JIRSEA

JOURNAL OF INSTITUTIONAL RESEARCH SOUTH EAST ASIA

JIRSEA Issue: Vol. 22 No. 1

JIRSEA/UPM Special Issue

April 2024

ISSN 1675-6061

http://www.seaairweb.info/journal/index.aspx

Submission Timeline

Received: 30/10/2023

Revised as per Preliminary Review: 15/01/2024

Final Revision & Acceptance: 15/03/2024

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Mohd Shahridwan Ramli, Ahmad Fauzi Mohd Ayub, Fazilah Razali, and Norliza Ghazali

CITE ARTICLE: Ramli, M.S., Ayub, A.F.M., Razali, F. & Ghazali, N. (2024). Effects Of Flipped Classroom Towards Calculus Performance And Mathematical Creative Thinking Skills Among Higher Institution Students, *Journal of Institutional Research South East Asia*, 22(1), 70-96

SOUTH EAST ASIAN ASSOCIATION FOR INSTITUTIONAL RESEARCH

UNIVERSITI PUTRA MALAYSIA

Publisher: SEAAIR Secretariat

C/O Suan Dusit Rajaphat University
295 Nakhon Ratchasima Rd, Dusit, Dusit District, Bangkok 10300, THAILAND
email:seaair.info@gmail.com
http://www.seaairweb.info/

EFFECTS OF FLIPPED CLASSROOM ON CALCULUS PERFORMANCE AND MATHEMATICAL CREATIVE THINKING SKILLS OF HIGHER INSTITUTION STUDENTS

Mohd Shahridwan Ramli[1], Ahmad Fauzi Mohd Ayub[1,2*], Fazilah Razali[2] and Norliza Ghazali[2]

[1]*Institute for Mathematical Research, Universiti Putra Malaysia, Malaysia*

[2]*Faculty of Educational Studies, Universiti Putra Malaysia, Malaysia*

*Corresponding email: afmy@upm.edu.my

ABSTRACT

This study investigates how flipped classroom deployment affects students' calculus performance and mathematical creative thinking skills. In this study, a pretest-posttest quasi-experimental format with a control group was employed. Forty-nine students from a higher institution participated in this study. Pre-test, post-test, and delayed post-test were used to assess students' performance and mathematical creative thinking skills. The treatment group of 25 students employed a flipped classroom, whereas the control group of 24 participants used the conventional approach. The covariance analysis revealed a significant difference in the post-test and delayed post-test regarding the calculus performance of the students. Additionally, the results demonstrated that students who utilised flipped classrooms had significantly better scores in mathematical creative thinking skills in the post-test and delayed post-test. This study showed that, in terms of performance and creative thinking skills, using a flipped classroom to teach mathematics to students in higher education was more effective than the conventional approach. However, the fluency domain in creative thinking skills indicated no significant difference between the groups in the post-test and delayed post-test. This study showed that educators must allocate more time for students to participate in active discussions and develop more ideas and solutions. Therefore, it is recommended that this instruction approach be used continuously in teaching and learning in the future.

Keywords: 21st century learning approach, cognitive skills, experimental study, higher education, mathematic performance

1. Introduction

The dismal Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) scores demonstrate how poorly Malaysian students continue to do in mathematics. This is corroborated by a study conducted by Shin et al. (2019), which reveals that student performance in mathematics has declined significantly despite considerable financial investments to improve education in Malaysia. According to a needs analysis of students at higher education institutions, students continue to face difficulties in mathematics, especially in calculus (Hoban, 2019). Numerous research have revealed that calculus is a difficult subject for students (Carnell et al., 2018; Çekmez, 2020). Integration and derivatives have been identified as the two most difficult calculus topics (Tatar & Zengin, 2016). Meanwhile, Carnell et al. (2018) provided an explanation for why students perceive calculus to be complex, citing insufficient prior knowledge as a contributing reason. The teacher's role is extremely important during the transition period, such as at the higher institution stage, in understanding and stressing the importance of fundamental mathematical concepts particularly in calculus that students must understand in order to learn the subject at the next level (Kouvela et al., 2018). For students to grasp calculus, in particular, more deeply, lecturers need to get more involved in the classroom.

According to a Research Institute of National Higher Education study, many graduates have outstanding grades but cannot find jobs matching their qualifications (Heong et al., 2020). Many employers have expressed concern about certain graduates' knowledge, skills, and attitudes (Puad & Nawe, 2021). Creative thinking skills are among the skills graduates fail to acquire (Yusof & Jamaluddin, 2017). According to Hanapi et al. (2017), a new study shows a significant gap between thinking skills and employability, particularly regarding graduates' creative thinking and leadership capacity. Furthermore, Nirmala and Kumar (2018) stress that graduates' creative ability is a prerequisite for employment. This issue has been carried over to higher education, where students struggle to develop their capacity for creative thinking (Sari et al., 2017). Consequently, to fulfill the demands of modern society, students must equip themselves with creative thinking skills. Classroom learning and assessment may enhance students' ability to think creatively (Widana, 2018). Therefore, to generate students who can satisfy the demands of future employers, lecturers should play a crucial role in helping these students develop their creative thinking skills in the early semester of entrance.

