Mathematics Learning Outcomes and Student Engagement Through the Implementation of a Flipped Classroom Learning Model

Ma Ul Uyun, Mailizar Mailizar, Elizar Elizar*

Universitas Syiah Kuala, Aceh, Indonesia

*elizar@usk.ac.id

Abstract: This study compares the improvement in mathematics learning outcomes and student engagement between students participating in the flipped classroom model and those participating in conventional learning. This quantitative research employed a pretest-posttest control group design. The research sample consisted of 127 Grade 11 students from one of the high schools in Banda Aceh. We collected data using two instruments: a mathematics learning outcome test and a student engagement questionnaire. The results of the data analysis indicate that the improvement in mathematics learning outcomes and student engagement for students who participated in flipped classroom learning was better than that of students who participated in conventional learning. However, there was no significant difference in behavioral engagement between the experimental and control groups. The findings demonstrate that the flipped classroom model can improve student engagement and mathematics learning outcomes.

Keywords: flipped classroom learning model, mathematics learning outcomes, and student engagement

INTRODUCTION

Technological developments have stimulated the education system and teachers to integrate technology into learning, thus providing more experiences for students to interact with technology as a powerful learning tool (Clark-Wilson et al., 2015). This development allows teachers and students to communicate through the Internet and increases opportunities for better learning (Martinovic et al., 2013). These findings highlight how technological advancement supports improvements in students' mathematics outcomes by offering interactive, flexible, and engaging tools for learning.

However, in the 21st century generation of learners, technology-enabled mathematics learning in the traditional classroom has made little progress in improving mathematics learning (Limniou et al., 2018). This is also seen in one of the Senior High Schools in Banda Aceh, Indonesia. Based on these observations, students had insufficient preparation before entering the class. Students learn when the teacher presents the material using PowerPoint, discusses concepts, and solves problems at home. These materials are collected before the next session without further presentation or discussion related to the assigned tasks.

Another concern is the use of class time. Pre-discussion activities before group work in class consume significant time (Chang & Brickman, 2018), whereas the typical duration of mathematics classes in schools is only 90 minutes per session. This limited time-frame allows teachers enough time to thoroughly and accurately explain each mathematical concept, leaving fewer opportunities for students to actively engage in learning. Consequently, this contributes to students' low understanding of the material and poor mathematics learning outcomes.

To address these challenges, a learning model is required to actively engage students in learning and enable them to solve diverse mathematical problems while effectively utilizing information and communication technology. One such model is the flipped classroom learning model. The flipped classroom represents a strategic reversal of the traditional classroom structure (Bergmann & Sams, 2012). In this model, students engage in initial exposure or exploration of learning content outside the classroom, while in-class time is dedicated to activities such as discussion, reflection, problem-based learning, and evaluation (Abah et al., 2017; Bergmann & Sams, 2012; Lo et al., 2017; Singh et al., 2018; Yang et al., 2019).

Students watch the video on the Canvas LMS platform prior to in-class learning. Canvas LMS enables teachers to create various content, including assignments, quizzes, discussions, and learning videos (Pahliansyah, 2021). After studying the basic material, students must make individual notes and compile a list of questions related to the content on Canvas LMS for in-class discussion (Ramadhani et al., 2019; Wei et al., 2020). This model fosters increased teacher-student interactions during classroom learning sessions (Singh et al., 2018; Utami, 2017).

The flipped classroom model has garnered significant attention in education (Goodwin & Miller, 2013; Hamdan et al., 2013). Its benefits have been widely documented over the past decade (Bishop & Verleger, 2013; Chua & Lateef, 2014; Love et al., 2014; Missildine et al., 2013; Yarbro et al., 2014). Studies have shown that students engaged in flipped classroom learning often achieve better mathematics learning outcomes than those in traditional classes (Nurfadilla, 2022; Pratiwi, 2021; Tirani et al., 2022), unlike previous research, which primarily compared learning outcomes between two groups, this study examines differences in the improvement of learning outcomes for students engaged in flipped classroom learning versus those in conventional learning.

Recent studies have also explored the impact of the flipped classroom model on student engagement (Cevikbas & Kaiser, 2022; Cronhjort et al., 2018; Lo & Hew, 2020; Hodgson et al., 2017). However, few have specifically addressed student engagement within the context of high school mathematics education, nor have they compared the enhancement of engagement between flipped classrooms and conventional classes. Cronhjort et al. (2018) holistically examined student engagement in flipped classrooms without focusing on individual engagement components, such as behavioral, cognitive, and emotional dimensions. Conversely, some researchers have examined only specific dimensions, such as cognitive engagement (Lo & Hew, 2020) or behavioral engagement (Hodgson et al., 2017). Therefore, in contrast to previous studies, this research delves deeper into student engagement by examining all three dimensions: behavioral, cognitive, and emotional. In addition, this study will specifically measure students' mathematics learning outcomes, focusing on their mathematical understanding and representation ability related to functions and their modeling. To support out-of-class instruction and learning activities, the Canvas LMS platform will be utilized, allowing for structured access to instructional content and interaction beyond the classroom. Based on the aforementioned considerations, this study proposes the following research questions.

a. Is the improvement in mathematics learning outcomes of students participating in flipped classroom learning greater than that of students participating in conventional learning?

b. Is the improvement in engagement of students participating in flipped classroom learning greater than that of students participating in conventional learning?

c. Are the behavioral, emotional, and cognitive engagement levels of students participating in flipped classroom learning greater than those participating in conventional learning?

