post-assessment performance using the flipped classroom strategy was five (5) scores. Moreover, the majority of the respondents achieved eight to ten scores. From the result, it was found that both teaching methodologies produced different results in students' performance for this study. Besides, the students also provided good feedback from the strategy based on the result of the interview: (a) fun and interesting, (b) curiosity, (c) providing students' autonomy, (d) initiating communication, (e) integrating the use of technology in learning mathematics, (f) preparing for the final exam. Overall, the students found that the flipped classroom strategy is potentially enhancing student's engagement and performance in mathematics education. The findings have implications for the instructors to implement the flipped classroom strategy for mathematics subjects to acquire better performance among undergraduate students. The flipped classroom requires self-directed learning among students that can be more interesting learning experiences among the students.

Keywords: *flipped classroom, flipped learning, and self-directed learning*

INTRODUCTION

The traditional teaching method is a method that teachers transfer knowledge to students through oral language, telling method, and interpret method. Students are familiar with this method and are generally comfortable in the traditional classroom. Since the

traditional method has been used starting from when they were in kindergarten. The method has been practiced by many people and it is a method that yields positive results. However, it certainly is not the best approach for everyone, both in terms of learning style and flexibility, as well as the course that involves problem-solving skills and techniques. For instance, mathematics is involved with problem-solving, analytical thinking, quantitative reasoning that requires the students to understand the concepts and memorize many formulas and steps in solving the mathematical problems. Therefore, an alternative teaching practice to assist the students in mastering the skills is required for learning mathematics.

Previous research found that students within a flipped classroom still performed as well as their peers in a traditional classroom on the final exam, representing conceptual understanding, and the students in the flipped classroom not only did still learn the necessary mathematical skills from their linear algebra course work but also enjoyed the classes more (Love, Hodge, Grandgenett & Swift, 2014). Integrating the self-regulated strategy into flipped learning can improve students' self-efficacy as well as their strategies of planning and using study time, and hence they can learn effectively and have better learning achievements (Lai & Hwang, 2016). A flipped classroom is an instructional strategy and a type of blended learning that reverses the traditional learning environment by delivering instructional content, often online, outside of the classroom. It moves activities, including those that may have traditionally been considered homework, into the classroom (Shen, 2019).

According to past studies and feedback from e-Cevas, student self-directed learning is very low among undergraduate students. It found that only a few studies on self-directed learning among undergraduate in mathematics courses rather than post-graduate students. Mathematics students need a new approach since the learning involves many concepts and formulas, and long steps of calculation that require mathematics students' maturity; their interest, curiosity, and motivation in learning. Moreover, a wealth of resources which are available online nowadays (Learning Management System-UUM OL, tutorial video, databases, etc.) should be also considered in developing the new technique. According to Adult Learning Theory, students are the focus and the teacher is a guide whereas students take responsibility for learning (Kenner & Weinerman, 2014).

This study introduces the flipped classroom technique to undergraduate mathematics students. This method may assist the students in effectively memorising the steps and formulas since math tends to encourage self-directed learning skills. The research objectives are:

1. To examine the self-directed learning experience among mathematics students.
2. To investigate the effectiveness of the flipped classroom strategy among undergraduate students.
3. To explore student-teacher experiences using the flipped classroom strategy by qualitative approach (open-ended survey).

LITERATURE REVIEW

This study adapted the flipped classroom model which focused on self-directed learning methods. It was found that implementation of this method encouraged more students to involve and participate in the class (Mohamad Yahya Abdullah, 2019) as well as students' learning attitudes, motivation, and self-evaluation (Prevalla & Uzunboylu, 2019). Besides, the study also encouraged teachers to apply modern technologies in their teaching strategies. At the same time, many students agreed that the combination of the flipped classroom and problem-based learning teaching approach could help to improve their performance (Hu, 2019). Furthermore, students demonstrated a positive feeling towards the flipped classroom approach (Amy, O'Reilly, Ng & Zhang, 2019) where both teachers and students saw some benefits in terms of improving students' learning experience (Prevalla & Uzunboylu, 2019).

