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Effectiveness of Flipped Classroom Model on Mathematics Achievement at the University Level: A Meta-Analysis Study

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Many studies have been conducted on the differences in the effectiveness of the flipped classroom model compared to traditional learning models on mathematics learning achievement. However, the results of previous studies have inconsistent results. Therefore, this study aims to test the effectiveness of the flipped classroom model on mathematics learning achievement when compared to traditional learning models. For this purpose, the study design used was a contrast group meta-analysis. The studies analyzed were 20 independent studies from 13 main studies published in Scopus-indexed journals. Data analysis using JASP software version 0.16.4. The results of the analysis showed that the combined effect size using random effect estimation was (Cohen'd = 0.494; $p < 0.001$). This effect size belongs to the medium effect category. These results prove that students' mathematics learning achievement using the flipped classroom model is more effective than the traditional learning model. The results of this study suggest that the difference in size from the previous study became clear after the meta-analysis, namely the moderate effect category. These results are also expected to be the basis for policymaking in improving the quality of mathematics learning.

Keywords: mathematics, flipped classroom model, meta-analysis, effect-size, learning

INTRODUCTION

Mathematics has contributed to the development of science such as in the fields of language, religion, culture, and social justice (Larnell et al., 2016; Ishartono et al., 2019;

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Habibi & Prahmana), as well as technical ones such as engineering, architecture, and economics (Mensik, 2015; March & Steadman, 2020). In learning mathematics, understanding concepts have a role in achieving learning objectives (Kilpatrick et al., 2001; Setyaningrum, 2018). Educators must also realize that each student has a different time understanding mathematical concepts as a whole. Students with high academic abilities need less time to understand concepts than students with lower academic abilities (Prayitno et al., 2022). With current technological advances, educators must be able to create learning strategies that can facilitate the diversity of student learning needs (Setiawan et al., 2022). For this problem, the flipped classroom model can be used as an alternative solution.

The flipped classroom learning model reverses the traditional learning model. Before studying in class, students first study the material by watching videos or other teaching materials and then continue to do homework (Bergmann & Sams, 2012; Network, 2014; Ramakrishnan & Priya, 2016; Shih & Huang, 2020). Sessions in class can be continued with active learning. For example, practicing what they have learned during sessions outside the classroom, collaborative group work, discussion, problem-solving, and working on projects with instructor feedback and guidance (Mok 2014; Huang & Hong, 2016). In class activity sessions, educators act as student facilitators (Bergmann & Sams, 2012). The speed and diverse learning needs of students can be facilitated with the flipped classroom model (Bergmann & Sams, 2012; Prescott et al., 2018; Angelona et al., 2020).

Research on flipped classrooms has become a familiar topic in various fields of study including mathematics (Lo & Hew., 2017). Research from Hung et al (2018) in a middle school in China shows that the flipped classroom learning model with MOOCs can improve student motivation and learning outcomes. The results of research by Bhagat et al (2016) also reveal that flipped classrooms can increase students' motivation and achievement in learning mathematics in Taiwan. Furthermore, the results of Lo & Hew's (2018) research also reveal that flipped classrooms with the help of Moodle can improve students' mathematics learning achievement. Flipped classrooms are also identified as having a better effect than traditional learning models at the university level (Emily, 2015; Daniel, 2015; Sergis et al., 2017; Li et al., 2017)

Although the achievement of learning mathematics using the flipped classroom model was identified as having a better effect than the traditional learning model at the university level, different results were found by Files, 2016; Clark, 2015; and Briggs, 2014. The results of their research show that mathematics learning achievement at the university level between the flipped classroom model and traditional learning is not significantly different. Inconsistent research results on the same topic can of course lead to ambiguous conclusions. on the other hand, mathematics teachers want to obtain accurate and mutually supportive information to be considered in improving the quality of mathematics learning. Meta-analysis needs to be done because of the reality that no research is free from errors in research even though researchers have tried to minimize errors or errors in the research. The meta-analysis study aimed to find the effect size. Effect size is a quantitative index used to summarize study results in a meta-analysis.

This means that the effect size reflects the magnitude of the influence, the magnitude of the difference, and the relationship of a variable with other variables (Schmidt & Hunter, 2004; Retnawati et al., 2018).

So far, a meta-analysis study on the effectiveness of flipped classrooms on mathematics learning achievement has been conducted by Yakar (2021) in Turkey. However, the meta-analysis studies conducted were limited to the elementary school level. Based on the literature review that we examined, there has been no meta-analysis research on the effectiveness of the reverse class model on mathematics learning achievement at the university level. This study attempts to measure the effectiveness of the flipped classroom model on mathematics learning achievement at the university level when compared to traditional learning models. The results of this meta-analysis can provide clear conclusions from the inconsistent results of previous studies so that they can be used as a basis for policy-making in improving the quality of mathematics learning at the university level.