At higher education institutions, it is the lecturer's responsibility to help students reach their full potential. Previous studies show that university students' cognitive learning performance and creative thinking skills correlate positively (Siburian et al., 2019; Susanti, 2019). Nonetheless, Kassim and Zakaria (2015) note that several lecturers' lack of variety in their teaching approaches makes them less able to incorporate thinking skills into their classrooms. Furthermore, a study demonstrates that educators have the bare minimum of information about understanding and utilising thinking skills in school (Rasyid et al., 2021). The teaching strategy is essential to interest students in mathematics (Acharya, 2017). Few students participate in classroom activities due to a conventional approach largely reliant on lecture explanations of class material and home assignments at all educational levels (Afrasiabifar & Asadolah, 2019). Within this framework, conventional lectures are delivered by the lecturer in front of the class utilising a teacher-centred approach. According to Hadibarata and Rubiyatno (2019), activities in the classroom appear to follow the same routine, with the lecturer providing full supervision and the students just having to sit and listen to the explanation. It disregards how students have developed cognitively, particularly in thinking skills. According to Hong et al. (2017), mathematics instruction still retains a conventional approach that focuses more on the classroom than on allowing students to use creativity and apply what they have learned to real-world scenarios. To help students reach their full potential, lecturers must adopt a student-centred approach and modify their method of instruction.

Assessments conducted in a classroom or through centralized assessment systems are typically used to quantify mathematical achievements. Malaysia's PISA score in mathematics is one indicator of mathematical proficiency worldwide; the country joined PISA in 2009. According to PISA, Malaysia is 47th of 78 nations (Malaysian Ministry of Education, 2019), indicating that Malaysia still ranks in the middle of participating countries. Malaysia has also taken part in the worldwide TIMSS evaluation. Between 1999 and 2019, Singapore and Malaysia participated in TIMSS, with Singapore having the highest average score. Malaysia lagged behind Singapore by a large margin using average scores in mathematics as a comparison (Yee et al., 2018), and this was the case from 1999 to 2019. This indicates that mathematics achievement as measured by TIMSS and PISA is still lacking in Malaysia and needs to be improved. Most students in these cohorts are already furthering their studies at higher education institutions. Various stakeholders, such as lecturers, administrators, and curriculum drafters, have varied perspectives on student achievements in higher learning institutions. These stakeholders frequently believe that student achievement is determined by how well students do on standardized assessments (Bressoud et al., 2016). As a result, authorities such as lecturers have to be heavily involved in elevating mathematical achievement at higher education institutions.

One of the six goals of the Malaysian Education Blueprint (2013–2025) is the development of thinking skills, which are now considered essential to education in the country (Malaysian Ministry of Education, 2013). Higher-order thinking skills (HOTS) and lower-order thinking skills (LOTS) are the two categories of thinking skills (Krathwohl, 2002). National education aims to use HOTS to create a generation of students who can compete globally (Hock et al., 2015; Letchumanan et al., 2023). HOTS also contain creative thinking skills (Ahmad et al., 2017; Ibrahim et. al, 2019). Globally, the curriculum for mathematics education has made developing creative thinking skills a primary priority (Butera et al., 2014). The capacity to process and generate original and ingenious ideas is known as creative thinking skills (Jakpar, 2015). According to Krupiah and Kannadasan (2021), creative thinking skill is the capacity to generate something novel and worthwhile by thinking outside the box and utilising one's imagination naturally. Fluency, flexibility, originality, and elaboration are the four categories into which Torrance (1990) splits creative thinking skills. Leung and Silver (1997), in the meanwhile, identified a way to use problem-solving and problem-posing as an indication of students' creative thinking (fluency, flexibility, and novelty). Fluency and flexibility are the two aspects of mathematical creative thinking skills that are evaluated in this study. This is based on a study by Rahayuningsih et al. (2021) that exclusively uses open-ended mathematical problems to examine the two domains according to rubric specifically in mathematics. Most of the previous researchers only included the domains of fluency and flexibility in mathematics subjects above their suitability compared to other domains that can be tested in other subjects, such as in studies by Hästö et al. (2019), Bye et al. (2022) and Shaw et al. (2020). Fluency is indicated when the student fluently produces different ideas which are appropriate to the question task (Siswono, 2011). Perhaps, fluency is also defined as the ability to give more than one mathematically correct answer (De-La-Peña et al., 2021). Meanwhile, flexibility refers to a student’s ability to solve a problem using many different methods or ways (Siswono, 2011). In short, flexibility is based on the ability to show more than one correct mathematical solution (De-La-Peña et al., 2021). Thus, encouraging students to think creatively is a component of the endeavour to help them become better thinkers.

According to Mursyid and Kurniawati (2019), thinking skills have become vital in today's world, because they allow students to address problems. According to data from the National Association of Colleges and Employers on the relevance of thinking skills for employment today, thinking skills may also be essential in many other professions (Fajari, 2020). According to some experts, students' academic success and ability to think creatively are interrelated (Mursyid & Kurniawati, 2019). Numerous studies have been done in recognition of the importance of thinking skills, particularly creative thinking skills. Several research studies have shown that developing students' creative thinking capacity can improve their mathematics performance (Chukwuyenum, 2013). Consequently, for students to develop these skills and their academic performance, educators have an essential role in fostering HOTS, particularly creative thinking skills, in the classroom.