On a similar note, Amy S H, O'Reilly, Johan Ng & Zhan (2019) also suggested that this approach has considerable potential to fulfill basic cognitive needs among university students in the field of education. Undeniably, this could be a better option over the traditional lecture-based classroom. Students who experience a flipped-classroom strategy are found to be more satisfied because it promotes self-directed learning, a deeper understanding of the taught contents, autonomous working, and time management; thus, increase the classroom session effectiveness (Urios, Rangel, Córcoles, Tomás & Salvador, 2017). Nonetheless, students also experienced a burden of workload (Hu, 2019). Students claimed that they need to put more

effort to fulfil the assessment of self-directed learning methods (Urios et al., 2017). Another concern raised is the declining access to self-study materials before face-to-face interactions in classes among students (Shen, 2019).

Past studies also showed that students' study behaviour in the flipped course did not appear to be very different from that of students in a regular course. Furthermore, study behaviour did not appear strongly related to student performance in both flipped and the regular course. Exploration of student references to their learning regulation in the course evaluations showed that some students experienced the flipped course design as intended to support their learning process. Other students, however, demonstrated resistance to changing their study behaviour even though changing study behaviour is expected to benefit from the flipped classroom (Boevé, 2017).

Adult Learning Theory

This study adapted the Adult Learning Theory developed by Knowles in 1968. This theory introduced andragogy that can be defined as “the art and science of helping adults learn” (Kaufman, 2003). Kaufman (2003) further explained that andragogy is how adults learn and their attitude towards and motivation for learning. Considering college and university students to be the adults that most of them are, or soon will be (Halx, 2010), five assumptions about adult learning based on Adult Learning Theory by Kaufman (2003): (a) adults are independent and self-directing, (b) they have accumulated a great deal of experience, which is a rich resource for learning, (c) they value learning that integrates with the demands of their everyday life, (d) they are more interested in immediate, problem-centered approaches than in subject-centered ones, and (e) they are more motivated to learn by internal drives than by external ones.

MATERIALS AND METHODS

Participants

A class of forty-six actuarial mathematics students majoring in Business Mathematics were participating for the study and they

would be assessed on their mathematical performance. Also, six of them would be randomly selected for a survey with an open-ended interview via google form.

METHODOLOGY

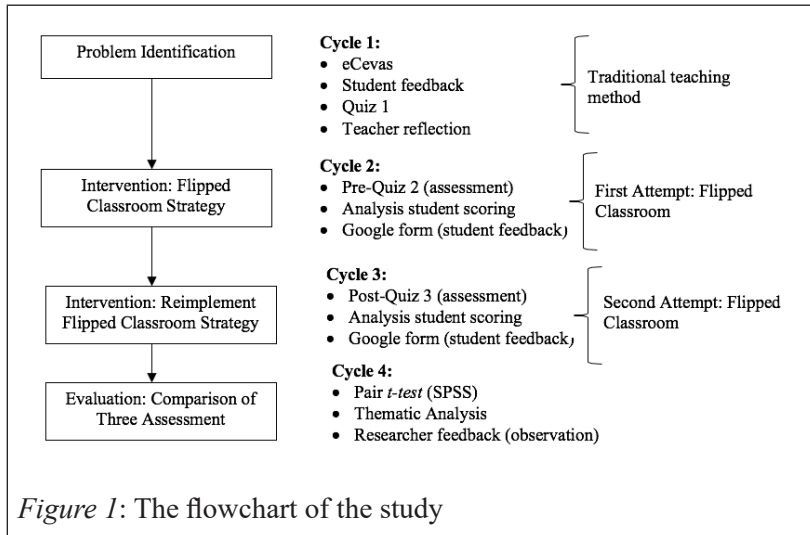
Overall, there are three cycles involved in this study which are problem identification, intervention, and evaluation. In the first cycle, researchers need to identify the problem based on student achievement on Quiz 1 as a pre-assessment quiz which uses a traditional teaching method, where the instructor showed and explained all the steps to solve mathematical problems in the class. After the lecture, the understanding of the students will be assessed by conducting a pre-assessment quiz. The quiz questions were uploaded through the Online Learning Portal.