METHOD

Search and Screening Literature

Search for primary studies that match the inclusion criteria using several databases, such as: Education Resources Information Center (ERIC), Google Scholar, Directory of Open Access (DOAJ), Springer publishing, AIP Proceedings, IOP Sciences, and Elsevier. The keywords used in the search for primary studies were “Flipped Classroom” AND “Mathematics”.

Based on the initial search data using the database and keywords above, 218 preliminary studies were found. The initial studies found were then screened using the following inclusion criteria: 1) Articles published from 2015 to 2021; 2) Articles must be indexed by Scopus; 3) Experimental research related to flipped classroom and math achievement; 4) Minimum research sample is 15 people; 5) Articles are required to report data on the mean, number of samples, and standard deviation of the control and experimental classes.

Based on the search results that match the specified inclusion criteria, found independent studies (k = 20) from 13 main studies for further evaluation. The final data collected is then performed with variable coding and data extraction in Microsoft Excel for further data analysis. Table 1 describes information on primary studies that have been published by various Scopus-indexed journals.

Table 1
Summary of study search results

Author (Year)	Journal	Scopus
Anderson & Brennan (2015), Study 1 Anderson & Brennan (2015), Study 2 Anderson & Brennan (2015), Study 3	PRIMUS (Problems, Resources, and Issuesin Mathematics Undergraduate Studies)	Q1
Asarta & Schmidt (2016)	The Internet and Higher Education	Q1
Emily (2015)	PRIMUS (Problems, Resources, and Issuesin Mathematics Undergraduate Studies)	Q1
William (2017), Study 1 William (2017), Study 2 William (2017), Study 3	PRIMUS (Problems, Resources, and Issuesin Mathematics Undergraduate Studies)	Q1
Li et al (2017)	Eurasia Journal of Mathematics Scienceand Technology Education	Q2
Maciejewski (2015)	Teaching Mathematics and its Applications	Q2
Overmyer (2015), Study 1 Overmyer (2015), Study 2	PRIMUS (Problems, Resources, and Issuesin Mathematics Undergraduate Studies)	Q1
Daniel (2015)	Teaching of Psychology	Q2
Petrillo (2015)	International Journal of MathematicalEducation in Science and Technology	Q2
Schroeder (2015), Study 1 Schroeder (2015), Study 2	PRIMUS (Problems, Resources, and Issuesin Mathematics Undergraduate Studies)	Q1
Etheridge (2016)	Journal of Applied Research in HigherEducation	Q3
Sergis et al (2017)	Computers in Human Behavior	Q1
Wasserman et al (2015), Study 1 Wasserman et al (2015), Study 2	International Journal of Science andMathematics Education	Q1

Data analysis

Data analysis in this meta-analysis used JASP software version 0.16.4. The steps of meta-analysis data analysis follow these steps: 1) Calculating the effect size of each study; 2) Conduct heterogeneity test; 3) Calculating the size of the Combined effect; 4) Evaluation of publication bias. Classification of the effect sizes of each study and the combined effect refers to the classification of Cohen et al. (2018) which is shown in Table 2 below:

Table 2
Effect size (ES) experimental study

No	Category	Interval
1	No Effect	$0.00 < ES \leq 0.19$
2	Small Effect	$0.19 < ES \leq 0.49$
3	Moderate Effect	$0.49 < ES \leq 0.79$
4	Large Effect	$0.79 < ES \leq 1.29$
5	Very Large Effect	$ES > 1.29$

As described previously, the main objective of this meta-analysis study was to calculate the combined effect size. The combined effect size was calculated after the heterogeneity test. The aim is to select an appropriate effect size estimation model. If the heterogeneity assumption is met, then the random effects model is used to estimate the combined effect size, and if the heterogeneity assumption is not met (homogeneous data) then the effects model is still used. Furthermore, to ensure that the research included in the meta-analysis has shown objective results, an assessment of publication bias is carried out (Retnawati et al., 2018; Setiawan al., 2022; Muhtadi et al., 2022). Evaluation of publication bias in this study used the FSN (File-Safe N) approach.

FINDINGS

The effect size of each study

The first step is to calculate the effect size of each study. Table 3 presents a summary of effect sizes, variances, and standard error values for each study calculated using the JASP software. The effect size range of the 20 studies ranged from 0.036 to 1.18. This shows that the effect sizes range from having no effect to having a large effect. There are four effect sizes (n = 4) in the no effect category. Eight effect sizes (n = 8) were categorized as small effects, five effect sizes (n = 5) were categorized as moderate effects, and three effect sizes (n = 3) were categorized as large effects.