One pedagogy that is becoming more popular in education is the flipped classroom. Flipped classroom is described by Alsowat (2016) as a teaching strategy that focuses LOTS achieved outside the classroom and maximizes class time for concept discussion sessions and focuses more on HOTS questions inside the classroom. Simultaneously, the flipped classroom is described as an emerging 21st-century learning approach in which students learn outside the classroom and then apply the knowledge inside the classroom (Kutty, 2019). According to Strayer (2007), there are three primary phases that students go through in a flipped classroom: before instruction, during instruction, and after education. In actuality, students will participate in activities inside the classroom to enhance their learning and obtain their knowledge and experiences outside of it (Kutty, 2019). Afterward, following their interaction period, students will complete post-learning tasks via online activities. The benefits of flipped classrooms for teaching and learning have been demonstrated in several research. According to Masri and Mahamod (2020), flipped classrooms can allow students to engage with materials before the actual class period begins. As a result, activities involving peers and teachers that aren't as important in conventional learning might take up more time in the classroom. Furthermore, according to Zainuddin et al. (2019), the flipped classroom positively influences learning activities, promotes student involvement, and supports student-centred learning. Recent research have also demonstrated how the flipped classroom positively impacts creative thinking skills in mathematics (Ariani et al., 2022; Sya'Roni et al., 2020; Tabieh & Hamzeh, 2022). Meanwhile, Tsai et al. (2020) found that flipped classrooms may assist engineering students in strengthening their creative thinking skills while improving mathematics performance and motivation. In summary, implementing a flipped classroom as an intervention approach in experimental study can provide advantages for students and support educators in facilitating more successful teaching and learning inside the classroom.

2. Research Objectives and Hypotheses

This study sought to investigate the effect of flipped classroom on students' performance in learning calculus at higher education institutions. Eight hypotheses were generated after three research objectives were established to accomplish the following objectives:

1. Compare the effects of the flipped classroom and conventional approach on higher institution students' performances (post-test and delayed post-test) in calculus.
2. Compare the effects of the flipped classroom and conventional approach on higher institution students' mathematical creative thinking skills (post-test and delayed post-test) in calculus.

3. Compare the effects of the flipped classroom and conventional approach on domains in students' mathematical creative thinking skills (fluency and flexibility) among higher institution students (post-test and delayed post-test) in calculus.

Research hypotheses are as follows:

H_{01}: There is no significant difference in the means of the student's performance test scores (post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

H_{02}: There is no significant difference in the means of the student's performance test scores (delayed post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

H_{03}: There is no significant difference in the means of the student's mathematical creative thinking skills (post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

H_{04}: There is no significant difference in the means of the student's mathematical creative thinking skills (delayed post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

H_{05}: There is no significant difference in the means of the student's fluency (post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

H_{06}: There is no significant difference in the means of the student's fluency (delayed post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

H_{07}: There is no significant difference in the means of the student's flexibility (post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

H_{08}: There is no significant difference in the means of the student's flexibility (delayed post-test) between the flipped classroom and conventional approach while controlling pre-test scores in calculus.

In addition, the conceptual framework of the study is shown in Figure 1. From this framework, there were two groups tested and conducted pre-tests on before the experiment commenced. Following the intervention, post-tests and delayed post-tests were conducted to observe the intervention's effects on calculus performance and creative thinking skills, encompassing fluency and flexibility domains.

