The Role of Gender and Self-efficacy on the Relationship between Flipped and Flex Blended Learning and Mathematics Abilities

Muhammad Jamaluddin*, Mustaji Mustaji, Bachtiar S. Bachri, and Auditya Purwandini Sutarto

***Abstract*—The pandemic is the right momentum for developing countries to shift their education system towards blended learning adoption despite all the potential challenges. This study aims at investigating the effects of flipped and flex blended learning models on mathematics abilities as well as the role of gender and self-efficacy. A pre-post-test quasi-experimental design with 128 eighth-grade students who were equally divided into the flipped and flex classroom models was employed. PROCESS Macro model 1 analysis revealed that flipped classroom students performed better in their problem-solving abilities than those in the flex class. A similar effect was not observed in students' conceptual understanding. Self-efficacy belief was also a strong predictor of mathematics abilities. However, it did not significantly moderate the relationship between blended models and math-related achievement. Furthermore, gender was also not associated with the effectiveness of blended learning models. This study provides insights into the potential of blended learning adoption as a future education system in developing countries.**

***Index Terms*—Blended learning, flipped classroom, mathematics, secondary school**

I. Introduction

The advance in communication and information technology creates many opportunities to improve teaching methodology for effective learning experiences which facilitate communication and interaction, engagement, and collaboration between teachers and students [1]. This led to the emergence of a blended learning system, in which a face-to-face learning system is mixed with mobile learning and online activities to provide flexible, timely, and continuous learning [2]. It aims at resulting in better learning engagement and flexible learning experiences.

Research has shown the benefits of blended learning in improving students' performance across many disciplines including mathematics [3–7]. In the mathematics discipline, for a student to be mathematically proficient, she or he should possess two main mathematical abilities: conceptual understanding and problem-solving [8]. Scholars have reported the use of conventional learning strategies made students find it difficult to understand and apply the concept of mathematics in a real-world context [9, 10]. Although previous research has documented the effectiveness of blended learning in facilitating growth in math learning as compared to the face-to-face approach, traditional lectures are still predominant in K-12 mathematics education. Teaching mathematics online has been recognized as complex due to the visual nature of the discipline [5]. There is also a view that mathematics is highly heavily structured and objective and organizes lectures differently from many other disciplines [5]. In their meta-analysis study, Cheng, Ritzhaupt, and Antonenko [11] reported that most research has focused on higher institutions mainly because the population is easier to access than K-12 schools.

Most of the blended learning approaches resemble one of four models: rotation, flex, self-blended, and enriched virtual [12]. Ashraf *et al*. [13] analyzed 57 systematic review studies and found that flipped classroom, a sub-model within the rotation model, was the most frequently implemented model while the flex model was the second. When the quality of instruction a student received was well-managed, both models demonstrated positive impacts on students' learning [6]. However, very few studies have compared the effectiveness of flipped classrooms and flex models on students' mathematics outcomes.

The blended paradigm requires students to learn the ability to self-regulate their performance and become aware of the limitation in their knowledge of complex conceptual tasks [5]. This view is aligned with the social theory of Bandura[14] which emphasizes self-efficacy beliefs as a crucial factor in individual functioning. Self-efficacy refers to an individual's belief that he or she can carry out actions necessary to achieve particular performance goals. Besides students' cognitive learning outcomes, prior research has demonstrated the effectiveness of blended learning in promoting self-efficacy.

In addition, gender is also the main determinant of the students' perception in different learning environments [15–17]. Studies have shown that male students were more motivated in blended learning environments and performed better than their female counterparts [16]. Therefore, exploration of gender differences may also offer a comprehensive profile of the blended learning approach.

Blended learning continues to provide a more innovative and high-quality learning environment, although implementation in developing countries has not received much attention [18, 19]. Developed countries have greater opportunities to cultivate blended learning environments and experiences because they are equipped with more adequate educational resources and infrastructure [20]. Developing countries, on the other hand, lack the economic resources to support blended learning adoption. Due to economic resource constraints, developing countries encounter key challenges including technological proficiency and competency that students and teachers encountered with technological use in

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Muhammad Jamaluddin and Auditya Purwandini Sutarto is with Universitas Qomaruddin, Gresik, Indonesia.

Mustaji Mustaji and Bachtiar S Bachri are with Universitas Negeri Surabaya, Surabaya, Indonesia.

*Correspondence: muh.jamaluddin27@gmail.com (M.J.)

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blended learning environments [21]. In a more recent review, Ashraf *et al* [20] reported that lack of ICT skills and infrastructure are also the most encountered barriers for teachers, students, and institutions. Accordingly, the existing evidence of the impact of blended learning on K-12 education, particularly in the mathematics domain, in emerging countries is still scarce.