LITERATURE REVIEW

Student Engagement

This research focuses on the three dimensions of student engagement described by Fredricks et al. (2004). This three-dimensional framework is based on a comprehensive synthesis of educational research, encompassing all aspects of student engagement in the school environment. These dimensions have been widely adopted in student engagement research (Bond, 2020).

First, the core concept of behavioral engagement is participation, which includes both positive behaviors (e.g., following rules) and the absence of disruptive behaviors (e.g., skipping class) (Fredricks et al., 2004). Behavioral engagement also encompasses completing pre-class learning tasks in flipped classroom models (Cevikbas & Kaiser, 2022). Second, emotional engagement pertains to students' affective reactions, such as interest, satisfaction, and anxiety. Third, cognitive engagement refers to the degree of investment in learning (Fredricks et al., 2004). This dimension is characterized by students' willingness to exceed learning objectives and their preference for challenges, such as a desire to comprehend complex material (Mursalina et al., 2019).

Flipped Classroom Learning Model

The literature offers various definitions of the flipped classroom. According to Kellinger (2012), a flipped classroom is a learning model in which students utilize technology to master content at their own pace at home and engage in group discussions to prepare for subsequent lessons. Kordyban and Kinash (2013) described the flipped classroom as a model in which students access traditional content outside of class through mediums such as videos, podcasts, interactive games, blogs, or traditional reading materials. Their homework may involve watching videos, taking notes, and preparing questions or discussion points for the next class session. Based on these definitions, the flipped classroom can be characterized as a learning model with two components: activities conducted outside the classroom, such as watching videos, listening to podcasts, or reading articles, and interactive learning during class sessions, often facilitated through group discussions.

The flipped classroom offers several significant advantages. It fosters teamwork and class discussion, enables students to watch videos anytime and anywhere, allows learners to set their own pace according to their needs, and encourages critical thinking inside and outside the classroom (Kellinger, 2012). Additionally, this model allows teachers to employ various learning strategies, providing more time for teacher-student interactions and enabling educators to better understand students' emotional needs (Susanti et al., 2019). Parents can also play a supervisory role, offering support to their children. Furthermore, the flipped classroom model gives students more creative exploration time (Goodwin & Miller, 2013).

Despite its advantages, implementing the flipped classroom model poses several challenges. The most significant challenge is the time required to prepare teaching materials, such as videos, images, and written content, particularly during the first year of implementation in schools or institutions (Susanti et al., 2019). Another challenge is ensuring that students fulfill their responsibilities outside the classroom (Bristol, 2014). Additionally, some students face obstacles in adopting the flipped classroom model due to a lack of access to essential equipment, such as smartphones, tablets, or computers, and issues with internet connectivity (Kordyban & Kinash, 2013). Thus, the flipped classroom model's benefits and challenges may arise from the model's design, the learning environment, or the way educators implement it.

Mathematics Learning Outcomes

Learning outcomes are a central indicator of the effectiveness of the educational process. According to Aditya (2016), learning outcomes refer to the abilities acquired by students due to their learning experiences in school. These relatively stable outcomes represent potential behavior changes resulting from knowledge and training. Similarly, Pandey (2017) defines learning outcomes as the acquisition of knowledge or information demonstrated through students' understanding, skills, and techniques developed in a particular subject at a given stage. In this context, mathematics learning outcomes reflect students' mathematical abilities gained through the teaching and learning process over time, typically measured through test scores.

Multiple factors influence students' mathematics learning outcomes. Gunaseelan and Pazhanivelu (2016) categorize these factors into demographic, instructional, and individual domains. Expanding on this, Maamin et al. (2021) highlight that in ASEAN countries, student-related factors (such as gender, demographics, skills, knowledge, attitudes, and engagement) and family-related factors (such as socioeconomic status) significantly affect mathematics achievement. Additionally, teacher-related aspects—including pedagogical content knowledge, teaching strategies, and attitudes—and school-level factors, such as institutional policies and engagement, are also influential. These interconnected factors must be considered early in the learning design to enhance student outcomes effectively.

Given these influencing factors, the flipped classroom model has emerged as a promising way to improve mathematics learning outcomes. In this model, direct instruction occurs outside of class, freeing classroom time for collaborative problem-solving, discussions, and deeper learning activities. Research consistently shows that the flipped classroom can positively influence students' performance in mathematics. Research consistently shows that this model can positively impact students' mathematics learning outcomes. For instance, Baybayon and Lapinid (2024) reported a significant difference between pre-assessment and summative assessment scores, with a substantial effect size, indicating improved student performance in solving quadratic equations. Similarly, O'Flaherty and Phillips (2019) found that incorporating quizzes and maintaining face-to-face class time further strengthened the effectiveness of flipped classrooms. Other studies, such as those by Sopamena et al. (2023), have shown moderate but consistent positive effects on student achievement in university-level mathematics.