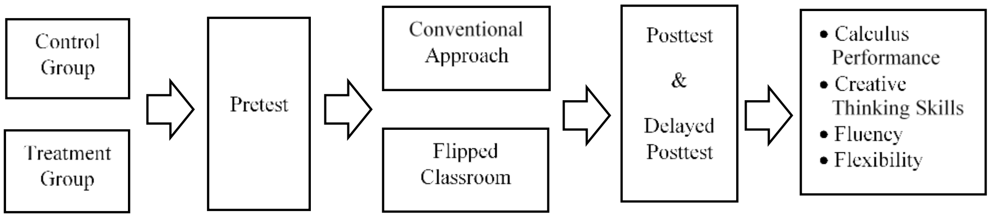


Figure 1: Conceptual framework

3. Methodology

This research employs a pretest-posttest quasi-experimental methodology with a control group, using first-year student tutorial groups as the treatment group and another as the control group. The treatment group utilises the flipped classroom, while the control group employs the conventional approach. The choice of having a quasi-experimental design is because this study is looking into the cause and effect of implementing flipped classrooms in teaching and learning calculus. Researchers have to use intact groups in this study. Participants' availability or the environment's proscription against forming artificial groups might be the reason (Klassen et al., 2012). Learning in the classroom will be hampered by randomly allocating students to control and treatment groups. Even so, because this study's statistical analysis is based on inferential analysis, a randomized procedure is conducted by randomly choosing two groups at one higher institution in the east coast of peninsular Malaysia. There are 90 tutorial groups and two tutorial groups are chosen randomly. The selection is made by first taking two lecture groups randomly from the nine available lecture groups. Each lecture group has 10 tutorial groups, and one tutorial group is randomly selected from each of the two previously selected lecture groups. The research design model employed in this study is depicted in Table 1. Purposive sampling is used to choose the study sample. A total of two classes are randomly selected into a control group of 24 students and a treatment group of 25 students. Every tutorial commonly consists of 23 to 25 students per class. Three performance tests including pre-tests, post-tests, and delayed post-tests, are given to the students to assess their performance with six-item questions for each test. Additionally, a creative thinking skill rubric adapted from Firdaus (2016) is used to assess the students' mathematical creative thinking skills during the intervention as in Appendix. Firdaus (2016) adapted the domains in the Torrance instrument by developing a rubric from a scale of 1 to 4 specific for the respondent's mathematics performance test script. In mathematical creative thinking skills, fluency and flexibility are the two domains that are measured in line with the study by Rahayuningsih et al. (2021). The rubric is used in scoring mathematical creative thinking skills through student scripts on the post-test and delayed post-test. There are three items to measure the fluency and flexibility domains for creative thinking skills and rubrics for domains of fluency and flexibility are assessed separately. The creative thinking skill score is calculated from the total score of both domains. Each respondent's script is marked using an adapted rubric and a score value will be given for each item tested from a scale of 0 to 4. For this rubric score, the lowest possible score is 0, and the highest is 4. This rubric is suitable for assessment in the Malaysian context because Malaysia has started using the band 1 to 6 method in classroom assessment recently. However, since this study adapts a rubric instrument from a previous study that used a score of 0 to 4, the researcher maintained the score or band from a previous study carried out by Firdaus (2016) to facilitate marking the script. A pilot study was conducted earlier, and all the tests have been carried out. For the pre-test, the reliability was 0.80; for the post-test, it was 0.75; and for the post-delayed test, it was 0.75. Meanwhile, the post-test reliability for the creative thinking skill rubric is 0.73, and the delayed post-test reliability is 0.72. A panel of experts validated the reliability and validity of the instruments. The improvement was updated in light of the feedback.

Table 1: Quasi-experiment Pre-test, Post-test and Delayed Post-test

Group	**Pre-test**		**Post-test**	**Delayed Post-test**
Conventional	O_1	X_1	O_2	O_4
			O_3	O_5
Treatment	O_1	X_2	O_2	O_4
			O_3	O_5

X_1: Conventional approach
X_2: Treatment group (Flipped classroom)
O_1: Pre-test
O_2: Post-test
O_3: Creative thinking skill (post-test)
O_4: Delayed post-test
O_5: Creative thinking skill (delayed post-test)

Before the experiment begins, pre-test was given to both groups. A pre-test was administered to each group to determine the primary difference between the treatment and control groups. The pre-test served as a baseline for the variables under consideration and as a way of deciding whether or not the means of the two groups differed significantly. Consequently, the pre-test was incorporated as the covariate in the study. While the control group followed the conventional approach, the treatment group employed a flipped classroom adapted from the O-PIRTAS model developed by Guo (2019) as in Figure 2.

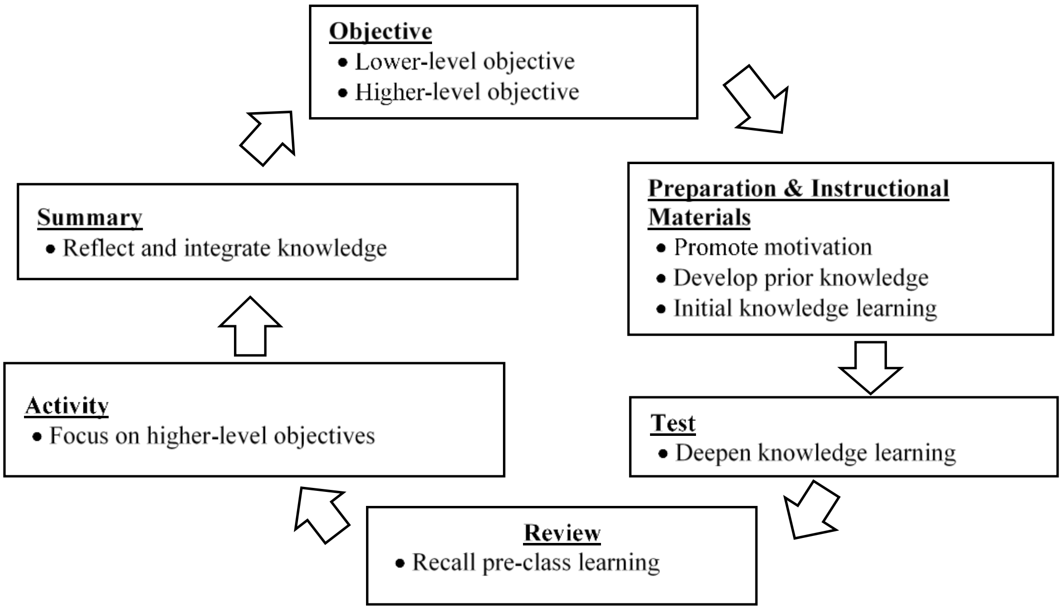


Figure 2: O-PIRTAS model

Both groups were given the same questions and notes during the experiment. The control group employed the conventional approach, using teacher-centred approach. Meanwhile, the treatment group utilised flipped classroom via pre-class learning before the class began. Pre-class learning included brief notes, pre-questions that students needed to complete before the class began, along with solution videos, and an online pre-quiz to help the instructor to identify which parts the students still did not understand well, and which students still did not grasp the topic taught. In-class activities for the treatment group would focus on group discussions for more challenging questions, including open-ended and non-routine problems, compared to the control group, which leaned more towards a teacher-centred approach. During group discussions, students in the treatment group were encouraged to present and defend a variety of answers and solution forms obtained to enhance mastery in the domains of fluency and flexibility. The experimental study for both groups was carried out simultaneously beginning pre-test to delayed post-test.