Table 3
Effect size (ES), variance, and standard error (SE) for each study

Author	ES	Varians	SE	Category
Anderson & Brennan (2015), Study 1	0.482	0.014	0.117	Small Effect
Anderson & Brennan (2015), Study 2	0.572	0.017	0.132	Moderate Effect
Anderson & Brennan (2015), Study 3	0.372	0.068	0.261	Small Effect
Asarta & Schmidt (2016)	0.053	0.007	0.082	No Effect
Emily (2015)	1.139	0.035	0.188	Large Effect
William (2017), Study 1	0.036	0.052	0.228	No Effect
William (2017), Study 2	0.481	0.054	0.232	Small Effect
William (2017), Study 3	0.509	0.054	0.232	Moderate Effect
Li et al (2017)	1.188	0.041	0.203	Large Effect
Maciejewski (2015)	0.389	0.007	0.083	Small Effect
Overmyer (2015), Study 1	0.021	0.017	0.132	No Effect
Overmyer (2015), Study 2	0.604	0.028	0.166	Moderate Effect
Daniel (2015)	0.732	0.096	0.310	Moderate Effect
Petrillo (2015)	0.406	0.027	0.163	Small Effect
Schroeder (2015), Study 1	0.539	0.050	0.223	Small Effect
Schroeder (2015), Study 2	0.543	0.050	0.224	Moderate Effect
Etheridge (2016)	0.032	0.042	0.204	No Effect
Sergis et al (2017)	0.918	0.095	0.308	Large Effect
Wasserman et al (2015), Study 1	0.235	0.027	0.163	Small Effect
Wasserman et al (2015), Study 2	0.206	0.027	0.163	Small Effect

Heterogeneity Test

Heterogeneity is the variation of data within each study (within-group variation) or between primary studies (between-group variation). The heterogeneity test was performed to select the combined effect size estimation model. In this study, heterogeneity test used p-value. The summary of heterogeneity test is visualized in table 4 below.

Table 4
Heterogeneity test data summary

	Q	Df	p-value
Omnibus test of Model Coefficients	35.263	1	< 0.001
Test of Residual Heterogeneity	72.649	19	< 0.001

The results of the heterogeneity test (see Table 4), obtained p-value < 0.001. These results indicate that the data variance between the primary studies is heterogeneous. Thus, the estimation model used to calculate the combined effect size is a random effect.

Overall Effect Size

The calculation of the combined effect size aims to confirm the research question in this meta-analysis study, namely how large the effect size of using the flipped classroom model is compared to the traditional model on mathematics learning achievement. The combined effect size was calculated using a random effect approach. A summary of the results of calculating the combined effect size using the random effects model is visualized in table 5 below.

Table 5
Coefficient estimation using random-effect model

	Effect Size (Cohen'd)	SEM	z-value	p-value	95% Confidence Interval	
					Lower Limit	Upper limit
Overall	0.494	0.075	5.938	< 0.001	0.298	0.591

The results of the analysis using JASP 0.16.4 software (see Table 5), the combined effect size was obtained (Cohen'd = 0.494; $p < 0.05$), and the standard error was (SE = 0.075). This effect size belongs to the moderate effect category. These results indicate that the effect of using the flipped classroom model has a moderate effect on student achievement when compared to the traditional learning model.

Evaluation of Publication Bias

Meta-analytical studies that can reflect objectivity and are scientifically justified can be assessed by evaluation of publication bias. In this study, the File-Safe N Approach (FSN) was used to evaluate publication bias. Table 6 presents a summary of the publication bias test.

Table 6
File-Safe N

File Drawer Analysis			
	Fail-safe N	Target Significance	Observed Significance
Rosenthal	921	0.05	< 0.001

The results of the publication bias test analysis (see Table 6), obtained an FSN value of 921. This value is greater than 5k+10=110. Thus it can be concluded that this meta-analysis study does not have publication bias problems. The following table provides a summary of the evaluation of publication bias.

DISCUSSION

The results of this meta-analysis indicate that student achievement with the flipped classroom model is more effective than the traditional learning model. The combined effect size value was (Cohen'd = 0.494; $p < 0.05$). This effect size belongs to the medium effect category. This finding is in line with the meta-analysis research conducted by Strelan et al (2019). The results of their study showed that student achievement using the flipped classroom model was more effective than the traditional learning model, but the effect size was in the small effect category ($d = 0.35$). Another fact found in their research is that the effect sizes found in other fields of study fall into strong categories such as the humanities ($d = 0.98$; $k = 34$). These findings suggest that the inverse class effect may not be as strong in disciplines with highly structured materials such as mathematics. The use of the flipped classroom has a different effect on scientific disciplines, of course, this becomes the basis for further research. Thus, there is room for future researchers to expand our understanding of the inverse class effect in various disciplines. A similar meta-analysis was also carried out by Algarni (2018), the results of his research show that the flipped classroom is effective in learning mathematics, but the effect size found is in a small category. Therefore, it can be concluded that the use of the flipped classroom has a positive contribution to learning mathematics. The findings of this meta-analysis reinforce previous research examining the effectiveness of the inverted classroom model on student mathematics achievement at the university level.