While benefits are evident, challenges such as technological barriers and varied student readiness remain, as noted in Indonesian-based studies (e.g., IOP Science, 2020). Addressing these issues through thoughtful instructional design and support is critical for optimizing the impact of flipped learning environments. In conclusion, individual, instructional, familial, and institutional factors shape students' mathematics learning outcomes. When effectively implemented and supported, the flipped classroom model provides a conducive framework for addressing these variables and enhancing student achievement in mathematics.

METHODS

Research Design

This study employed a quantitative research approach with a pre-post-test control group design. Both pretests and post-tests were administered to the control and experimental groups. The experimental group utilized the flipped classroom learning model, while the control group adhered to the conventional learning model. The study was conducted over a total of 12 hours spanning four weeks. During this period, the experimental group was required to bring a cell phone or mobile wireless device to school.

Sample

The research population comprised 175 Grade 11 students from a high school in Banda Aceh, Indonesia, distributed across five classes with 35 students per class. The sampling technique used was cluster random sampling, resulting in a sample of 127 students, with 66 students assigned to the experimental group and 61 to the control group.

Instrument

The primary instrument used in this study was a mathematics learning outcomes test. This test consisted of nine long-answer questions incorporating various problems related to functions and their modeling. The test was designed based on indicators of mathematical understanding and representation skills. The indicators of mathematical understanding were adapted from Kilpatrick and Swafford (2020) and included 1) Representing learned concepts, 2) Classifying objects based on whether they meet the criteria defining a concept, 3) Applying concepts algorithmically, 4) Providing examples and non-examples of learned concepts, 5) Presenting concepts in various mathematical representations, and 6) Establishing connections among different concepts, both internal and external to mathematics.

The indicators of mathematical representation refer to three types proposed by Villegas (2009) (see Table 1).

Representation	Indicator
Pictorial Representation	Create tables, diagrams, or graphs to solve the given problem.
Symbolic Representation	Mathematical modeling is used to solve the problem based on the given information.
Verbal Representation	Solve problems using written or spoken words.

Table 1: Indicator of Mathematical Representation

This study also utilized a modified student engagement questionnaire based on Norazmi et al. (2017). The questionnaire employed a Likert scale of 24 positive and negative statements, each with five response options. Each response was assigned a score ranging from 1 to 5. In a study on student engagement by Fredricks et al. (2004), student engagement encompasses multiple dimensions. Therefore, the questionnaire was adapted from their meta-construct to measure student engagement across three dimensions: behavioral, cognitive, and emotional, in alignment with the objectives of this study.

The following modifications were made to ensure the questionnaire's relevance and clarity for this research: The original English version was translated into Indonesian to ensure students could easily comprehend each statement. All "flipped classroom" instances were replaced with "math learning" to avoid potential confusion among students.

The questionnaire items were tailored to reflect the mathematics material taught. Specifically, the term "Writing" from English learning was replaced with "Functions and their Modeling" to align with the mathematics content of this study. The instruments were validated by two experts: one specializing in Mathematics Education and the other in Measurement and Evaluation. Both instruments were subsequently trial-tested. The reliability coefficient for the math learning outcomes test, calculated using the Kuder-Richardson Formula 20 (KR-20), was 0.718. Similarly, the internal consistency of the student engagement questionnaire was determined using Cronbach's Alpha, yielding a reliability coefficient of 0.837.

Data Analysis

We examined the normality of the data on mathematics learning outcomes and student engagement to determine the appropriate statistical tests. The results indicated that the N-Gain data for mathematics learning outcomes were normally distributed ($p > 0.05$). Consequently, the data were analyzed using the Independent Sample t-test to address the first research question. In contrast, the N-Gain data for student engagement were not normally distributed ($p < 0.05$). Therefore, non-parametric statistical tests, specifically the Mann-Whitney U Test, were employed to address the second research question. For the third research question, post-test data were analyzed using the Independent Sample *t*-test. All statistical analyses were conducted using SPSS version 25.

RESULTS

After the pretest, students were assisted in creating an account and instructed on using the Canvas application. They watched a video outside the classroom and posted their questions in the comment section. Other students responded to these questions, while the teacher corrected any inaccurate answers (see Figure 1). Following the discussion activity outside the classroom, the students completed a quiz to assess their understanding after watching the video.

In class, the teacher organized students into groups to solve the problems provided in the worksheet. Students were encouraged to present the outcomes of their discussions and engage in debates on the given problems. Additionally, this process was continued until the end of the learning session.