In the second cycle, this study focuses on the implementation of flipped classrooms as an intervention to enhance self-directed learning among the respondents. The students were taught using a flipped classroom strategy, where the students were given the solutions including all the steps to solve mathematical problems without guidance or explanation from the instructor. They were given some time to review the solutions. Later, the students were given similar mathematical problems to be solved by themselves by referring to the example given. To evaluate the understanding of students on the solutions, they will be assessed by conducting Quiz 2 as an assessment quiz. In this stage, the researcher also collected the students' feedback on the flipped classroom technique as a guideline to enhance the effectiveness of the next stage of research.

In the third cycle, this study will reimplement the flipped classroom strategy again with some improvement by considering student feedback on Quiz 2 and student feedback at cycle two before. At the end of this stage, the respondent will be given Quiz 3 as a post-assessment quiz.

At the final cycle, this stage was considered as an evaluation cycle. The effectiveness of the flipped classroom is measured by comparing the

results from pre-assessment, assessment, and post-assessment quizzes. At the same time, researcher feedback and student feedback also were analysed by using thematic analysis to evaluate the effectiveness of flipped classrooms. Figure 1 below represents the flow chart of the research activities in sequence.



1. Cycle 1: Problem Identification: Traditional Teaching Method.

- a. Quiz 1 pre-assessment quiz is conducted, in which students are assessed on what they have learned in a prior learning session. A set of questions are constructed meticulously based on the course learning outcome of a particular chapter in a mathematics subject.
- b. Lecturer reflection on students' feedback (e-Cevas) and Rubric on students' self- learning

Based on the lecturer's observation in the classroom, he/she will reflect his/her teaching methods and also student performance in class. Lecturers also will reflect on students' comments on e-Cevas to analyse the problems. The e-Cevas (evaluation of academic course) is an available system on students' portal which will be used by the university to collect the students' feedback about one learning for every semester. Moreover, lecturers also

- identify the level of self-directed learning among the students by using a specific rubric.
 - c. Identify the new teaching technique to enhance student achievement. Once the score of the quiz for each student is obtained, a histogram is plotted to visualize the distribution of each student score for every quiz.
2. Cycle 2: Intervention: Flipped Classroom Strategy.
- a. Pre-Assessment Quiz (Quiz 2).

In this stage, a flipped classroom will be introduced. Students will be instructed to the following tasks:

 - i. Firstly, teaching materials (e.g. lecture note, online tutorial video) are uploaded in OL before the lecture
 - ii. In class, a set of questions with solutions (examples) will be provided for each of the students.
 - iii. They will be given time to study/understand the questions and the solutions provided.
 - iv. After the time is finished, the set of questions with solutions are taken from them.
 - v. Then, a set of new questions with similar problems are given to them. They need to solve the new questions given based on their understanding from the set of examples given before.
 - vi. Finally, the lecturer will facilitate and correct the students on how to solve the example problems and new problems.

Similar to Quiz 1, a set of questions are identified and prepared based on the course learning outcome for a selected learning session (scheme of work). However, instead of performing prior learning, students are given a set of questions with answers that are different compared to the one they are going to answer in Quiz 2.

- b. Analyze the student feedback after using the flipped classroom technique.

The student feedback will be used to measure the effectiveness and learning experience provided by the flipped classroom technique towards students.

3. Cycle 3: Intervention: Reimplement of Flipped Classroom Technique
 - a. Post-Assessment Quiz (Quiz 3).

In this stage, a similar flipped classroom strategy is constructed such as in 2 (a).

- b. Analyse the student feedback after using a flipped classroom.

student feedback will be used to measure the effectiveness and learning experience. Supposedly, it must be similar and better compared to the result obtained in Cycle 2.