The post-test assessed the students' performance after a six-week long experimental study after pre-test. Two weeks following the post-test, the researchers administered a delayed post-test. The study procedure's duration in a quasi-experimental study depends on the intervention type. According to Hua (2016), an experimental study requires a long time and energy to obtain results. This is important because too short a study period may result in the effect of treatment not being fully visible. Salam et al. (2015) in their study did a quasi-experimental study for six weeks, which is in line with the duration of this study. Preliminary analysis, descriptive statistics, and inferential analysis are the three stages of data analysis. Descriptive statistics and exploratory data analysis (EDA) are preliminary data analysis methods. The exploratory data analysis of both groups indicated that the performance test score is normally distributed by using skewness and kurtosis. The value of skewness and kurtosis was set between -2 and +2 as according to Hair (2009). Descriptive statistics were employed to describe the distribution of participants among treatment groups and control groups on mean and standard deviation. However, inferential statistics including ANCOVA and MANCOVA addressed the study issues. The first to fourth hypotheses were analysed using ANCOVA since pre-test was used as covariate and did not involve any domain in calculus performance, while the fifth to eighth hypotheses were answered using MANCOVA since pre-test was used as covariate and involved two domains in creative thinking skills.

4. Results and Analysis

This section discusses the findings of the study's research objectives and the evaluation of the flipped classroom approach in the actual study. The performance test of mean and standard deviation (SD) for both groups at the higher institution is shown in Table 2. At the post-test, the treatment group's performance score (M = 46.36, SD = 15.830) was higher than the control group (M = 35.13, SD = 17.984). In the delayed post-test, the treatment group (M = 46.06, SD = 17.045) also performed better than the control group (M = 35.50, SD = 15.131).

Table 2: Descriptive data for post-test and delayed post-test

Tests	Group	Mean	Std. Deviation	N
Post-test	Control	35.13	17.984	24
	Treatment	46.36	15.830	25
Delayed post-test	Control	35.50	17.045	24
	Treatment	46.06	15.131	25

Levene's test was used to investigate the equality of variances in this study (see Table 3). The post-test Levene's test results [F (1,47) =.241, p =.626 >.05] were not significant, indicating that the homogeneity of variance assumption was not violated. Additionally, the delayed post-test results of Levene's test [F (1,47) =.067, p =.797 >.05] did not show statistical significance, indicating that the homogeneity of variance assumption was also not violated.

Table 3: Levene's test of equality of error variances of post-test and post-delayed test

Test	F	df1	df2	Sig.
Post-test	.241	1	47	.626
Delayed post-test	.067	1	47	.797

Table 4 indicates that there was a significant difference in the mean post-test scores between the treatment and control groups [F (1,46) = 7.785, p =.008 <.05] after adjusting for the pre-test mean scores. Additionally, there was a statistically significant difference in the delayed post-test results between the two groups at the performance test [F (1,46) = 7.729, p =.008 <.05]. According to these findings, students in the treatment group outperformed those in the control group by a significant difference in post-test and delayed post-test. Therefore, H_{o1} and H_{o2} were rejected. Then, there were significant differences in the means of the student's performance test scores at post-test and delayed post-test between the treatment and conventional groups while controlling pre-test scores in calculus.

Table 4: Tests of between-subject effects of post-test and post-delayed test scores

Test	Source	Type III Sum of Squares	df	Mean squares	F	Sig.	Partial Eta Squared
Post-test	GROUP	1672.193	1	1672.193	7.785	.008	.145
Delayed post-test	GROUP	1476.145	1	1476.145	7.729	.008	.144

Table 5 displays the mean and standard deviation of the two groups of higher institution students' mathematical creative thinking skills. The treatment group (M = 9.40, SD = 3.082) outperformed the control group (M = 6.38, SD = 2.810) in mathematical creative thinking at the post-test. Furthermore, the treatment group (M = 8.92, SD = 2.482) exceeded the control group (M = 6.25, SD = 2.847) in the delayed post-test, demonstrating greater mathematical creative thinking skills.

Table 5: Descriptive data for creative thinking skills at post-test and delayed post-test

Tests	Group	Mean	Std. Deviation	N
Creative thinking skills (post-test)	Control	6.38	2.810	24
	Treatment	9.40	3.082	25
Creative thinking skills (delayed post-test)	Control	6.25	2.847	24
	Treatment	8.92	2.482	25

The equality of variances in this study was examined using Levene's test (see Table 6). The findings of Levene's test showed that the mathematical creative thinking skills at the post-test [F (1,47) =.165, p =.687 >.05] were not significant, proving that the homogeneity of variance assumption was not violated. Furthermore, there was no statistically significant difference in the delayed post-test results of Levene's test for mathematical creative thinking skills [F (1,47) =.131, p =.719 >.05], suggesting that the homogeneity of variance assumption was also not violated.