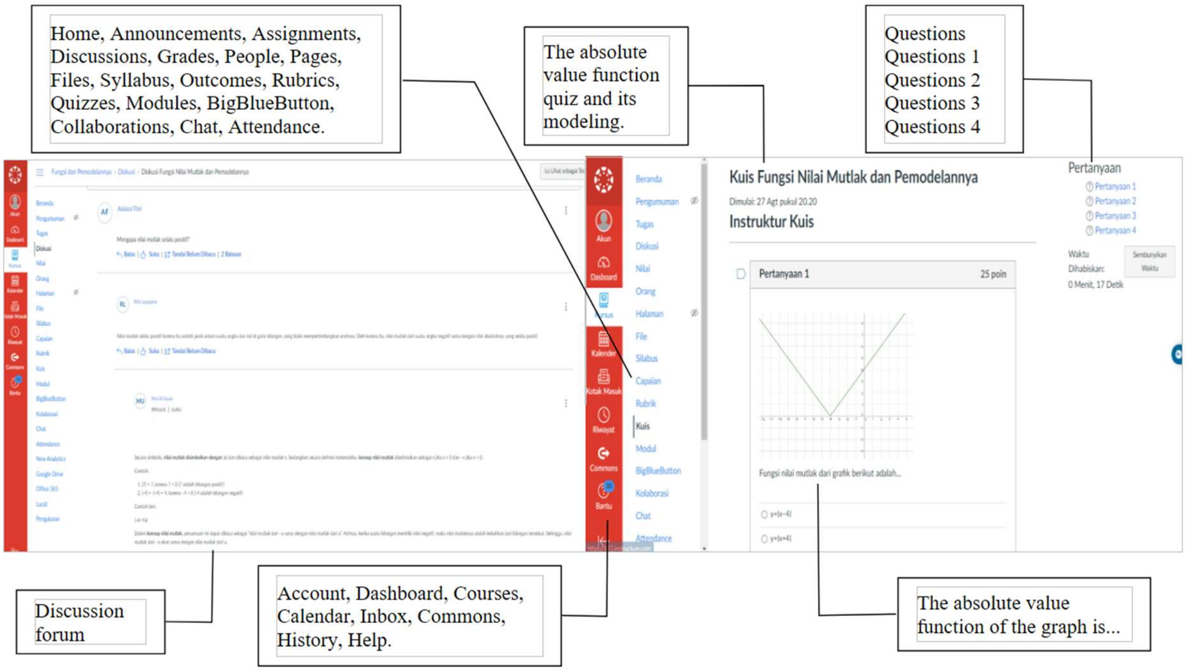

Figure 1: Students' Activities Outside the Classroom Through Canvas Application

Findings Related to Question 1

The descriptive statistics and the t-test results of the N-Gain for the mathematics learning outcomes data are presented in Table 2.

Group	Test	*N*	Mean	*SD*	Average N-Gain	*t*	*p*
Experiment	Pretest	66	38.33	11.57	0.57	4.754	<0.001*
	Posttest	66	73.98	9.73			
Control	Pretest	61	40.04	9.72	0.42		
	Posttest	61	66.35	7.30			

Table 2: The t-test results of the N-Gain for the mathematics learning outcomes data
*$p < 0.001$ is reported as 0.000 in the statistical output.

Based on Table 2, the t and p values demonstrate a significant difference between the experimental and control classes' N-Gain ($t = 4.754$, $p < 0.001$). This finding indicates that the average improvement in mathematics learning outcomes for students who participated in flipped classroom learning was significantly higher than that of students who participated in conventional learning.

Findings Related to Question 2

Table 3 presents the descriptive statistics of student learning engagement and the results of the Mann-Whitney U Test on the N-Gain scores for the experimental and control groups.

Group	Test	*N*	Mean	*SD*	Average N-Gain	*U*	*p*
Experiment	Pretest	66	71.89	13.27	0.09	1417.000	0.004
	Posttest	66	77.47	12.72			
Control	Pretest	61	73.11	13.78	-0.05		
	Posttest	61	71.02	16.51			

Table 3: The t-test results of the N-Gain of Student Learning Engagement

Table 3 shows a significant difference between the N-gains of the experimental and control classes (U = 1417.000, p = 0.004). It can be concluded that the average increase in learning engagement of students who participated in flipped classroom learning was better than that of students who participated in conventional learning.

Findings Related to Question 3

To determine the level of students' behavioral, cognitive, and emotional involvement in each item of the involvement questionnaire statement, we first calculated using the Independent Sample t-test on the post-test data of the two sample groups.

	Group	N	Mean	SD	*t*	*p*
Behavior	Experiment	66	3.25	0.52	1.674	0.097
	Control	61	3.10	0.43		
Emotional	Experiment	66	3.31	0.52	4.008	<0.001*
	Control	61	2.90	0.62		
Cognitive	Experiment	66	3.39	0.60	4.187	<0.001*
	Control	61	2.88	0.73		

Table 4: T-test Results of Engagement Data Based on Behavioral, Emotional, and Cognitive Dimensions

*$p < 0.001$ is reported as 0.000 in the statistical output.