Meanwhile, the COVID-19 pandemic has severely impacted the education system in over 150 countries, leading to a drastic change in some forms of remote learning [22]. At the later stages of the pandemic, schools and universities in most countries including Indonesia still were enforced to combine both online and offline courses (i.e., blended learning) to prevent the spread of the coronavirus while ensuring continued learning. The unprecedented manner and scope of the pandemic have exacerbated the aforementioned barriers because Indonesia was not prepared for this abrupt change in the educational system. However, some scholars have suggested that blended learning is gaining momentum in developing countries' education systems to shift toward blended learning practice [22, 23]. It is, then, of importance to obtain scientifically-based information.

Research Goals and Contributions

This study aims to examine the effectiveness of blended learning models (i.e., flipped and flex) in improving mathematics abilities among secondary school students. Moreover, the role of gender and self-efficacy levels in the above relationship is also explored. This current study may offer exploratory insights on whether the adoption of blended learning models can contribute to enhancing students' mathematics proficiencies.

II. Literature Review

A. *Blended Learning Models in Mathematics*

The National Council of Teachers of Mathematics (NCTM) identifies procedure knowledge, conceptual understanding, and problem-solving as three of the main strands to being mathematically proficient [8]. Conceptual understanding and procedural knowledge are essential to the development of problem-solving skills. According to a survey of an algebra test in secondary schools, students acquired high levels of procedural understanding but had low levels of conceptual understanding [10]. This may lead to students' misconceptions and errors in problem-solving. The authors suggested that education reform is needed to enhance mathematical proficiency by shifting from a major emphasis on procedure and memorization to understanding the concepts. The difficulties to understand and apply the concept of mathematics in a real-world context are largely due to conventional learning strategies which are unable to improve the students' mathematics core abilities [9]. In a more recent study, Al-Mutawah *et al* [24] found a significantly positive correlation between conceptual understanding and problem-solving skills in five domains of mathematics among 350 high school students. Students who did not possess an appropriate level of conceptual understanding of the five content domains will suffer from problem-solving capabilities. Their inability to identify and solve real-world problems will adversely impact their future professional life [25]. A blended learning approach has been proposed as a solution to this challenge. It has been developed to enhance student-centered teaching and deliver better students' learning experiences and competence development [26].

Blended learning is defined by Staker and Horn [12] as "a formal education program in which a student learns at least in part through online delivery of content and instruction with some element of student control over time, place, path, and/or pace and at least in part at a supervised brick-and-mortar location away from home." They further classified K–12 blended-learning into four-model taxonomy: 1) rotation model, 2) flex model, 3) self-blend model, and 4) enriched virtual model. The rotation model is subsequently divided into station rotation, lab rotation, flipped classroom, and individual rotation. Among other blended models, a flipped classroom is the most popular [27]. It consists of four pillars: flexible environment, learning culture, intentional content, and professional instructors [28]. Flexible environments enable teachers to understand the students' difficulties and learning styles so they may customize and update the curriculum. This learning culture shifts the learning pattern toward a student-centered setting with teachers serving as facilitators by encouraging students' participation and promoting activities with personally meaningful activities [27].

In a face-to-face learning approach, teachers employ some instructional times to convey the subject, followed by providing extracurricular activities such as practice and exercises. Students in conventional learning are often less enthusiastic and motivated; hence, they struggle to comprehend the subject [29]. On the other hand, flipped classroom students learn materials outside of the classroom using various media at their own pace. Students are allowed to repeat and review the material as much as needed. They devote the in-class session to discussing, sharing thoughts, completing exercises, and making collaborative learning [30, 31]. The flipped classroom results in better learning performance self-efficacy, intrinsic motivation, and flexibility compared to other blended, traditional, and e-learning approaches [26, 27, 32–34].

A recent systematic review reported the flex model is the second most frequently used blended learning strategy [13]. In this strategy, digital platforms facilitate mostly self-directed learning. However, teachers are accessible on-site to provide support and guidance on a flexible and adaptive as-needed. Students move on an individually customized, fluid schedule among learning modalities. The teachers provide face-to-face support through activities such as small-group instruction, group projects, and individual tutoring that are flexible and adaptive as required [35]. The syntaxes of both models are displayed in Fig. 1. While the flex model offers a fluid learning schedule that is useful for professional students and the distance-based education system, its effectiveness among K-12 students at lower education levels remains unclear. In their conceptual paper, Salleh *et al* [36] compared both models in English as a Secondary Language (ESL) classrooms. The authors suggested that when being compared to the flex classroom, a flipped model is more suitable for ESL learning because the presence of students in the Language Lab to learn English is not necessarily required. So far, however, neither quantitative nor experimental study has compared to what extent the effectiveness of the flipped and flex models implemented in other subjects, such as mathematics.