Table 6: Levene's test of equality of error variances of creative thinking skills at post-test and post-delayed test

Test	F	df1	df2	Sig.
Creative thinking skills (post-test)	.165	1	47	.687
Creative thinking skills (delayed post-test)	.131	1	47	.719

After controlling for the pre-test mean scores, Table 7 shows that there was a significant difference in the mean of mathematical creative thinking skills between the treatment and control groups in post-test scores [F (1,46) = 12.679, *p* =.001 <.05]. In addition, the findings of the delayed post-test for mathematical creative thinking skills showed a statistically significant difference between the two groups [F (1,46) = 90.351, *p* =.000 <.05]. These results indicate that students in the treatment group significantly outperformed those in the control group for mathematical creative thinking skills in the post-test and delayed post-test. Therefore, H_{o3} and H_{o4} were rejected. There were also significant differences in the means of the students' mathematical creative thinking skills at the post-test and delayed post-test between the treatment and conventional groups while controlling pre-test scores in calculus.

Table 7: Tests of between-subject effects of creative thinking skills at post-test and post-delayed test scores

Test	Source	Type III Sum of Squares	df	Mean squares	F	Sig.	Partial Eta Squared
Creative thinking skills (post-test)	GROUP	112.582	1	112.582	12.679	.001	.216
Creative thinking skills (delayed post-test)	GROUP	90.351	1	90.351	14.055	.000	.234

The mean and standard deviation for the two groups' domains of fluency and flexibility abilities are shown in Table 8. At the post-test, the treatment group's fluency score (M = 3.32, SD = 2.056) was higher than that of the control group (M = 2.38, SD = 1.861). In the post-test, the treatment group (M = 6.08, SD = 1.470) achieved better flexibility than the control group (M = 4.00, SD = 1.888). Additionally, in the delayed post-test, the treatment group (M = 3.28, SD = 1.860) surpassed the control group (M = 2.33, SD = 1.834), indicating higher fluency. In the delayed post-test, the treatment group (M = 5.64, SD = 1.150) outscored the control group (M = 3.92, SD = 1.613), indicating greater flexibility.

Table 8: Descriptive data for fluency and flexibility at post-test and delayed post-test

Tests	Group	Mean	Std. Deviation	N
Fluency (post-test)	Control	2.38	1.861	24
	Treatment	3.32	2.056	25
Flexibility (post-test)	Control	4.00	1.888	24
	Treatment	6.08	1.470	25
Fluency (delayed post-test)	Control	2.33	1.834	24
	Treatment	3.28	1.860	25
Flexibility (delayed post-test)	Control	3.92	1.613	24
	Treatment	5.64	1.150	25

Levene's test assessed the equality of variances in this investigation (Table 9). The results of Levene's test demonstrated that the homogeneity of variance assumption hadn't been violated and that the fluency at post-test [F (1,47) =.477, p =.493 >.05] was not significant. The homogeneity of variance assumption was not violated, as evidenced by Levene's test results, which revealed that the flexibility at post-test [F (1,47) =1.751, p =.192 >.05] was not significant. Furthermore, there was no statistically significant difference in the delayed post-test results of Levene's test for fluency [F (1,47) =.477, p =.493 >.05], suggesting that the homogeneity of variance assumption was also not violated. There was no statistically significant difference in the delayed post-test results of Levene's test for flexibility [F (1,47) =1.751, p =.192 >.05], suggesting that the homogeneity of variance assumption was also not violated.

Table 9: Levene's test of equality of error variances of fluency and flexibility at post-test and post-delayed test

Test	F	df1	df2	Sig.
Fluency (post-test)	.006	1	47	.941
Flexibility (post-test)	1.741	1	47	.193
Fluency (delayed post-test)	.477	1	47	.493
Flexibility (delayed post-test)	1.751	1	47	.192

Table 10 indicates that there was no significant difference in the mean fluency between the treatment and control groups at the post-test [F (1,46) = 2.759, p =.104 >.05] after controlling for the pre-test mean scores, which implies that H_{o5} failed to be rejected. Nonetheless, the results indicate that in the post-test, the treatment and control groups' means of flexibility differed significantly [F (1,46) = 18.729, p =.000 <.05]. Therefore, H_{o7} had to be rejected. There was a significant difference as well in the means of the students' flexibility (post-test) between the treatment group and conventional group while controlling pre-test scores in calculus. Likewise, no statistically significant difference was observed between the two groups in the results at the delayed post-test for fluency (F (1,46) = 11.593, p =.064 >.05), and H_{o6} failed to be rejected. At the delayed post-test, the mean flexibility between the treatment and control groups differed significantly, according to the results [F (1,46) = 20.316, p =.000 <.05], and H_{o8} was rejected. There was a significant difference in the means of the students' flexibility (delayed post-test) between the treatment group and conventional group while controlling pre-test scores in calculus. According to these findings, students in the treatment group significantly outperformed those in the control group in the post-test and delayed post-test, but only in flexibility.