Based on Table 4, the t and p values indicate no significant difference in behavioral engagement between the experimental and control classes (t = 1.674, p = 0.097). This suggests that the average behavioral engagement of students who participated in flipped classroom learning was not higher than that of students who engaged in conventional learning. However, for the emotional dimension, there was a significant difference between the two classes (t = 4.008, $p < 0.001$), indicating that the average emotional engagement of students who participated in flipped classroom learning was higher than that of students in conventional learning. Similarly, the cognitive dimension also showed a significant difference between the two classes ($t = 4.187$, $p < 0.001$), demonstrating that the average cognitive engagement of students in the flipped classroom model outperformed those in conventional learning.

Statement	Experiment	Control	Sig.
B1: I can focus well during math lessons.	3.09	2.40	<0.001*
B2: I actively participate in math education.	3.52	2.95	<0.001*
B3: I can complete the assigned tasks effectively.	3.26	3.47	0.179
B4: I can complete assigned tasks using the learning materials provided.	3.52	3.07	0.006
B5: I strive to complete activities and tasks during math learning.	3.09	3.08	0.897

Table 5: Average Difference in Behavioral Engagement Items
*$p < 0.001$ is reported as 0.000 in the statistical output.

Based on Table 5, item B2: "I actively participate in math education" (mean = 3.52), and item B4: "I can complete assigned tasks using the learning materials provided" (mean = 3.52) received the highest scores among all items in the experimental class. In contrast, item B1: "I can focus well during math lessons" (mean = 3.09), and item B5: "I strive to complete activities and tasks during math learning" (mean = 3.09), received the lowest scores among all items in the control class. According to the significance values (Sig.) in Table 5, there is a significant difference ($p < 0.001$ for B1 and B2, $p = 0.006$ for B4) between the two groups on most items, except items B3 and B5.

Statement	Experiment	Control	Sig.
E1: I am happy with the math I have learned in this class.	3.52	3.06	0.007
E2: I think the math lessons are interesting.	3.52	2.46	<0.001*
E3: I feel confident doing the tasks given to me during the math lesson.	3.10	2.62	0.004
E4: I liked the math lesson because it allowed me to learn at my own pace.	3.09	2.46	<0.001*
E5: I like how mathematics is conducted because it allows me to learn anytime and anywhere.	3.52	3.15	0.039
E6: The math lesson was boring.	3.32	2.96	0.038
E7: The math lesson motivated me to learn about functions and their modeling.	3.52	3.07	0.006
E8: I feel anxious (worried, anxious, afraid, nervous) learning about functions and their modeling without a teacher.	3.52	3.33	0.089
E9: I enjoy receiving feedback on the tasks I have completed.	3.10	3.07	0.843
E10: I am worried about my ability to solve function problems and their modeling after participating in	3.26	2.36	<0.001*

math learning.			
E11: I feel ready to learn about functions and their modeling with the implemented math learning.	3.52	3.07	0.007

Table 6: Average Difference in Emotional Engagement Items
*$p < 0.001$ is reported as 0.000 in the statistical output.

Based on Table 6, the items E1: "I am happy with the math I have learned in this class" (mean = 3.52), E2: "I think the math lessons are interesting" (mean = 3.52), E5: "I like the way mathematics is conducted because it allows me to learn anytime and anywhere" (mean = 3.52), E7: "The math lesson motivated me to learn about functions and their modeling" (mean = 3.52), E8: "I feel anxious (worried, anxious, afraid, nervous) learning about functions and their modeling without a teacher" (mean = 3.52), and E11: "I feel ready to learn about functions and their modeling with the implemented math learning" (mean = 3.52) received the highest scores among all items in the experimental class. According to the significance values (Sig.) in Table 6, most items showed significant differences between the experimental and control groups. Items E2, E4, and E10 were highly significant ($p < 0.001$), items E1, E3, E5, E6, E7, and E11 were significant ($p = 0.006–0.039$), except items E8 and E9.

Statement	Experiment	Control	Sig.
C1: I experience confusion when learning mathematics.	3.52	3.07	0.008
C2: I find learning functions and modeling materials easy with the implemented math learning.	3.52	2.62	0.003
C3: I often review learning materials to complete my assignments.	3.26	2.76	0.003
C4: I can clearly express my ideas to complete the task with the implemented math learning.	3.52	2.36	0.006
C5: The math lesson helped me review the lesson.	3.57	2.62	<0.001*
C6: The math lessons helped me remember what I had learned and what I was learning in class.	3.55	2.62	<0.001*
C7: I believe that I can solve problems with functions and their modeling well.	2.98	2.69	0.072
C8: Math learning encouraged me to explore more about functions and their modeling online to complete assignments.	3.26	2.76	0.003

Table 7: Average Difference in Cognitive Engagement Items
*$p < 0.001$ is reported as 0.000 in the statistical output.

Item number C5: The math lesson helped me review the lesson (mean = 3.57) in Table 7, which received the highest score among all items in the experimental class. Item C7: I believe I can solve problems or problems of functions, and their modeling well (mean = 2.98) got the lowest score among all items in the control class. Based on Table 7, most items showed significant differences between the experimental and control groups. Items C5 and C6 were highly significant

($p < 0.001$), items C1, C2, C3, C4, and C8 were significant ($p = 0.003–0.008$), whereas item C7 did not show a significant difference.