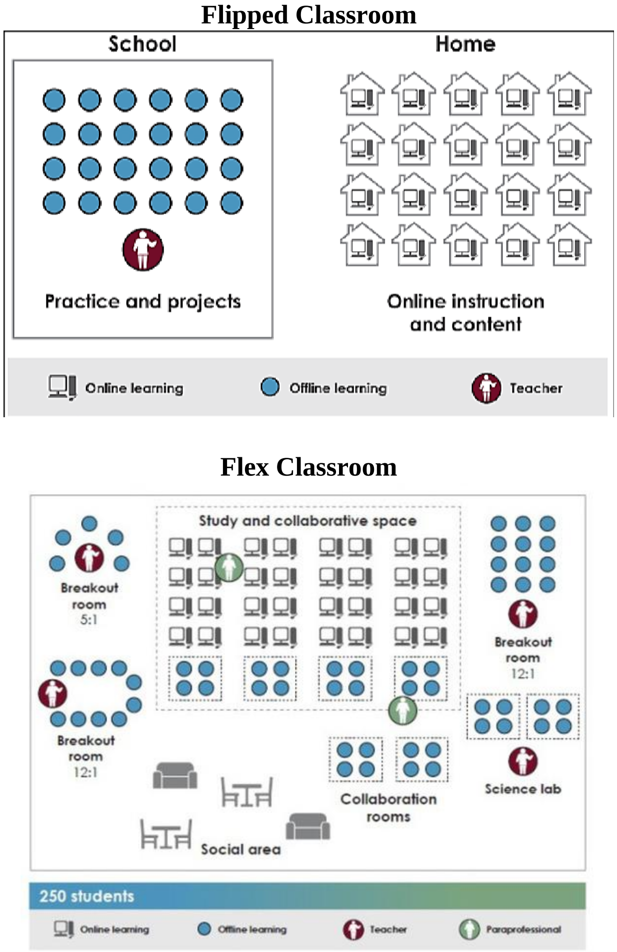

Fig. 1. Syntaxes of Flipped (above) and Flex (below) Classroom Blended Learning Models (Staker and Horn [12]).

B. *Self-efficacy and Gender*

Besides cognitive abilities, prior studies have shown that affective factors, such as self-efficacy, also significantly influenced the success of blended learning practice [37–39]. Students with high self-efficacy beliefs are likely to engage in a given task because they feel confident and competent enough to accomplish task-related goals [40]. They are also more willing to accomplish more cognitively demanding problems. When reviewing traditional learning models, [41] further reported that students whose self-efficacy is higher are more accurate in mathematical computation. They use their time and effort to solve complex mathematics problems more efficiently instead of managing stress and anxiety. While several studies have demonstrated that blended learning in mathematics courses has also enhanced students' self-efficacy levels [3, 4, 42–44], it is still little known whether students' self-efficacy levels will moderate the effect of blended models on mathematics learning outcomes.

Furthermore, gender has generally been an important issue in educational studies. Gandhi and Lynch [45] suggested that gender was associated with one's confidence in using technology learning. Although gender differences in mathematics achievement tend to diminish after students start their tertiary or higher education, the phenomena may still be prevalent even in developed countries [40]. Preliminary results indicated that male students and high-ability students were more motivated in the blended learning environment [46]. On the other hand, compared to traditional classroom learning, female students may benefit from a blended learning approach (e.g., flipped classroom) because they are satisfied with more interaction, flexibility, and many self-paced learning opportunities [15]. Moreover, Chen *et al*. [17] found that despite different topic interests in pre-calculus courses, female and male students performed equally well. Since the results of prior studies are inconclusive, it is important to explore gender differences in the effectiveness of blended learning.

Based on the aforementioned literature, accordingly, the following research questions were proposed:

1) Is there any significant difference in student's conceptual understanding and problem-solving abilities between the flipped and flex classrooms?
2) Do self-efficacy and gender correlate to students' conceptual understanding and problem-solving abilities?
3) Do self-efficacy and gender moderate the relationship between blended learning models and mathematics abilities?

III. Method

A. *Participants and Study Design*

The research design is illustrated in Fig. 2. The participants were 128 eighth-grade students from a private school in East Java, Indonesia. They were assigned equally (n = 64) into flipped and flex classrooms. The sample selection was carried out using a purposive sampling technique based on prior knowledge of the population and the specific study objectives [47].

To avoid sampling bias, the quasi-experimental study using pre-test and post-test design with careful control was adopted, as suggested by Shadish *et al*. (2002) [48]. The same teacher delivered the same learning material (i.e., Pythagorean theorem) twice a week during the six weeks of 30-minute lessons.

B. *Instruments*

To determine self-efficacy, a standardized and constructed questionnaire, developed by Setyarini [49] was used, according to the recommendation of Bandura [14]. The author reported a high degree of reliability (Cronbach alpha =0.80) and good psychometric properties. The questionnaire consists of 12 items. For individual items, the student answered on a Likert scale of 1–4 (1=strongly disagree to 4 =very appropriate). The higher the final score, the higher the self-efficacy belief. The Cronbach's alpha α in this study was 0.75.

