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Blended Learning Effect on Mathematical Skills: A Meta-Analysis Study

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ABSTRACT

Blended learning facilitates the learning needs of students with maximum study time. Students will be more ready to accept material in class because they have previously studied the material at home. Previous research investigating the effect of implementing blended learning in improving math skills showed ambiguous results. Based on this gap, the purpose of this study was to examine the effect of blended learning in improving students' mathematical abilities using a meta-analytic research design. This meta-analytic study synthesized 37 effect sizes derived from 26 primary studies. The results of the study obtained a combined effect size of ($d=1.01$; $p=0.00$), this effect size is in the large effect category. It can be concluded that the use of blended learning has a major effect on students' mathematical abilities when compared to traditional learning. The results of the research based on the moderator variable show that the effect of the blended learning model on math skills is different based on the type of skill ($Qb=20.10$; $p=0.00$), media platforms ($Qb=4.12$; $p=0.04$), grade of education ($(Qb)=20.14$; $p=0.00$), and type of publication ($Qb=12.71$; $p=0.00$). However, there was no difference based on the sample size group ($Qb=0.20$; $p=0.65$). The results of this study can enrich insights into knowledge about the effectiveness of applying blended learning in improving math skills, so that it can be used as a basis for making the right decisions for stakeholders.

1. INTRODUCTION

Students' mathematical abilities can be improved through the application of appropriate learning models [1-4]. Learning is generally carried out by the teacher by delivering material in class and then students doing exercises or practices during class. Learning flow like this does not facilitate students with maximum study time. Application of learning strategies by providing appropriate study time can develop skills [5, 6]. Thus the teacher needs to facilitate the various needs of student learning time by using the right learning model. One appropriate learning model is blended learning.

Blended learning is learning that combines online learning with conventional learning (face-to-face) [7-12]. Blended learning combines indirect learning, direct learning, computer-assisted learning, and collaborative learning [13]. Blended learning facilitates students' varying learning needs with optimal study times [14-16].

In the application of blended learning, students can study independently through video teaching materials or other learning resources at home, and in other parts they can learn face to face in class. They can also ask questions easily through discussion forums to both teachers and other students [8]. Blended learning is identified as being able to increase student learning independence [17, 18]. We can say that this model facilitates student learning independence by utilizing technology.

Blended learning is able to increase learning engagement and can overcome weaknesses in traditional learning models [19-21]. The advantages of blended learning compared to traditional learning include: saving time and costs, learning is more effective and efficient, learning is not limited by space and time, students can easily access learning materials, students are free to study material online, educators can facilitate access to everyone who need it [22].

Several previous studies have examined the effect of applying blended learning models in improving mathematical abilities, providing ambiguous conclusions. Several research results such as Ayuningtyas and Prastowo; Marito and Riani; Muncarno and Astuti; Albawi; Pertiwi et al.; Ardiana et al.; Ario and Asra; Khofifah et al.; and Lo and Hew concluded that blended learning has a significant effect on mathematical ability [23-31]. While Flick's research; Jackson; and Ramdhani concluded that blended learning was not effective in improving math skills [32-34]. The results of different studies certainly provide conclusions that are still ambiguous. Based on this gap, it is necessary to carry out further research by combining or quantitatively synthesizing the results of previous research that examines the effect of blended learning in improving math skills, so that it is expected to provide more accurate results. Thus a meta-analysis research approach can be carried out.

Meta-analysis is a quantitative approach design that aims to study systematically and combine the results of estimation quantitatively from a number of previous studies that address the same research problem [35]. A meta-analysis was conducted to evaluate the results of previous studies to reach more recognized conclusions [36-38]. The nature of the meta-analysis is more objective than other review methods [35, 36]. Meta-analyses focus more on data, not on conclusions from various studies. Meta-analysis is easier to do because it is done quantitatively and focuses on effect sizes.

Setiawan et al. [15] have previously reported meta-analysis results on the blended learning effect on students' mathematical skills. Their research concluded that blended learning is effective in improving students' mathematical abilities, but the research carried out only focuses on research conducted in Indonesia. Several limitations of the research carried out was not analyzing moderator variables. Therefore, the purpose of this meta-analysis research is to examine the effect of the blended learning model in improving mathematical abilities. In addition, we also investigate whether there are other factors that can affect the effectiveness of the application of blended learning in improving mathematical mathematical abilities by analyzing moderator variables such as type of skill, media platform, level of education, type of publication, and sample size.