DISCUSSION

Improvement of Students' Mathematics Learning Outcomes

The data analysis revealed that students who participated in flipped classroom learning demonstrated a greater average improvement in mathematics learning outcomes than in conventional learning. This result can be attributed to several advantages of the flipped classroom model. One of its key strengths is the incorporation of various interactive activities into the classroom, such as problem-solving, discussions, question-and-answer sessions, and group work (Bergmann & Sams, 2012; Bishop & Verleger, 2013; Tekin & Emmioğlu-Sarikaya, 2020).

Another notable advantage of the flipped classroom model is that students can revisit video content as needed, allowing repeated and personalized engagement with the material (Bergmann & Sams, 2012). For instance, students in the study by Clark-Wilson et al. (2015) reported that watching videos enhanced their comprehension of lesson content. Abeysekera and Dawson (2015) further highlighted that video-based learning can help students manage cognitive load and support those underprepared during the initial stages of learning. Similarly, it is noted that this model benefits students by offering additional support early in the learning process (Lo & Hew, 2020).

These findings align with those by Uy (2022), which demonstrated that students in the experimental group who learned mathematics through the flipped classroom model significantly outperformed their peers in the control group. Harmini et al. (2022) also reported that students studying calculus with the flipped classroom model achieved higher scores than those in conventional classrooms. Wei et al. (2020) found that students utilizing the flipped classroom model outperformed those using traditional instructional methods.

Increased Student Learning Engagement

The results of the data analysis showed that the average learning engagement of students who participated in flipped classroom learning was better than that of students who participated in conventional learning. Cassum et al. (2017) suggested that when teachers provide active learning opportunities in the classroom, such activities should encourage communication, student engagement, creativity, independence, and critical thinking. Students' experiences in both groups showed that the flipped classroom model positively impacted student engagement. Therefore, active learning, peer instruction, and discussion in the flipped classroom were critical for the success of this model.

The results of this study are in line with several other studies. Lo and Hew (2020) showed that students in gamification-based flipped classrooms significantly outperformed those with a non-flipped classroom model (lecture-based and online teaching). The findings indicate that students in flipped classrooms have higher levels of cognitive engagement. Similarly, Muir and Geiger (2016) and Muir (2017) demonstrated that the flipped classroom increased student engagement in mathematics at the school level. Clark (2015) also found that the flipped classroom positively affects engagement, especially during classroom activities. In addition, Hodgson et al. (2017) attempted to assess behavioral engagement in three pre-college settings using an observation instrument. However, they found that the flipped classroom intervention did not increase behavioral engagement more than traditional learning, contrary to commonly reported results.

Behavioral, Cognitive, and Emotional Engagement of Students

The study results show that the behavioral engagement of students who participated in flipped classroom learning was not better than that of students who participated in conventional learning. The questionnaire results revealed that students in the flipped classroom could not effectively complete the learning activities. It is possible that this finding of student behavioral engagement is an impact of students' lack of ability to use technological media. This causes students to not perform all activities that should be performed outside the classroom. Students who do not conduct activities outside the classroom watch videos and take quizzes at the beginning of learning in class, while students who have done quizzes still ask questions about things they do not understand.

Akçayır & Akçayır (2018) found that inadequate student preparation before class is one of the main challenges in flipped classrooms. Other studies have also reported decreased student attendance (Giannakos et al., 2014). This is supported by Larsen (2015), who observed that secondary students tend to withdraw from class discussions and even deliberately skip class. In his case, the flipped classroom had a negative effect on students' behavioral engagements.

One of the main challenges in the flipped classroom is students' readiness or preparedness to participate in in-class activities, e.g., watching the assigned recorded videos before class. Failure to do this will affect in-class learning because students who have not completed their homework will not have the basic concepts or knowledge of the topic and cannot fully participate in the in-class activities (Skamp et al., 2019). According to Akçayır & Akçayır (2018), students who have not worked on out-of-class activities affect their preparation and learning when in class. Therefore, adequate preparation and support should be considered when planning lessons implementing the flipped classroom model (Leo & Puzio, 2016; Ngo & Eichelberger, 2021).

The results also revealed that the emotional and cognitive engagement of students who participated in flipped classroom learning was better than that of students who participated in conventional learning. Several concurrent studies (e.g., Dove & Dove, 2015) have reported that positive flipped classroom learning experiences helped students reduce their anxiety when learning mathematics. Lo and Hew (2020) found that using game design elements (e.g., digital points and badges) in the flipped classroom can motivate students to complete more difficult tasks with higher quality than students in a traditional learning environment. Meanwhile, Van Sickle (2016) found that students in an algebra class that implemented a flipped classroom were less satisfied with the class than those in a traditional classroom. Research findings related to emotional engagement in flipped classrooms appear to be inconsistent.