The instrument used to evaluate students' comprehension related to the Pythagorean theorem consisted of 16 multiple choice questions with four possible answers and only one is correct. Correct answers were scored with one, and incorrect or omitted answers were given a value of zero. The instrument for problem-solving assessment consisted of four open-ended questions. Each question has a score range of 1–8. The content validity for both instruments was conducted through expert judgment. The construct validity was determined by calculating the Pearson's item-total correlation (*r*), a correlation between the question score and the overall assessment score. If the calculated *r* of each item exceeds the critical value of 0.21 (derived from Pearson's correlation table for a degree of freedom 60 and α =5%, one-tailed test), the respective item is considered valid. Fig. 3 depicts the instruments used in this study while Table I displays the Pearson's item-total correlation for all questions. The conceptual understanding and problem-solving test instruments had acceptable reliability of 0.73 and 0.69, respectively.

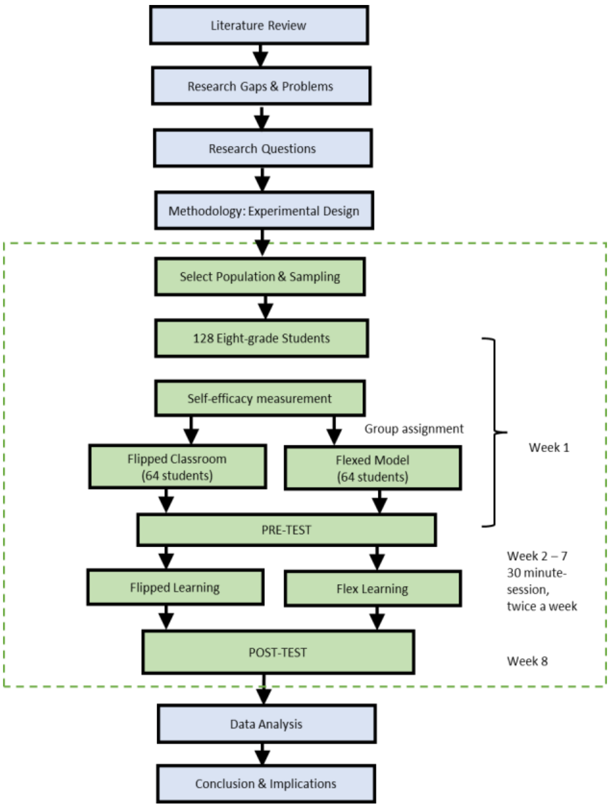

Fig. 2. Research Design and intervention procedure diagram.

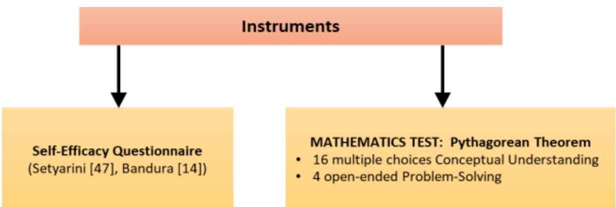

Fig. 3. Instruments used in this study.

TABLE I: PEARSON'S COEFFICIENT FOR ITEM-TOTAL CORRELATION

Conceptual Understanding				Problem-Solving	
Item	*r*-value	Nomor	*r*-value	Item	*r*-value
1	0.63	7	0.36	1	0.68
2	0.59	8	0.52	2	0.66
3	0.38	9	0.58	3	0.76
4	0.49	10	0.32	4	0.78
5	0.48	11	0.54		
6	0.64	12	0.60		

C. Procedure

This research was carried out after the second wave of COVID-19 in Indonesia during the enforcement of policy for local restrictions on the community. The policy limited people by 25–50% of the maximum capacity of workplaces or schools, depending on the area's number of COVID-19 infected cases. Prior to learning activities, the students in both blended groups completed the self-regulation questionnaires. Students were then given 90 minutes to answer the pre-test of mathematics, consisting of 16 multiple-choice questions on conceptual understanding and four open-ended questions on problem-solving. Fig. 1 (covered in dash lines) displays the flow of the intervention.

Before starting the blended learning, the teacher introduced how to access and use the learning platform and discussed the difficulties that students might encounter. For the flipped group, students watched the instructional video and self-studied other learning materials during the pre-class session. During the in-class session, they took part in the group discussions, reviewed the prior self-studied materials, and completed the worksheet or learning tasks. For the flex group, students learned the online material as directed by the teacher using electronic devices such as smartphones and computers in the classroom. The teacher supervised the class by providing flexible support according to the needs of students through tutorials and small group sessions, group projects, and personal guidance. A summative assessment (post-test) was conducted one week following the last session of the intervention. Table II illustrates the instructional design of the two groups.