Table 10: Tests of between-subject effects of fluency and flexibility at post-test and post-delayed test scores

Test	Source	Type III Sum of Squares	df	Mean squares	F	Sig.	Partial Eta Squared
Fluency (post-test)	GROUP	10.848	1	10.848	2.759	.104	.057
Flexibility (post-test)	GROUP	53.535	1	53.535	18.729	.000	.289
Fluency (delayed post-test)	GROUP	11.593	1	11.593	3.602	.064	.073
Flexibility (delayed post-test)	GROUP	37.215	1	37.215	20.316	.000	.306

5. Discussion

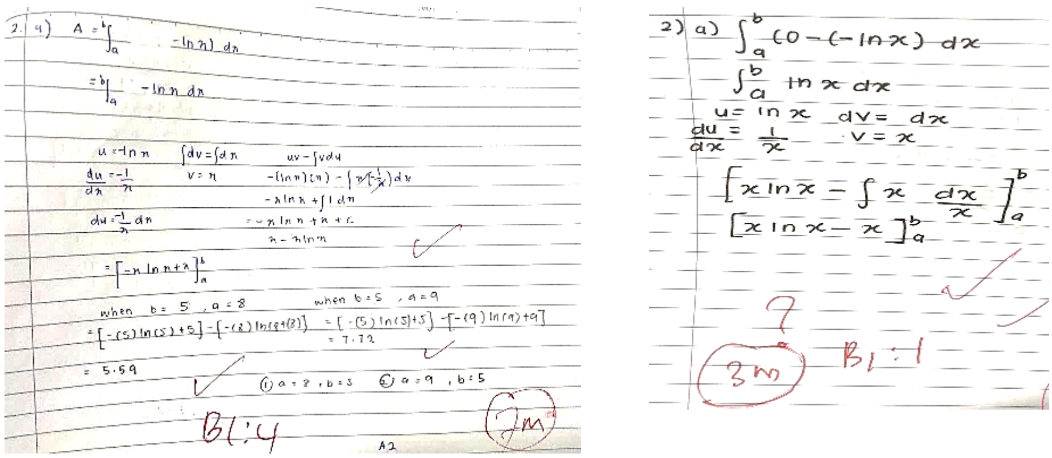
According to Syah Muhibbin (2017), each learner can accomplish a particular level. However, it is frequently said that educators are in charge of helping students to reach their full potential, which encompasses cognitive, emotional, and psychomotor domains (Nurmalia et al., 2021). Therefore, improving learning performance and developing thinking skills in the classroom was one of the goals of using the flipped classroom approach. This study examined how students in higher institutions used the conventional approach and the flipped classroom. The post-test and delayed post-test results demonstrated that students in the treatment group significantly outperformed those in the control group. According to the results, the flipped classroom improves students' mathematical performance (Albalawi, 2018; Atwa et al., 2022; Wei et al., 2020). At the same time, recent studies also show that flipped classrooms can significantly increase calculus achievement (Cablas, 2023; Collins, 2019; Harmini et al., 2022; Jafar et al., 2020; Mustofa, 2022) although it is a difficult subject for students of higher education institutes (Arnellis & Amalita, 2019; Samsudin et al., 2020). According to Zhang et al. (2016), the flipped classroom helps prepare students for more engagement in active discussions during class activities. They claim that due to the flipped classroom, students are enthusiastic and prepared for class, which motivates them to participate in the activities.

Additionally, because they are already familiar with the basic concepts, it makes it easier for students to absorb the material throughout the learning activity (Osman et al., 2023). To further aid in their understanding of the subject, students can also often review the notes and video solutions supplied at their speed, any time, and anywhere (Mangan, 2013; Seo et al., 2018; Tomas et al., 2019). The results also demonstrate a significant difference between the two groups during the delayed post-test. This indicates that flipped classrooms can enhance students' retention and long-term memory impacts. Day (2018) found that one of its benefits is influencing the flipped classroom's long-term impact on student performance.

The findings also show that the group of students who used the flipped classroom indicated significantly better scores in mathematical creative thinking skills compared to the control group in the post-test and delayed post-test. The findings of previous studies show that the use of a flipped classroom can enhance creative thinking skills compared to conventional learning (Rahayu et al., 2022; Rodríguez et al., 2019; Wannapiroon & Petsangsri, 2020) and specifically in mathematics (Ariani et al., 2022; Sya'Roni et al., 2020; Tabieh & Hamzeh, 2022). A flipped classroom can allow students to explore and learn the content they will cover in class beforehand (Milman, 2012). Students learn topics more quickly in school, which enables them to actively participate in discussions before presenting and contrasting different types of answers and solutions

(Libre, 2021). According to this study, flipped classrooms can help students become more engaged in learning and provide an environment where they can use their creativity to develop various answers and solutions. Through active discussions within groups, students will present a variety of correct answers and solution forms and defend them with clear evidence and arguments. This is achieved by mastering the basics through pre-class learning and active group discussions.

The findings show no difference between the two groups for the fluency domain in the post-test and delayed post-test. This study contradicts the findings from experimental studies by Sya'Roni et al. (2020), Kiran and Farooq (2022), Tabieh and Hamzeh (2022), and Sari et al. (2022), who showed that flipped classrooms can increase fluency in mathematics learning. However, several studies showed no significant difference between students who use the flipped classroom and the conventional approach in fluency (Jiang et al., 2023; Sheikhipour et al., 2021). For the advanced calculus level studied by higher institution students, it is quite difficult for students to give multiple possible answers due to time constraints. However, the findings still show in a descriptive analysis that the treatment group achieved a higher mean score than the conventional group. This can be seen through the comparison of student scripts from both groups for the fluency domain in Figure 3. Students in the treatment group (a) achieved higher scores for the fluency domain by showing two correct answers compared to students in the control group (b) who did not show any correct answer. Future studies may need to allocate more time to student discussion activities so that an increase in ideas can occur to improve the fluency domain.

