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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

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; 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	PRIMUS (Problems, Resources, and Issues in Mathematics Undergraduate Studies)	Q1
Anderson & Brennan (2015), Study 2		

Anderson & Brennan (2015), Study 3

Asarta & Schmidt (2016)

The Internet and Higher Education

Q1

Emily (2015)

PRIMUS (Problems, Resources, and Issues in Mathematics Undergraduate Studies)

Q1

William (2017), Study 1

PRIMUS (Problems, Resources, and Issues in Mathematics Undergraduate Studies)

Q1

William (2017), Study 2

William (2017), Study 3

Li et al (2017)

Eurasia Journal of Mathematics Science and Technology Education

Q2

Maciejewski (2015)

Teaching Mathematics and its Applications

Q2

Overmyer (2015), Study 1

PRIMUS (Problems, Resources, and Issues in Mathematics Undergraduate Studies)

Q1

Overmyer (2015), Study 2

Daniel (2015)

Teaching of Psychology

Q2

Petrillo (2015)

International Journal of Mathematical Education in Science and Technology

Q2

Schroeder (2015), Study 1

PRIMUS (Problems, Resources, and Issues in Mathematics Undergraduate Studies)

Q1

Schroeder (2015), Study 2

Etheridge (2016)

Journal of Applied Research in Higher Education

Q3

Sergis et al (2017)

Computers in Human Behavior

Q1

Wasserman et al (2015), Study 1

International Journal of Science and Mathematics Education

Q1

Wasserman et al (2015), Study 2

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 ≤ 0.19
2		

Small Effect

0.19 < ES ≤ 0.49

3

Moderate Effect

0.49 < ES ≤ 0.79

4

Large Effect

0.79 < ES ≤ 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