TABLE II: INSTRUCTIONAL DESIGN FOR FLIPPED AND FLEX CLASSROOM

Class		Flipped	Flex
Before Class	Teacher	- Making instructional videos and other materials - Assigning students videos, text, videos, or content - Creating in-class worksheet	- Making instructional video - Preparing a learning management system - Creating homework
	Student	- Watching videos and studying learning materials - Preparing questions	- Doing previous-session homework
In-Class	Teacher	- Facilitating discussion and collaboration - Giving in-class worksheet	- Assigning students online materials to study in-class - Providing one-on-one or small group instruction when needed - Giving homework
	Student	- Reviewing prior self-studied material - Engaging in discussion - Completing in-class worksheet	- Studying materials as directed - Raising questions - Engaging in discussion
After-class	Teacher	- Preparing next lesson - Reflecting for class	Preparing next lesson
	Student	- Summarizing lesson - Providing feedback	- Doing homework

D. Data Analysis

Students were categorized as having low and high levels of self-efficacy based on their median values after adding up the scores for each item. An independent *t*-test was conducted to evaluate the association between main variables (learning models, gender, and self-efficacy levels) and math learning outcomes before and after the intervention. The paired *t*-tests were also performed to examine to what extent the math scores improved within each group.

To evaluate the moderation effects of gender and self-efficacy, PROCESS Macro model 2 was performed [50]. The dependent variable is the final students' conceptual understanding and problem-solving scores in math. The moderator variables were gender (male and female) and self-efficacy (high and low). The pre-test scores served as covariates. The statistical model is depicted in Fig. 4. Each dependent variable. All statistical analysis was conducted using SPSS 23 (IBM) at a significance level α of 0.05.

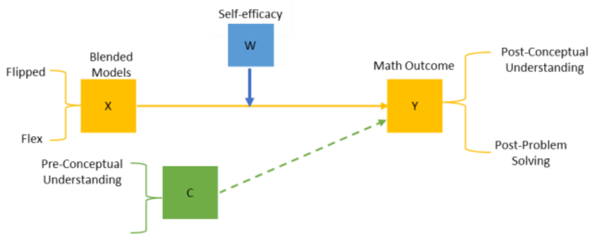

Fig. 4. Conceptual models for the effect of blended learning models (X) on mathematics performance (Y) (post-conceptual understanding and post-problem solving were analyzed separately), moderated by gender (W) and self-efficacy (Z). Pre-test scores (C) served as covariates (dash-lines).

IV. Results

A. Descriptive Statistics and Mathematics Abilities Scores at Pre and Post Intervention

Table III displays scores of conceptual understanding and problem-solving tests for each group according to the blended models, gender, and levels of self-efficacy. The independent *t*-test showed that before the intervention, there are no significant differences in mathematics scores between blended models. These indicate each group has similar baseline conditions with respect to blended models and gender. After the intervention, paired *t*-test analysis showed significant improvement within each group in both conceptual understanding and problem-solving abilities (all $p<0.001$). The flipped classroom significantly increased scores on problem-solving abilities ($t=6.32$, $p<0.001$) but not on conceptual understanding ($t=0.72$, $p=0.47$), as compared to the flex model.

B. Distribution of Mathematic Performance Scores based on Moderator Variables: Self-Efficacy and Gender

The descriptive statistics of math performance scores in each blended model based on the moderator variables and their respective statistics are shown in Table IV and Fig. 5. Independent *t*-tests showed that in both flipped and flex classes, students with high levels of self-efficacy showed significantly improved problem-solving abilities ($t=3.02$, $p<0.05$, and $t=2.34$, $p<0.05$, respectively). A similar finding was also found in conceptual understanding in the flex class group for high self-efficacy students ($t = 2.00$, $p<0.05$). However, in the flipped classroom, no significant difference between low and high self-efficacy students in their final conceptual problems scores ($t=1.02$, $p=0.31$) was noted. With respect to gender, female and male students perform equally well in conceptual understanding and problem-solving scores regardless of their blended classes (all $p>0.05$). Paired *t*-test analysis showed significant improvement following the intervention in each group (all $p<0.001$).

TABLE III: Descriptive Statistics of Main Variables and Mathematics Abilities Scores at Pre- and Post-intervention

		N	Pre Mean (SD)	Ind *t*-val	Post Mean (SD)	Ind *t*-val	Pair *t*-val
Conceptual Understanding							
Model	Flipped	64	5.56 (2.49)	0.35	11.08 (2.52)	0.72	25.68$^{\uparrow}$
	Flexed	64	5.41 (2.60)		11.39 (2.38)		23.70$^{\uparrow}$
Gender	Male	70	5.40 (2.61)	0.36	11.21 (2.37)	0.16	22.68$^{\uparrow}$
	Female	58	5.56 (2.50)		11.26 (6.34)		25.97$^{\uparrow}$
Efficacy	Low	43	3.84 (2.18)	5.87$^{\uparrow}$	10.60 (2.41)	2.10*	21.99$^{\uparrow}$
	High	85	6.32 (2.30)		11.55 (2.41)		30.72$^{\uparrow}$
Problem-Solving		N	Pre	Ind *t*-val	Post	Ind *t*-val	Pair *t*-val
Model	Flipped	64	9.73 (2.81)	0.74	24.75 3.54	6.32$^{\uparrow}$	42.26$^{\uparrow}$
	Flexed	64	9.38 (2.68)		21.11 (3.00)		30.46$^{\uparrow}$
Gender	Male	70	9.43 (2.67)	0.47	22.91 (3.60)	0.04	29.59$^{\uparrow}$
	Female	58	9.66 (2.81)		22.94 (3.86)		33.40$^{\uparrow}$
Efficacy	Low	43	8.93 (2.65)	1.86	21.42 (3.60)	3.40$^{\uparrow}$	22.06$^{\uparrow}$
	High	85	9.87 (2.75)		23.69 (3.57)		40.73$^{\uparrow}$

Notes: Ind *t*-val=Independent *t*-test value (between groups), Pair *t*-val = paired *t*-test value (within group). *Significant at $^{*}p<0.05$, $^{\uparrow}p<0.001$.