2. METHOD

2.1 Research design and procedures

In this study, the effectiveness of applying blended learning in improving students' mathematical abilities was tested using a meta-analytical approach. The procedure for this meta-analysis included: Determination of inclusion criteria, literature collection, literature screening, coding, and data analysis. For more details, it can be seen in Figure 1 below.

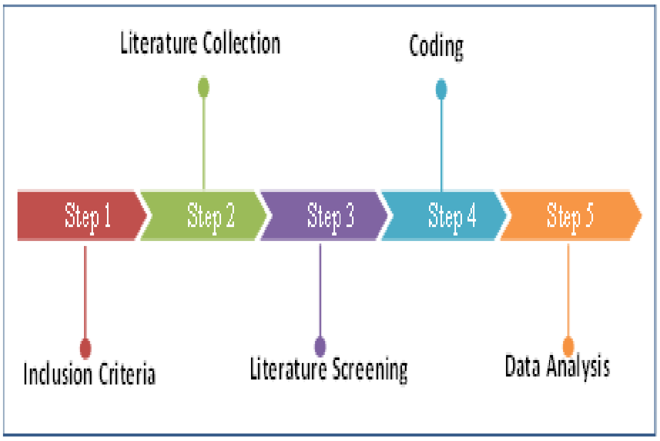

Figure 1. Meta-analytic study procedure

2.2 Inclusion criteria

Inclusion criteria were determined to determine which studies were eligible for inclusion in the meta-analysis. The inclusion criteria in this study include: a) Online publication for the last five years (2018 to 2022); b) Studies that include a master's thesis or doctoral dissertation and articles published in national or international journals; c) Using experimental or quasi-experimental research; d) There is an experimental group with a blended learning model and a control group as a comparison group; e) Studies must report statistical data such as: sample size, mean value, and standard deviation of each control and experimental group.

2.3 Literature collection

Search for relevant literature on the effectiveness of blended learning on math skills using the Google Scholar online database, ERIC, Springer publishing, DOAJ, and Elsevier. The keywords used in the literature search are "Blended learning" AND Mathematics.

2.4 Literature screening

The purpose of screening the literature is to assess the feasibility of articles used as material for meta-analysis. Screening is carried out through four stages, namely identification, screening, eligibility, and inclusion. The identification results resulted in 26 primary studies that met the inclusion criteria. However, there are several studies involving more than one control group resulting in 37 effect sizes to be analyzed.

2.5 Coding

Based on the primary studies that were collected, then the study characteristics were identified by coding. In this research, coding involved three raters. Coding content in this study includes: a) Skill type; b) Media platforms; c) Grade of education; d) Type of publication; and e) Sample size. Table 1 shows the results of the coding.

Table 1. Studies included in the Meta-analysis

Coding Content		Frequency	Percentage
Type of Skill	Learning Achievement	24	64.86%
	Critical Thinking	3	8.11%
	Problem Solving	6	16.22%
	Concept Understanding	4	10.81%
Media Platforms	LMS	21	56.76%
	Social Media	16	43.24%
Grade of Education	College	13	35.14%
	Senior High School (SHS)	9	24.32%
	Junior High School (JHS)	11	29.73%
	Primary School (PS)	4	10.81%
Sample Size	30 or less	16	43.24%
	31 or over	21	56.76%
Type of Publication	Journal	31	83.78%
	Thesis/Dissertation	6	16.22%

2.6 Data analysis

Data analysis in this meta-analysis study includes: a) Determine each study's effect size; b) performing heterogeneity test; c) calculating the combined effect size; d) moderator variable analysis; and e) publication bias evaluation. Data analysis was carried out using the OpenMEE application. As previously explained, the focus of meta-analysis studies is effect size. The classification of the effect sizes of each study and the combined effect sizes in this meta-analysis study were referred to by Cohen et al. [39] shown in Table 2 below.

Table 2. Effect size groups categories using the Cohen interpretation

Classification	Interval
No Effect	0.00 < effect size ≤ 0.19
Small Effect	0.19 < effect size ≤ 0.49
Medium Effect	0.49 < effect size ≤ 0.79
Large Effect	0.79 < effect size ≤ 1.29
Very Large Effect	effect size > 1.29

3. RESULT

3.1 Effect sizes of each study

In this meta-analysis study, the effect size of each study was calculated using the OpenMEE application. Table 3 visualizes the results of calculating the effect size of each study.