One of the advantages of the flipped classroom compared to the traditional model is that it can facilitate the speed and learning needs of diverse learners with maximum study time (Stakern & Horn, 2012; Bergmann & Sams, 2012; Network, 2014; Shih & Huang, 2020; Angelona). et al., 2020). The flipped classroom model overcomes the limitations of learning time by providing additional time to carry out learning activities outside the classroom (Bergmann & Sams, 2012; Network, 2014; Anderson & Brennan, 2015; Petrillo, 2015; Schroeder, 2015; Wasserman et al., 2015; Ramakrishnan & Priya, 2016; Li et al., 2017; Sergis et al., 2017; Ramadhani, 2019; Shih & Huang, 2020).

The flipped classroom model provides opportunities for students to be more independent in managing their learning (Ishartono et al., 2022). They can study outside the classroom with flexible time before in-class learning. They can learn material such as videos or other teaching materials at their own pace of learning (Holton et al., 2016). The flipped classroom must be supported by active learning activities (student-centered). Teachers not only provide information but make them independent learners (Bergmann & Sams, 2012; Abeysekera & Dawson, 2015). Another benefit of the flipped classroom model is the positive perception of students. Student perceptions tend to be positive because students are facilitated to learn according to their learning style and speed through the various media used. Students also want to use the media for positive things and become independent learners. Student-centered learning can be carried out well with the flipped classroom model. However, further, development is still needed to improve the soft skills and 21st-century skills of students. Future research is expected to conduct a meta-analysis study related to flipped classrooms on the achievement of 21st-century skills.

Anderson et al (2001) and Bregmann (2012) revealed the elements in the flipped classroom model, including; 1) Providing opportunities for students to get first exposure before learning in class. The mechanisms used to study at home can vary, from textbooks, modules, video podcasts, and other learning resources. Students can also complete assignments or quizzes; 2) Provide more time for students to prepare material before participating in the learning process in class; 3) Provide procedures or procedures for assessing students' understanding of knowledge. 4) Activities in the classroom focus on higher-level cognitive activities. Where student activities in class are discussions, data analysis, or synthesis activities. The key is that students use class time to deepen their understanding.

The flipped classroom model consists of three phases, namely the pre-class phase, the in-class phase, and the post-class phase (Roeheling, 2018; Ishartono et al., 2022). In pre-class activities students are given preliminary knowledge (schemas) before continuing with active learning in class. In addition to studying the material, students work on assignments. Lecturers give assignments related to topics, such as summarizing notes, answering questions, or playing quizzes using additional platforms. Furthermore, students are advised to note things that have not been understood. This list will be discussed later in class. This means that before studying in class, students already have an overview of the material to be taught. This situation will encourage students to be more prepared to carry out discussions and find solutions to problems given under the guidance of the teacher (Bergmann & Sams, 2012; Lai & Hwang, 2016). The same statement was also made by Ishartono et al. (2022) who revealed that giving assignments and teaching materials to students before studying in class can enrich students' prior knowledge so that they are better prepared when studying in class.

Preparations that must be done by the lecturer before the learning process include; Prepare learning media, in this case in the form of learning videos or other teaching materials that support independent learning activities, then send them to students one week before face-to-face learning in class. Lecturers need to prepare study instructions that students must study at home. While student activities at home can be; study independently or in groups related to the material provided by the lecturer. Students must understand the instructions regarding the activities to be carried out. Students record things that have not been understood and things they want to learn further regarding the material in the learning video to be further discussed in class.

This research also has limitations. This study analyzed only 20 effect sizes from 13 primary studies. The mathematics achievement measured in this study is still general in nature. Future research can expand the sample and analyze mathematical achievement more specifically, for example: understanding mathematical concepts, creative thinking, critical thinking, and others. In addition, further research can analyze it further by examining the analysis of moderator variables, so that other variables that are thought to influence the effect size can be found.

CONCLUSION

The results of this meta-analysis show that the use of the flipped classroom model has a moderate effect on mathematics learning achievement, compared to the traditional learning model. The meta-analysis studies carried out also did not have publication bias problems, the results of this study were objective and scientifically acceptable. The results of this study can provide a clear conclusion that the confusing effect size differences between the variables of the flipped classroom model and students' mathematics learning achievement at the university level become clearer. In addition, the results of this study are expected to provide an overview of the effect of the flipped classroom model on student achievement, so that it can be used as a basis for policymaking in improving the quality of mathematics learning.

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