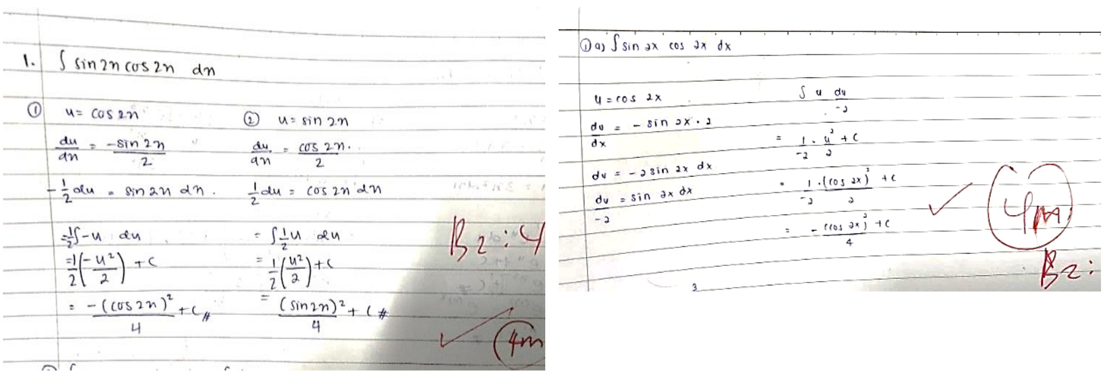


(a) Treatment group (b) Treatment group

Figure 3: Comparison of respondents' scripts for fluency

The findings regarding the flexibility domain show that the treatment group obtained a more significant score than the control group for the post-test and delayed post-test.

This can be seen through the comparison of student scripts from both groups for the flexibility domain in Figure 4. Students in the treatment group (a) achieved higher scores for the flexibility domain by showing two correct solutions compared to students in the control group (b) who only showed one correct solution. These findings show that flipped classroom successfully increases flexibility in mathematics. The findings of this study are in line with the findings of previous studies that show flipped classrooms can increase the domain of flexibility in creative thinking skills (Al-Zahrani, 2015; Kiran & Farooq, 2022; Sya'Roni et al., 2020; Tabieh & Hamzeh, 2022). The use of a flipped classroom that utilises the exploration of materials before class allows students to be more prepared (Milman, 2012) and participate more in the discussion to provide various possible solutions representing domain of flexibility (Libre, 2021).



(a) Treatment group (b) Treatment group

Figure 4: Comparison of respondents' scripts for flexibility

6. Recommendation for future studies

This study used a quasi-experimental design to examine the effectiveness of flipped classrooms. The study was carried out on a small scale using a control group and a pre- and post-test design. Consequently, the researchers suggest that this study be carried out again with a few modifications. The first recommendation for further research relates to various fields of mathematics, including statistics and algebra. Additional research might yield different findings and viewpoints.

The second recommendation is to employ alternative intervention strategies in future studies. For this study, flipped classroom was used. Different constructivist approaches, such as project-based learning, differentiated learning, or mastery learning, might be used to conduct further studies. Additionally, previous studies indicate that these strategies help to improve students' achievement in mathematics. Given the issues associated with current learning, the two suggestions for more study need to be considered as well as put into practice.

7. Implication of the study

There are several implications to this study. Implication for teaching and learning has been identified as the first implication. Lecturers should choose effective strategies to improve students' understanding of a certain topic that is being studied. Choosing an effective strategy has a big impact on students. This study shows that flipped classroom is able to increase achievement in calculus. In addition, lecturers can prepare students to be more independent, responsible, and ready in their own learning. Through this study, lecturers can see the effect of flipped classroom more specifically in calculus and consider the use of this approach in teaching delivery.

In addition, the adoption of the flipped classroom model carries a theoretical implication that can impact educational practices. Flipped classroom aligns with constructivist theories of learning, emphasizing active engagement and participation. By placing the responsibility for initial content acquisition on students outside the classroom, the model supports active learning during in-person sessions, fostering a deeper understanding of concepts through collaborative activities and discussions.

8. Conclusion

According to the findings and discussion, flipped classroom can be regarded as an alternate teaching technique. The findings of this study add to the body of knowledge for assessment of students' creative thinking skills in mathematics learning at higher education institutions through the use of empirical evidence, which is important given the significance of mathematical performance and creative thinking skills in producing a generation with thinking capability. This study discovered that the flipped classroom enhances students' performance in mathematics and their capacity for creative thinking skills, particularly flexibility. Although the results for domain fluency among students exposed to the flipped classroom were not statistically significant, students should be given enough time to adjust to this new approach to learning mathematics. To accomplish the aims of national education, educators must adapt and shift their paradigm while using the flipped classroom in mathematics instruction. Changes must be undertaken carefully to provide students with the opportunity and support they require to master mathematics by the time they graduate.

Appendix

Appendix: Creative Thinking Skill Rubric

The Creative Thinking Skills Evaluation

Measured aspects	Students' responses to questions	Score
Fluency	*No answer*	*0*
	Giving incorrect answer	*1*
	Giving correct answer	*2*
	Give more than one correct answer but find no answer pattern	*3*
	Give more than one correct answer and find the answer pattern	*4*
Flexibility	*Not answering*	*0*
	Find a solution strategy but give the wrong answer	*1*
	Find a solution strategy with calculation processes and correct answer	*2*
	Finding more than one solution strategy but one of them is incorrect because there is a mistake in the calculation process	*3*
	Discover more than one solution strategy and calculation process and true answers	*4*

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