Table 3. Effect size of each study

No	Author	Effect Size	Variants
1	Ayuningtyas & Prastowo [23]	1.40	0.12
2	Marito & Riani [24]	1.81	0.11
3	Muncarno & Nelly [25]	0.92	0.12
4	Albalawi [26]	1.97	0.06
5	Pertiwi et al. [27]	0.92	0.06
6	Ardiana et al. [28]	1.40	0.07
7	Ario & Asra [29]	1.71	0.26
8	Arnawa & Setiawan study 1 [40]	0.52	0.04
9	Arnawa & Setiawan study 2 [40]	0.45	0.04
10	Flick [32]	0.05	0.04
11	HSB [41]	1.43	0.08
12	Jackson [33]	-0.20	0.08
13	Jarah & Diab study 1 [42]	0.98	0.05
14	Jarah & Diab study 2 [42]	0.97	0.05
15	Jarah & Diab study 3 [42]	0.91	0.05
16	Jarah & Diab study 4 [42]	0.19	0.05
17	Juniantari et al. [43]	1.19	0.07
18	Khofifah et al. study 1 [30]	1.43	0.08
19	Khofifah et al. study 2 [30]	0.66	0.06
20	Khofifah et al. study 3 [30]	1.40	0.08
21	Khofifah et al. study 4 [30]	0.98	0.07
22	Lo & Hew [31]	0.72	0.07
23	Makinde [44]	0.92	0.01
24	Pinontoan & Walean [45]	0.99	0.10
25	Pratiwi [46]	1.79	0.08
26	Ramadhani [47]	0.11	0.06
27	Safitri [48]	0.55	0.06
28	Sappaile et al. [49]	0.92	0.06
29	Saputra & Mujib [50]	3.15	0.13
30	Spotts & Blumme study 1 [51]	1.11	0.10
31	Spotts & Blumme study 2 [51]	0.69	0.09
32	Wei et al. study 1 [52]	0.62	0.04
33	Wei et al. study 2 [52]	0.49	0.14
34	Wei et al. study 3 [52]	1.53	0.17
35	Wei et al. study 4 [52]	0.21	0.13
36	Zebidi [53]	3.46	0.20
37	Zeineddine [54]	0.42	0.10

Based on the effect-size distribution in Table 3 above, the smallest effect size is -0.20 and the largest effect size is 3.46. The results of the analysis of the distribution of 37 effect sizes, obtained 10.81% (n=4) classified as no effect, 10.81% (n=4) classified as small effect, 13.51% (n=5) classified as moderate influence, 29, 73% (n=11) classified as big influence, and 35.14% (n=13) classified as very big influence. Figure 2 visualizes the effect size distribution diagram.

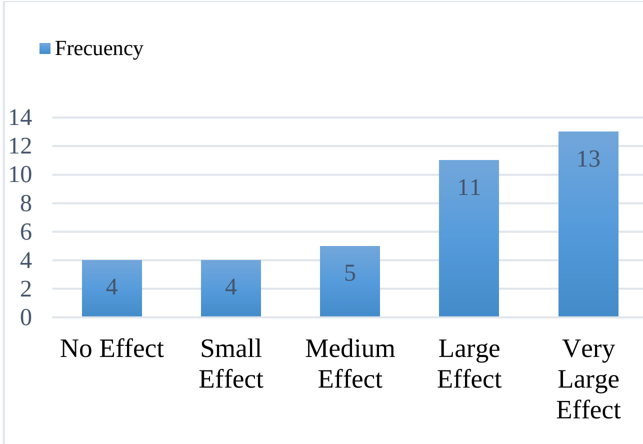

Figure 2. Effect size classification

3.2 Heterogeneity test and overall effect size

The purpose of performing a heterogeneity test is to select an estimation model for calculating the combined effect size (random effect or fixed effect). The Q parameter approach is used to test heterogeneity. Table 4 summarizes the results of the heterogeneity test and the calculation of the overall effect size.

Table 4. Heterogeneity test summary and overall effect sizes

Model	K	Effect Size (d)	[95% CI]	P	Heterogeneity		
					Q	p	I^2
Random	37	1.01	[0.81, 1.22]	0.00	197.03	0.00	81.73%
Fixed	37	0.91	[0.83, 0.99]	0.00			

Based on Table 4, the value of Q=197.03 > chi-square (x2=51.00; df=36) is obtained. This value concludes that the effect size variance is heterogeneous, so a random effect estimate is chosen to determine the combined effect size. From Table 4 above, The random effects model yielded a combined effect size of (d=1.01; p > 0.01). This value is included in the large effect category. It can be concluded that the application of the blended learning model has a major effect on improving mathematical abilities.