C. Moderation Effect of Self-Efficacy on the Relationship between Blended Models and Mathematics Performances

Originally, the intent was to explore the role of gender as a moderator variable. Since the result of bivariate analysis (see Table IV) revealed that gender did not significantly associate with all mathematic performance after the intervention, the evaluation of gender as a moderator variable was further dropped. Accordingly, the moderation effect of self-efficacy using model 1 (one moderator variable) was performed, instead of model 2 of PROCESS Macro [50] as previously planned. The outcome variables (*Y*) were post-conceptual understanding and post-problem solving, analyzed separately. The independent variable (*X*) for the analysis was the blended learning model while the moderator was self-efficacy (*W*). Pre-test scores served as covariates. The overall models were statistically significant for both conceptual understanding (R^2 =0.55, F (4, 123) = 37.098, p < 0.001) and problem solving (R^2 =0.50, F (4, 123) = 30.64, p < 0.001). As Table V and Fig. 6 shows, there was a significant influence of blended learning models on students' problem-solving ($t=5.05$, $p<0.001$) in which flipped students got higher scores than students in the flex class. Regarding conceptual understanding, no significant difference the two blended models was evident ($t=0.76$, $p=0.44$).

TABLE IV: Distribution of Mathematics Performance Scores in Each Blended Model Based on Self-Efficacy Levels and Gender

Model	Efficacy or Gender	N	Conceptual Understanding Pre-test Mean (SD)	Post-test Mean (SD)	Ind *t*-val	Pair *t*-val
Flipped	Low	21	4.05 (2.12)	10.62 (2.64)	1.02	17.51

	High	43	6.30 (2.33)	11.30 (2.46)		22.15
Flex	Low	22	3.64 (2.24)	10.59 (2.24)	2.00*	13.94
	High	42	6.33 (2.30)	11.81 (2.36)		21.60
Flipped	Male	32	5.63 (2.69)	10.94 (2.36)	0.44	19.88
	Female	32	5.50 (2.33)	11.22 (2.70)		16.98
Flex	Male	26	5.12 (2.54)	11.54 (2.39)	0.41	14.45
	Female	38	5.61 (2.67)	11.29 (2.39)		19.44
			Problem-Solving			
Flipped	Low	21	9.29 (2.72)	22.95 (3.31)	3.02*	24.50**
	High	43	9.95 (2.85)	25.63 (3.34)		37.51**
Flex	Low	22	8.59 (2.59)	19.95 (3.30)	2.34*	12.35**
	High	42	9.79 (2.66)	21.71 (2.60)		34.76
Flipped	Male	32	9.53 (2.80)	24.44 (3.28)	0.70	35.52
	Female	32	9.94 (2.84)	25.06 (3.80)		26.09
Flex	Male	26	9.31 (2.54)	21.04 (3.08)	0.16	15.61
	Female	38	9.42 (2.81)	21.16 (2.91)		28.93

Notes. * Ind *t*-val=Independent t-test value (between groups in each class), Pair *t*-val = paired *t*-test value (within a group based on self-efficacy or gender in each class). *Significant at **p*<0.05, ** *p*<0.01, ↑*p*<0.001.

TABLE V: MODERATING EFFECTS OF SELF-EFFICACY ON MATHEMATICS ABILITIES

Variable	Model 1		Model 2	
	Conceptual Understanding (*Y1*)		Problem Solving (*Y2*)	
	b **(SE)**	***t***	***b*** **(SE)**	***t***
Blended Model (*X*)	0.68 (0.89)	0.76	5.05 (1.42)	7.85↑
Self-Efficacy (*W*)	1.25 (1.00)	1.25	3.51 (1.61)	2.20*
Pre-Conceptual Understanding (*C1*)	0.77 (0.06)	11.71**	---	
Pre-Problem Solving (*C2*)	---		0.58 (0.09)	6.57↑
X * *W* in Conceptual Understanding	0.12 (0.6)	0.31		
X * *W* in Problem-Solving	---		1.22 (1.02)	1.21

Notes. *X* independent variable, *Y* dependent variable, *W* moderator. C1 covariates in model 1, C2 covariates in model 2. *Significant at *p*<0.05, ** *p*<0.01, ↑*p*<0.001.