4. Cycle 4: Evaluation

- a. Pair *t*-test Analysis

The comparison of the results between Quiz 1 (using traditional teaching method) and 3 (using flipped classroom) was made by using the paired *t*-test analysis. If the mean score for flipped classroom technique is higher compared to traditional teaching methods, and it is significant, then, the implementation of the flipped classroom is considered as an effective method to enhance self-directed learning among mathematics students in higher education.

- b. Thematic Analysis

For this study, the thematic analysis was conducted to analyse: (a) the students' feedback on the effectiveness of using the flipped classroom, (b) the feedback from all the researchers based on the observation in the class when implementing the flipped classroom strategy. The results were possible themes derived from the written feedback from the students about the class. The final themes will be finalized upon the researchers' discussion.

Data Analysis (A Triangulation Method)

Since this is a qualitative study, the researchers employed a triangulation method. In general, this method has three components which include teacher's reflection and researchers' feedback, quizzes (assessments

1, 2, and 3), and students' feedback to validate the findings. All these three components were evidence of several methods used to study the phenomenon.

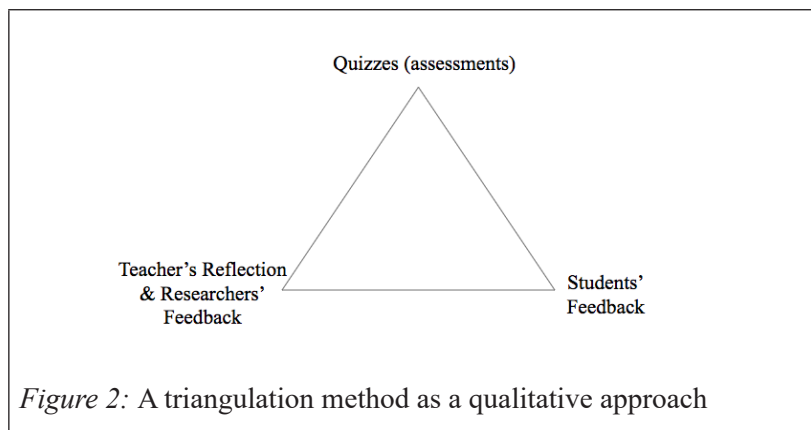


Figure 2 describes the relation of three main methods as the nature of this research. Every quiz performed on the students will be jointly analysed together by students and teacher feedback. Each method will provide particular information that needs to be synchronized together, such that, for every numerical result obtained from quizzes will be analysed and reflected in the context of student's experience, satisfaction, and also with the teacher's reflection. As student feedback is within an infinite space of responses, we perform a thorough thematic analysis, in which the student's feedback will be grouped into several related themes. Together, with the teacher's reflection, we then conclude the finding of this research in a comprehensive manner.

RESULTS AND DISCUSSION

In the result section, it is important to know that the total score per assessment is a 10 which consists of 10- multiple choice questions All the scores were calculated according to the number of students and total score for all assessments. In figure 3, data were visually plotted for three stages of the assessment to detect, observe, and understand the pattern of change in student performances. After the data analysis, the result showed major improvement from Quiz 1 (traditional teaching

method) to Quiz 2 (flipped classroom strategy). It was continued in Quiz 3 (flipped classroom strategy) as well. As we could see, the majority of the students obtained a very low score in between 0.5 to 6.5 (out of 10) while using the traditional approaches. Primarily, it was more than 50 percent (N=23) of the total students who received a score below 6.5 (out of 10). Only, one student received 0.5 which was far below than of other students in the classroom. And, there were very few students who obtained a score of 8 and above (N=5).

However, this pattern has drastically changed over the use of the flipped classroom strategy. In Quiz 2, the student performances indicated outstanding progress where a large number of students obtained between 7 (out of 10) in the assessment. It means more than 78% of students (N= 36) had a good achievement for Quiz 2. Interestingly, there were seven (7) students receiving a full score, and ten (10) students had 9 and 9.5 scores (out of 10) which means they only lost one score from the assessment 2. From the result, it was found that both teaching techniques produced different results in students' performance for this study.