3.3 Moderator variable analysis

This stage was carried out to investigate whether the variable type of ability, media platform, level of education, type of publication, and sample size affect the impact of implementing blended learning in improving mathematical ability. Table 5 summarizes the results of the moderator variable analysis.

Based on Table 5, the results of the analysis of the skill type group variables show that the effect size of each skill type variable category (learning achievement, critical thinking, problem solving, and concept understanding group) is significantly different (Qb=20.10; p=0, 00). This value confirms that the variable type of skill influences the impact of using the blended learning model on math skills. The largest effect size was the conceptual understanding group (d=1.40; p=0.00), followed by the critical thinking group (d=1.38;

p=0.00), then the learning achievement group (d=0.91; p=0.00), and the problem solving group (d=0.89; p=0.00).

Based on the media platform variable, the results showed that the effect size of each category of media platform variables (LMS and social media) was significantly different (Qb=4.12; p=0.04). This value confirms that the media platform variable influences the impact of using the blended learning model on math skills. The largest effect size was in the LMS group (d=1.15; p=0.00), and it was followed by the social media group (d=0.84; p=0.00).

Based on the education level variable, the results showed that the effect size of each education level variable (university, high school, junior high, and elementary school) differed significantly (Qb=20.14; p=0.00). This value confirms that the variable level of education influences the impact of using the blended learning model on math skills. The largest mean effect size was the college group (d=1.15; p=0.00), followed by the SHS group (d=0.89; p=0.00), junior high school (d=0.87; p=0.00), and group PS (d=0.51; p=0.15). Because the p-value in the PS group is greater than 0.05, it can be concluded that the use of the blended learning model has no effect on the PS group.

Based on the sample size variable, the results showed that the effect size of each category of sample size variables (samples of 30 or less and 31 or more) was not significantly different (Qb=0.20; p=0.65). This value confirms that the sample size variable has no effect on the impact of using the blended learning model on math skills. Although the mean effect size for the sample group of 30 or less (d=1.15; p=0.00) was larger than for the sample group of 31 or more (d=0.84; p=0.00), the mean differences - the mean effect sizes of the two groups were not significantly different.

Based on the publication type variable, the results showed that the effect size of each category of publication type variable (thesis/dissertation and journal) differed significantly (Qb=12.71; p=0.00). This value confirms that the variable type of publication influences the impact of using the blended learning model on math skills. The mean effect size of the journal group (d=1.09; p=0.00) was larger than that of the thesis/dissertation group (d=0.81; p=0.01).

Table 5. Results of combined effect sizes and moderator variables analysis

Variable Moderator	k	Effect size (d)	P	Heterogeneity Q	df	Qb	P
Type of Skill							
Learning achievement	24	0.91	0.00	128.58	3	20.10	0.00
Critical thinking	3	1.38	0.00	3.40			
Problem solving	6	0.89	0.00	13.17			
Concept Understanding	4	1.40	0.00	31.78			
Media platforms							
LMS	21	1.15	0.00	116.78	1	4.12	0.04
Social Media	16	0.84	0.00	76.13			
Grade of education							
College	13	1.15	0.00	78.52	3	20.14	0.00
SHS	9	0.89	0.00	20.87			
JHS	11	0.87	0.00	60.54			
PS	4	0.51	0.15	16.96			
Sample size							
30 or less	16	1.04	0.00	74.15	1	0.20	0.65
31 or over	21	1.00	0.00	122.68			
Type of publication							
Journal	31	1.09	0.00	158.7	1	12.71	0.00
Thesis/Dissertation	6	0.81	0.01	25.62			

Note: Qb=Q between; Qw=Q within; k=number of studies

Table 6. File-safe N

File drawer analysis				
	k	**Fail-safe N**	**Target significance**	**Observed significance**
Rosenthal	37	6322	0.05	< 0.001

3.4 Evaluation of publication bias

Evaluation of publication bias was carried out to assess the objectivity of the meta-analysis conducted. In this study, the FSN (file-safe N) approach was chosen to examine the issue of publication bias. The results of publication bias analysis are presented in Table 6 below.

The results of the publication bias evaluation analysis (See Table 6) obtained the value of FSN=6322. This value is greater than 5k+10=5 (37)+5 =195. It can be concluded that this meta-analysis study does not have a publication bias problem.