Interestingly although level of self-efficacy is a significant factor to students' problem-solving abilities (t = 2.20, p = 0.03) but its interaction with blended models was not significant (t=1.21, p = 0.23). Regarding conceptual understanding, the role of self-efficacy either as an independent (t =1.25, p = 0.21) or moderation variable (t = 0.31, p = 0.76) was not detected. Therefore, the data indicated that students' mathematics achievement was not dependent on students' self-efficacy beliefs.

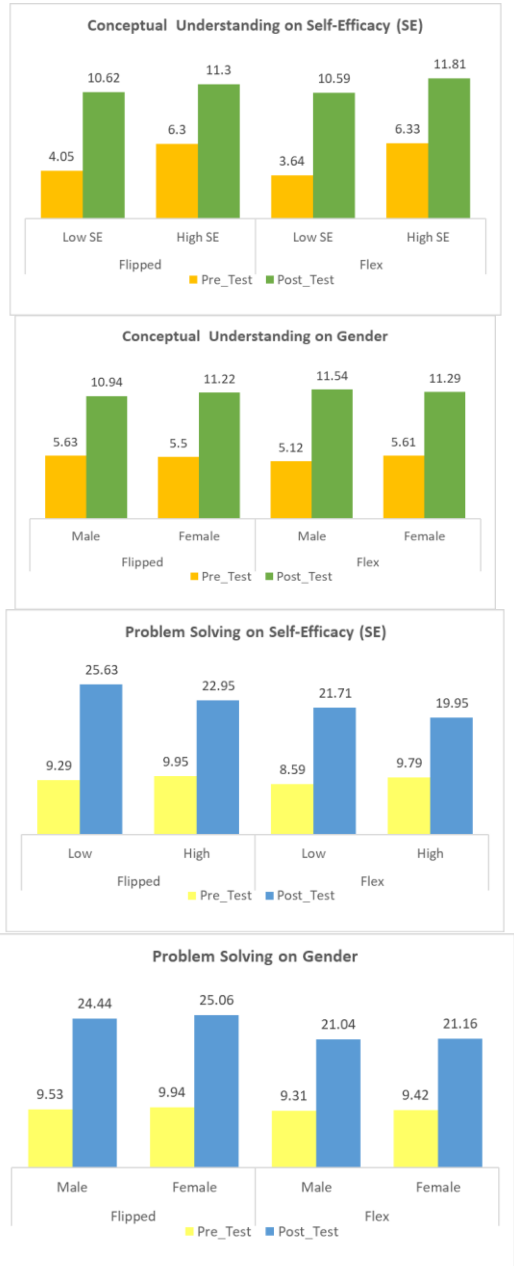

Fig. 5. Conceptual understanding and problem-solving scores before and after the intervention based on self-efficacy levels and gender.

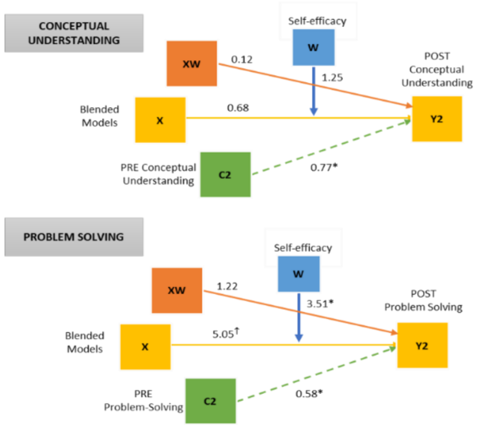

Fig. 6. Statistical diagram of the moderation of the effect of blended learning models on mathematics abilities (Y1 = Conceptual Understanding, Y2= Problem-solving) by self-efficacy (W) with pre-test score covariate. Values displayed are respective *b* regression coefficients. * Significant at *p*<0.05, *p*<0.001.

V. Discussion

This study aimed at exploring the effect of two blended learning models and the role of gender and self-efficacy as moderators on math learning outcomes. Both models improved the conceptual understanding and problem-solving scores after controlling the pre-test scores. Subjects who were assigned to the flipped classroom showed higher final problem-solving scores whereas no significant difference in conceptual understanding scores was observed between the flipped and flex classes. Furthermore, neither gender nor self-efficacy played significant roles as moderators in both blended learning models. A more detailed discussion is provided below.

These results corroborate the findings of previous work on the benefits of blended models over the traditional mathematic classroom either during normal circumstances [3, 33] or amid the pandemic [27, 51, 52]. Blended learning facilitates students to discuss the learning material and apply it as a starting point for gaining math proficiencies including conceptual understanding and problem-solving. Active blended learning promotes engagement between students and teachers. Blended learning students will be better self-regulated and tailor their learning activities at their own pace accordingly when being compared to their face-to-face counterparts.