In Quiz 3, the result illustrates major progress on student performance while the researchers reimplemented the flipped classroom strategy again. There were over nine (9) students who obtained a full score for Quiz 3. It was a great achievement for the course and topic in the classroom. In addition to that, the number of students who had scores between 7 to 10 (out of 10) was gradually increased using the flipped classroom strategy. As we observed, it showed an improvement for some students than Quiz 2. The final assessment (reimplementation) provided strong evidence that flipped classrooms may be a potential tool for educators to improve greatly student performances for math in general.

- a. The comparison between the assessment (quizzes) using paired samples t-test

Assessment	Mean	Standard Deviation (SD)	-value
Quiz 1	6.37	1.61	-5.684 0.001
Quiz 3	8.07	1.48	

To identify the effectiveness of the flipped classroom if either is better compared to the traditional teaching method, we perform paired samples t-test between flipped classroom strategy and traditional method based on a summation of score obtained by students for each particular score. A paired-samples t-test was conducted to compare the performance of the students using flipped strategy and traditional teaching techniques. There was a significance difference in the scores for traditional teaching method- Quiz 1 ($M = 6.37$, $SD = 1.61$) and flipped classroom strategy - Quiz 3 ($M = 8.07$, $SD = 1.48$) conditions, $t(45) = -5.684$, $p = 0.001$. These results suggest that flipped classroom strategy indeed improves student capability of answering the quiz as illustrated by the value of mean for Quiz 3 has a higher value compared to Quiz 1.b.

Students Feedback

As a part of the study, a brief survey was conducted through *google form* to gather student feedback and comments regarding both teaching methods (traditional vs RTT). A *google form* is a tool provided by Google to collect responses and a brief survey. Currently, it is widely used in educational settings as well. Regarding the feedback, we found that the flipped classroom strategy is an interesting approach for the students in learning math. Many of the students who showed progress toward their learning in the classroom. From the Thematic Analysis, we found several themes that related to the effectiveness of the RTT as a self-directed learning approach.

Fun and Interesting

Most of the student's feedback was a fun and interesting approach. The students said that this new approach introduced by the lecturer was able to create interest in this course. The research believes that this approach meets the needs of the students where they need extra challenges to use the formula and calculation in relation to other chapters. This method would engage them to use whatever the knowledge available to them to use it for the practice. Competitiveness to earn the highest scores between the students in the classroom may generate a healthy environment for them to learn new concepts and formulas. According to Student A;

“I find this approach is really work for me, I would be able to connect all the concepts, and formula from other chapters. It was really exciting and created an interest for learning this course.”

In addition to that, Student B mentioned about the competitiveness in the classroom may provide a good learning experience for them to do better in the class:

“I feel energetic and motivated to be a top scorer in the class, and I was a top. It made me proud of myself, to be the top, I’ve studied all the materials ahead of the class, and it was truly that allowed me to get ready for the quizzes and get a full score for the quizzes as well.

Curiosity

According to Student Q, this self – directed learning approach will be able to make herself curious about the topic that the instructor will like to present in the classroom.

“It was a great approach than the traditional learning approach (e.g., lecturing), the class created my curiosity to learn into specific topics in the class, the learning materials were very engaging.”

Despite having a curiosity regarding the chapters, the students embarked on a curiosity to know the right answers for the quizzes. Student A said that she feels curious to know what will be the right steps to get the right answer.

“I was eager to know about the right steps for the calculation, I feel it every time I get the wrong answer for the quizzes. I’ve led myself to study hard and put extra efforts for the next challenge in the class”

Providing Students’ Autonomy

Q feels that the class gives an autonomy for students to set a direction of the learning.

“I like the way of giving an opportunity for students autonomy to lead the discussion and the instructor will facilitate our discussion. ”

Besides, Q added her point of the sense of autonomy, “We were given time to prepare for our materials, I feel that the lecturer has some trust and relies on your work. I’ve always felt that it will test our creativity to solve the problem (autonomy).”