4. DISCUSSION

The main objective of this research is to test the effectiveness of the blended learning model in improving math skills. The analysis results obtained that the average combined effect size was (d=1.01; p=0.05) The effect size is classified as a large effect. These results reveal that the application of the blended learning model has a major effect on mathematical ability. The meta-analysis conducted by Anton et al. also found matching results. Their findings confirm that blended learning has an effect on students' mathematical abilities in Indonesia [15]. The results of another study conducted by Rahmi and Aisyah also confirmed that the blended learning model had an effect on thinking skills, independent learning, and motivation [55].

Blended learning is superior to traditional learning because in the application of the blended learning model, students have studied the material at home, so students will be more prepared to receive material when studying in class [56]. Whereas in traditional learning, they will only prepare themselves when learning in class. Traditional learning also cannot facilitate students to develop at their own pace, and it will be difficult to catch up. By applying the blended learning model, each student can learn according to their individual needs, starting from setting study time, choosing a comfortable learning environment, and choosing learning resources that suit their individual desires [27, 57-60].

Further analysis of the variable types of skills, the results of the analysis found that the variable types of skills affect the impact of using blended learning models in improving math skills. The most effective use of the blended learning model is to improve critical thinking skills in mathematics, followed by the ability to understand concepts, then the ability to learn achievement, and the ability to solve mathematical problems. Even though each group of types of skills differed significantly, the four groups emphasized that the use of blended learning proved to be effective on students' mathematical abilities in general.

Based on the media platform variable, the results of the analysis found that the media platform variable did not affect the impact of using the blended learning model in improving math skills. This means that the use of media platforms using LMS and social media is just as effective if the blended learning model is applied to learning mathematics. The results of this study are different from the findings of Purnomo et al. who revealed that math skills were more effective in the group using the LMS than those not using it [61]. Future research can investigate further by analyzing more primary studies involving blended learning using LMS and social media so that conclusions become more accurate. Although the two groups were identified as significantly different, the use of LMS and social media proved to be effective if the blended learning model was applied to mathematics learning.

Based on the education level variable, the results of the analysis found that the education level variable had an effect on the impact of using the blended learning model in improving math skills. The application of blended learning has a significant effect at the tertiary level, SHS, and JHS. However, it does not have a significant effect on the level of PS. This result is in line with the findings of Lin et al. [11] in Taiwan. The results of their research show that the learning outcomes of elementary school students using blended learning models are no better than traditional learning models. Future research needs to conduct further meta-analysis research specifically at the elementary school level to get more accurate conclusions.

Based on the sample size variable, the results of the analysis found that the sample size variable had no effect on the impact of using the blended learning model in improving math skills. These results confirm that the application of the blended learning model is equally effective when applied to groups with a sample size of 30 or less and groups with a sample size of 31 or more. This result differs from the findings of Purnomo et al. [61] who revealed that the effectiveness of using blended learning with a flipped classroom approach to math skills differed significantly based on the sample size group. To get more accurate and in-depth conclusions, it is necessary to involve more primary studies.

Based on the publication type variable, the results of the analysis found that the publication type variable had an effect on the impact of using the blended learning model in improving math skills. The use of the blended learning model in learning mathematics was reported to be more effective in the journal group than in the master thesis/doctoral dissertation group. We assume that results reported in journal publications tend to only report results of studies that are significant. The results of this study are in line with the findings of Yakar [61] and Purnomo et al. [62] which confirms that the use of blended learning on mathematical abilities varies based on the group of publications. Even though the two groups differed significantly, both groups confirmed that the use of blended learning proved to be effective on students' mathematical abilities.

5. CONCLUSIONS

Based on the results and discussion previously described, it can be concluded that the use of blended learning models has a major effect on improving math skills. Based on the analysis of the moderator variable, it can be concluded that the variable type of skill, media platform, level of education, and type of publication have an effect on the impact of using the blended learning model in improving math skills. However, the sample size variable was found not to affect the impact of using the blended learning model in improving math skills. This study shows consistency with the publication of previous research results that tested the effect of using blended learning models in improving math skills.

This study also has limitations, including: This study only analyzed 37 effect sizes. Future research can expand the research sample so that the analysis becomes broader. In addition, the variable mathematical ability that is measured has not involved many studies. Future research can analyze the dependent variable more specifically, for example mathematical communication, critical thinking skills, conceptual understanding, and others.

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