CONCLUSIONS

Based on the research analysis results, it can be concluded that learning with the flipped classroom model has a significant positive impact on students' mathematics learning outcomes, which are better than conventional learning. In addition, the flipped classroom model also increases student engagement, emotionally and cognitively, which is higher than the conventional model. However, although students' emotional and cognitive engagement was more optimal, students' behavioral engagement in flipped classroom learning did not show a significant difference compared to conventional learning. This finding shows that the flipped classroom can potentially improve the quality of learning. However, some aspects must be considered to improve students' behavioral engagement.

LIMITATIONS AND RECOMMENDATIONS

This study has several limitations. First, the experiment was conducted over a relatively short period—four weeks, encompassing four meetings and a pretest and posttest. While this timeframe was sufficient to cover the target material, extending the duration of the study in future research is recommended. A longer study period would enhance the reliability and generalizability of the findings.

The second limitation concerns students' readiness to actively engage in flipped classroom activities. Some students faced challenges downloading teaching materials, watching instructional videos, and completing quizzes on the Canvas application. As a result, they could not fully participate in all the activities intended for completion outside the classroom. To address this, teachers and future researchers should allocate additional time beyond a single day to train students on navigating the LMS platform, watching educational videos, extracting key ideas, and completing quizzes before implementing the flipped classroom model.

In addition, future studies may consider incorporating student perspectives to better understand the challenges they encounter in a flipped classroom environment. Including interviews or open-ended questions in the questionnaire could allow students to elaborate on their experiences and the reasons behind their level of engagement or preparedness, particularly regarding out-of-class learning tasks. Gaining qualitative insights into students' perceptions of non-readiness or lack of preparedness during synchronous sessions can provide valuable context for identifying specific barriers to effective learning and inform more responsive instructional strategies.

The findings of this study, conducted in Aceh, Indonesia, contribute to the growing body of international research on the flipped classroom model and its effectiveness in enhancing student learning outcomes and engagement in mathematics. While this study demonstrates the model's success in an Indonesian context, its implications extend beyond local settings. Similar trends have been observed globally, with research in various educational systems, such as the United States engagement (Lo & Hew, 2017) and Australia (Muir & Geiger, 2016), reporting improvements in students' cognitive, behavioral, and emotional engagement through flipped learning. These parallels suggest that the flipped classroom model is effective in specific cultural and educational contexts and can be adapted to different learning environments worldwide. However, the challenges identified in this study, such as students' readiness to engage in out-of-class activities, highlight the need for context-specific strategies to optimize the model's effectiveness. Future research should explore how socio-cultural factors, technological access, and institutional support influence the success of flipped learning in diverse global settings, ensuring that educators can tailor this pedagogical approach to meet the unique needs of students across various regions.

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APPENDIX

Appendix 1. Student Engagement Questionnaire

Name : ....
Grade : ....
Date of Completion : ....

Filling Instructions :

1. This questionnaire is solely for academic purposes. Please provide an honest answer.
2. Read and answer all questions carefully without missing any information.
3. Select the answer that is considered most appropriate to the conditions and circumstances that occur by placing a check mark (√) in the column provided with the following information:
   SD : Strongly Disagree
   D : Disagree
   MA : Moderately Agree
   A : Agree
   SA : Strongly Agree

No.	Statement	SD	D	MA	A	SA
1.	I can focus well during math lessons.					
2.	I actively participate in math education.					
3.	I can complete the assigned tasks effectively.					
4.	I can complete assigned tasks using the learning materials provided.					
5.	I strive to complete activities and tasks during math learning.					
6.	I am happy with the math I have learned in this class.					
7.	I think the math lessons are interesting.					
8.	I feel confident doing the tasks given to me during the math lesson.					
9.	I liked the math lesson because it allowed me to learn at my own pace.					
10.	I like how mathematics is conducted because it allows me to learn anytime and anywhere.					
11.	The math lesson was boring.					

No.	Statement	SD	D	MA	A	SA
12.	The math lesson motivated me to learn about functions and their modeling.					
13.	I feel anxious (worried, anxious, afraid, nervous) learning about functions and their modeling without a teacher.					
14.	I enjoy receiving feedback on the tasks I have completed.					
15.	I am worried about my ability to solve function problems and their modeling after participating in math learning.					
16.	I feel ready to learn about functions and their modeling with the implemented math learning.					
17.	I experience confusion when learning mathematics.					
18.	I find learning functions and modeling materials easy with the implemented math learning.					
19.	I often review learning materials to complete my assignments.					
20.	I can clearly express my ideas to complete the task with the implemented math learning.					
21.	The math lesson helped me review the lesson.					
22.	The math lessons helped me remember what I had learned and what I was learning in class.					
23.	I believe that I can solve problems with functions and their modeling well.					
24.	Math learning encouraged me to explore more about functions and their modeling online to complete assignments.					