Initiating Communication (in-class and outside class)

On the other hand, Student C expressed that this method of learning was actively encouraged by the students to share the knowledge and understanding that they obtained from the teaching materials outside of the classroom. Uniquely, the students made interactions not even in the classroom, but it also happens outside of the classroom. It does help the students to create a safe learning environment and a culture to assist others to comprehend the concept in math.

“Even though we competed against each other in the class, I ‘ve seen they were helping each other to understand all learning materials outside of the classroom, some of the students which I feel I’m not closely familiar with, surprisingly, they started to make an interaction with others. It’s really good to see this happens”

Also, Student C added that the flipped classroom strategy has established communication skills among the students.

“I feel like this approach will motivate them to ask and develop a circle of good communication among our classmates. The communication was not just happening in the class, it might continue on the *whatsapp* as well. This is totally new for me. ”

Integrating the Use of Technology in Learning Mathematics

In similar feedback, Student V admitted that the teaching approaches and materials by the instructors are updated as it is well- integrated

with technology as well. The flipped classroom strategy will use the technology and online materials, so the students can find information, concept, and formula regarding the math topic to enhance students' understanding before the class. The internet is widely used and accessible for the students. However, the instructor may provide reliable websites, databases, and pages for student references regarding the chapter and topic of the day.

“The computer and technology applications like video on *YouTube*, *Google Search* and Math articles are truly benefits for myself and my group to seek information about several concepts in math, even though there were a lot of information over there for us, As a student, I need to be selective and try to think about the materials, connect it and then learn it”

Preparing for Final Exam

Finally, student Z stated that the flipped classroom strategy helps him to prepare for the final exam.

“I realize that this method helps me to prepare for my final exam. I've created my own study notes. I memorised many formulas for the statistics, I got a good score for the quizzes, I feel great and I think I will get a good grade for this course.”

In addition, the student C added that she has an ample study material online and hardcopies for getting prepared for the future quizzes and exams.

“I have a collection of all from chapter one to the final chapter and it all included with tutorial videos. A variety of materials will help me excel in the final exam. I also have a few steps for calculation and potential math formula for the use of the exam”

Regarding the students' feedback, the researchers concluded the flipped classroom strategy approach will provide overall positive feedback which may predict the outcome of the learning such as

student's motivation, student performance, and students' engagement in the classroom. From the feedback, the teacher also may revise the teaching materials according to the students' learning style (e.g., visual, kinesthetic, auditory, and reflective).

c. Teacher Reflection

From this study, we pointed out several thoughts and concerns as a teacher reflection. For the findings, we believe that the flipped classroom strategy would provide positive encouragement for students in the classroom. The students were provided an opportunity to make a move to learn the chapter which is guided by the lecturer in the classroom. From the teacher's perspective, this teaching method is well adapted to the new era, where it is considering students' interest, motivation, and incitement to learn math. During the recruitment of the students, all undergraduate in math programs were recruited based on their interests and math performance. They are all free from math anxiety. The students are expected to have enthusiasm and desire to learn anything about math. The researchers believe if they would provide a space for them to explore the content on their own at the initial of each chapter, they will use their eagerness, self-determination, and curiosity to manipulate the formula and use the available resources to find the math solutions. This may provide an extra boost for the students to create their learning and steps to reach a goal in the learning.

Furthermore, the researchers asserted that the flipped classroom strategy would develop good interpersonal communication skills among students inside and outside of the classroom. Some of the students who were not engaged in the classroom started to interact with students. It would be a positive pushing factor for them interacting with other classmates. Also, a unique out-class interaction has made this approach the best, where the students would get in touch with each other regarding the topic of discussion. They also communicate through a *WhatsApp* application to prepare for the next class. The researchers found that students have established good netiquette to communicate either via the online or offline medium. This may provide a safe learning environment for the students to learn and respect each other.

To make the learning process go beyond the scope of the classroom, the instructor must integrate a technology application to the flipped classroom strategy as a self-directed learning tool that is accessible, available, and reliable for them. In this whole new world, we may find all the information at the tip of our fingers. The technology makes teaching updated and easy to navigate. For math education, the researchers acknowledged that the use of the Learning Management System (LMS), YouTube, and Google Classroom are meaningful tools to give the best experiences for students. The student could upload the materials online, review the video, comment on the post, and communicate with others and teachers anywhere and anytime. The students would have a good learning experience while gaining knowledge and learning math in more fun ways. The teachers predict the students to be more creative, innovative, and well- engaged with the learning as well.