Another important finding was the flipped classroom students significantly obtained greater problem-solving scores, compared to the flex model (see Table III). Nevertheless, it is somewhat surprising that a similar effect was not observed in conceptual understanding following the intervention. Both models helped students enhance their understanding of prior self-studies [53] but the flipped classroom was more effective in improving their problem-solving ability. Very little was found in the literature on the comparison of these two approaches in the mathematics discipline. The flex model mainly relied on online learning as the backbone of student learning [27]. Students follow a more fluid learning schedule based on their needs which is especially beneficial for the working professionals enrolled in university-level programs [54]. Lack of evidence, yet, was found in lower education levels as Anthony [6] argued that the flex model requires more fundamental modifications in instructional design than other blended models. Moreover, the flipped classroom allows students to access the learning resources as often as necessary to comprehend the explanations and activities of the topic [55]. This type of learning enables students to self-manage their whole progress and study without distraction [46]. Accordingly, they could devote their face-to-face session to reviewing the material and practice solving math-related problems. The classroom time will be utilized more effectively and efficiently. In a qualitative comparative study, Salleh [56] also suggested the flipped classroom is better appropriate for ESL classes than the flex one. The authors argued that flipped classroom teachers also get better insights into students' difficulties and learning styles, hence may provide more personal feedback and assistance to students. On the other hand, flex teachers are more difficult to accommodate students' scheduling which splits their attention [36]. These might explain why flex model was less effective than the flipped classroom in enhancing mathematical problem-solving skills.

Students' self-efficacy levels were also found significantly to influence mathematics abilities which supported evidence from previous blended learning studies [37–39, 44]. In the traditional learning approach, self-efficacy belief is also a significant determinant of students' mathematics outcomes, whether these outcomes are measured as criterion-referenced test scores or achievement indexes [40, 41]. It acts as a stronger predictor of achievement behaviors than other motivation variables such as math anxiety and academic engagement. These implied that regardless of the learning approach, students with higher self-efficacy are more persistent on challenging problems than do students with low self-efficacy. They tend to exploit their productive problem-solving strategies and become more accurate in their mathematics computation.

Contrary to expectations, this study did not find a significant moderator effect on self-efficacy in the relationship between blended models and math-related achievements. In both blended groups, students with either slow or high self-efficacy beliefs tend to demonstrate an increase in conceptual understanding and problem-solving scores. A possible explanation is that low self-efficacy students might show an increase in their self-efficacy levels after the blended learning implementation. Since this study focused on self-efficacy as a moderator rather than an outcome variable, the re-assessment of self-efficacy following the intervention was not conducted. One study showed that ninth-grade students in the algebra flipped classroom got greater results on the Mathematics Self-Efficacy Scale-Revised (MSES-R) test than those in the face-to-face classroom [42]. This result is also consistent with a recent review of the flipped classroom, which indicates that the self-efficacy level in collaborative learning has a favorable effect on the strategies adopted throughout the learning sessions [39]). Assuming self-efficacy is also measured during post-intervention, it is, therefore, possible to receive different (i.e., expected) outcomes. Further studies need to clarify this issue.

Furthermore, there is no significant correlation between gender and mathematics performance in both flipped and flex classrooms. Although it is somewhat counterintuitive, research on gender and blended learning remain inconsistent. For example, male students were more confident than female students in utilizing technology for learning and had more positive attitudes [16]. In contrast, the flipped classroom was perceived more positively among female students because of the flexibility, self-paced learning opportunities, and more collaboration features offered.

A. Limitations

This study has several limitations. First, it did not employ face-to-face or conventional methods as a control group, mainly due to the activity restriction in response to the pandemic. Future research should include a face-to-face group to strengthen the findings as it allows the researcher to confirm whether the blended model truly has effects. Second, this study focused on cognitive student learning outcomes as measured by conceptual understanding and problem-solving abilities. Further research needs to explore more diverse outcomes such as behavioral (e.g., retention rates) and affective (e.g., satisfaction, engagement) domains. Last, the results of this study may not generalize to other types of mathematics abilities or levels of education.

B. Implications

Despite the sudden implementation of hybrid learning due to the COVID-19 pandemic, this study suggests the potential benefits of both flipped and flex classrooms in improving mathematics abilities among secondary school students. The flipped classroom may be more favorable than the flex model, particularly for enhancing problem-solving performance, regardless of the students' gender and self-efficacy levels. Thus, policymakers and educators need to consider the widespread adoption of blended learning as a vital part of Indonesia's future education system. Providing necessary technology, skills, and other support or resources is then warranted.

VI. Conclusion

In summary, students in both flipped and flex classrooms showed improvement in mathematics proficiencies. The flipped classroom was more effective in increasing problem-solving abilities than the flex model. Although self-efficacy positively affected conceptual understanding and problem-solving but its role as a moderator on the blended learning models and mathematics abilities path was not significant. Furthermore, gender was not associated with blended learning math-related outcomes. Whether the unexpected findings are consequences of the impacts of our blended learning interventions or merely results of different statistical methods employed, more research needs to confirm this issue.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

MJ, MM, and AJ conceptualized the study, MJ collected the data, MM and AJ supervised the study, MM and AJ provided resources, MJ and APS performed data analysis, MJ and APS wrote the draft the manuscript. MM and AJ reviewed the draft. All authors have read and approved the final version.

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