Appendix 2. Math Learning Outcomes Pretest

Math Learning Outcomes Pretest

Subject : Math
Grade : XI
Problem Form : Essay
Material : Functions and Modeling
Number of Questions : 9 Items
Time : 60 min

Problem-solving Instructions:

1. Write your name and grade in the upper right corner of your answer sheet.
2. Look at each question provided. If there are questions that are not clear, ask the supervisor.
3. Do the questions honestly and independently.
4. Problems may be solved out of order.
5. Answer the given problem to the best of your ability and include the steps for solving the problem.

Questions:

1. Explain the definition of a s function.
2. Explain the difference between the shape and properties of a *piecewise* function graph and an absolute value function graph.
3. Name one example of each absolute value function and ladder function.
4. Tari is a 200-m runner. She participated in a race to commemorate the Independence Day of the Republic of Indonesia. She ran on a 200-m track in her village. For documentation purposes, a photographer stands next to the exact center of the track. Write down the function that expresses Tari's distance from the photographer in terms of Tari's distance from the track.
5. Determine the number of bacteria at the 6th minute present on a surface that started out as 50 if their proliferation is determined by an exponential function $f(t) = J_0(2)^t$ with t in minutes.
6. An employee in a company receives a salary increase because he or she has performed well. The company applies the rule that the deviation in the salary of employees with the same rank (position) is Rp 350,000.00. If the employee's salary was originally Rp2,000,000.00, determine the lowest and highest salary of employees with the same rank as the employee who received a salary increase.
7. *Playstation* rental place has the following rules. For the first hour, a fee of 20,000 is charged. If it exceeds 1 hour, up to 2 hours, the renter pays 4000. If it exceeds 2 hours until the three-hour limit, the renter must pay 60,000. The rule applies for the following hours as well. Draw a graph explaining the relationship between the length of *playstation* rental and the fee charged.
8. He walked from his house next to the highway. He cycled along the sidewalk beside the highway to the playground. The distance from his house to his playground was 10 km. Halfway between the shopping center and Made's house, there is a Singkawang Restaurant. Find the function that expresses Made's distance to Singkawang Restaurant in Made's distance to home.
9. Consider the following function:

$$f(x) = \begin{cases} 20x, 0 \le x < 2 \\ 30x - 20, 2 < x \le 3 \\ 10x + 20, 4 < x \le 6 \end{cases}$$

The function above represents the total distance traveled divided by the travel time of the three competitions of kayaking, cycling, and running in which Budi participated consecutively. Write down the information that can be obtained from the function.

Appendix 3. Math Learning Outcomes Posttest

Math Learning Outcomes Posttest

Subject : Math
Grade : XI
Problem Form : Essay
Material : Functions and Modeling
Number of Questions : 9 Items
Time : 60 min

Problem-solving Instructions:

1. Write your name and grade in the upper right corner of your answer sheet.
2. Look at each question provided. If there are questions that are not clear, ask the supervisor.
3. Do the questions honestly and independently.
4. Problems may be solved out of order.
5. Answer the given problem to the best of your ability and include the steps for solving the problem.

Questions:

1. What is an exponential function? Write down its general form.
2. Here, we explain the difference between the shape and properties of an exponential function graph and an absolute value function graph.
3. Name at least one example of a *piecewise* function.
4. Anang is a 100-m runner. He participated in a race to commemorate the Independence Day of the Republic of Indonesia. He ran on a 100-m track in his village. For documentation purposes, a photographer stands next to the exact center of the track. Write a function that expresses Anang's distance from the photographer in terms of Anang's distance from the track.
5. Determine the number of bacteria at the 4th minute present on a surface that started out as 100 if their proliferation is determined by an exponential function $f(t) = J_0(3)^t$ with t in minutes.
6. An employee in a company receives a salary increase because he or she has performed well. The company applies the rule that the deviation in the salary of employees with the same rank (position) is Rp500,000.00. If the employee's salary was originally Rp3,000,000.00, determine the lowest and highest salary of employees of the same rank as the employee who received a salary increase.
7. In an internet cafe, the internet rental payment is calculated in the following way. For the first 10 minutes, a fee of Rp2,000 is charged. This means that if an internet cafe user accesses his/her computer and internet for less than or equal to 10 minutes, he/she must pay two thousand rupiah. Likewise, for every 10 minutes thereafter, Rp2,000 will be charged. Draw a graph explaining the relationship between the length of time using an internet cafe facility and the cost of using it.
8. Kevin participated in a competition involving four activities: kayaking, cycling, swimming, and running. He traveled 30 km in a kayak for 3 hours. Next, he spent 2 hours covering 40 km on a bike course. Then, he swam 1 km for 20 minutes. Finally, Kevin ran for 2.5 hours 25 km. Let us write the function of total distance traveled divided by time traveled.
9. Consider the following function:

$$f(x) = \begin{cases} 10x, 0 \le x < 2 \\ 25x - 30, 2 < x \le 4 \\ 10x + 30, 4 < x \le 5 \end{cases}$$

The function above represents the total distance traveled divided by the travel time of the three competitions of kayaking, cycling, and running in which Amin participated. Write down the information that can be obtained from the function.