DISCUSSION

Various teaching techniques play an important role to improve the teaching and learning process among higher education students. As a lecturer, choosing the right teaching techniques in the classroom is important to improve the student's knowledge and skills. Teachers should try many different teaching techniques inside the classroom until they can choose a suitable technique for that course. One of the popular techniques that engage more students compared to traditional teaching techniques is related to active learning or self-directed learning (Taylor et al., 2011).

The comparison results of the mean value between Figure 2, Figure 3, and Figure 4 revealed the effectiveness of the flipped classroom strategy in enhancing self-directed learning among students substantially on the mathematical subjects. The performance of the students increases in each of the quizzes. It shows that by using a flipped classroom strategy, the level of student's understanding of mathematics courses has increased tremendously. They can easily remember all the steps and formulas in mathematics and give the right answers in all mathematical problems. Previous research among mathematics students revealed the significant role of self-directed learning in enhancing student

performance (Kleden, 2015). As mentioned by Kladen (2015), several aspects are considered as important in learning mathematics such as the rule of students to identify their learning needs and suitable resources or material for learning, including selecting their learning strategy. Besides, mathematics students also should be able to identify their abilities and doing self-evaluation as an important approach for them to identify what is correct and accurate. Hence, this self-directed learning approach was applicable for mathematics students because it helps them to be able to learn from their own mistakes and correct any identified mistakes.

Moreover, student feedback plays an important element in enhancing the quality of the learning process based on students' needs. Feedback on learning activities given benefits for both student and teacher as an assessment that promotes student engagement and learning (Black & William, 2009). Student feedback also known as student reflection has always become a key factor for a teacher to make an improvement and innovation in teaching and learning (Carrington & Macarthur, 2012). Based on the result, most of the students like flipped classroom strategy and find it as a more suitable way for understanding the topic compared to the traditional method. Also, teaching and learning in mathematics by the flipped classroom strategy involves the skill and cognitive ability to solve the mathematical problem compared to the traditional method. This study has proven that assessing the material before the class will help students gain some knowledge about the topic and materials. This is because self-directed learning allowed students to use their style or creativity in understanding the information (Punya, Chris & Danah, 2013).

Also, the flipped classroom strategy becomes a good approach to enhancing student active learning by focusing on the effectiveness of self-directed learning. Since students in higher education were considered in the adult stage, self-directed learning becomes an appropriate method to train their ability to learn as well as increase their skills and knowledge (Ellinger, 2004). The flipped classroom strategy also allows the lecturer to monitor students closely in their learning process and learning outcomes. As for future aims, a flipped classroom strategy will produce students who are masters in understanding the content of the subject by self-directed learning and then promote knowledge sharing behaviour among students.

Also, the flipped classroom strategy may help to improve student's communication and social skills. They can make a good discussion and help friends until all of them understand all the topics and can solve all mathematical problems. They also have a good relationship outside the classroom. Thus, we can conclude that using a flipped classroom strategy has given a more positive impact on the students in the mathematical course. However, some limitations should be noted in this study. This study only covered the flipped classroom strategy for one mathematical course at one university and may be different results will appear if tested for other courses.

CONCLUSION

This study has introduced a flipped classroom strategy for teaching and learning math in education. In the millennial age, this approach fits the current teaching practice for the Industrial Revolution (IR) 4.0 which focuses on student-directed learning. Concurrently, the educator will engage as a facilitator, and then the students would be experimenting with all teaching materials that could lead them to the learning objective. This type of method may spark an interest in learning math for students and develop students' self-confidence to master the content. It is a new way of teaching practice that the educator could consider to do to improve their students' performance. In the future, it is hoped that the flipped classroom strategy will be implemented in other courses as well.

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