

**Flipped Classroom Meta-Analysis of Critical Thinking Skills and Learning Outcomes in High School Physics Learning****Meili Dwi Indriyani*, Stepanus Sahala Sitompul, and Ray Cinthya Habellia**

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meilidwiindriyani@student.untan.ac.id**Abstract**

The main objective of this research is to analyze the effect of the flipped classroom on critical thinking skills and learning outcomes in high school physics learning. This study's specific objective is to determine the effect size and the influence of research characteristics from various literature articles. The population in this study amounted to 21 research articles, and then the research sample was taken from the population using a purposive sampling technique. The research instrument used coding sheets. The results of the meta-analysis of this study indicated that the flipped classroom could affect critical thinking skills and student learning outcomes in high school physics learning. The average effect size of the flipped classroom model on critical thinking skills in high school physics learning was 1.964, and the average effect size of the flipped classroom model on learning outcomes in high school physics learning was 2.058. This study analyzed eight research characteristics in the article that were thought to influence critical thinking skills and learning outcomes. Among them were the gender of the researcher, the research university, the research location, the physics material, the type of research, the sample size used, data collection tools, and statistical tests. The results of the analysis showed the characteristics of research articles that influence critical thinking skills and learning outcomes: sample size, researcher's gender, data collection tools, and materials, making these characteristics need to be considered in research.

Keywords: Critical Thinking Skills; Flipped Classroom; Learning Outcomes; Meta-Analysis

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INTRODUCTION

21st-century learning implements 4C skills. These 4C are critical thinking, communication, creativity, and collaboration (Arnyana, 2019; Misbah et al., 2022; Partono et al., 2021; Septikasari & Frasandy, 2018). Students

are at the center of 21st-century learning in all courses, particularly physics in high school. As a result, high school physics of the 21st century is expected to take an active and independent part in developing students' knowledge. Based on the essence of successful physics



learning, students may master acquiring knowledge, comprehending concepts, and producing physics products that can be utilized in daily activities. Therefore, critical thinking skills are one of the 4C skills that must be possessed and developed in high school physics learning (Hartini et al., 2020; Misbah et al., 2018; Yani et al., 2021).

Critical thinking skills include interpretation, analysis, explanation, evaluation, and conclusions (Emily, 2011; Mahanal et al., 2016). Meanwhile, Wayudi et al. (2020) defined critical thinking skills as high-level thinking skills that help students develop strong analytical understanding power. The critical thinking skills used in this study refer to Ennis (1989), which included one or more of the following aspects: providing simple explanations, deeper explanations, arranging tactics and procedures, and concluding.

Critical thinking skills are regarded to be capable of increasing high learning results. Learning outcomes are vital for students to understand their level of accomplishment in the learning process, particularly when learning physics in high school. However, students learning physics in high school continue to have low critical thinking skills. The statement is supported by a PISA survey published in 2018 (Kemendikbud, 2019) as well as studies by Pratiwi et al. (2019) and Anisa et al. (2021). Furthermore, the cause is high school physics learning that is done online, where learning is passive and not student-centered (Listari, 2021; Nurpianti & Wijaya, 2019).

The Ministry of Education and Culture (2020) recommends using the flipped classroom learning model to address this issue. The flipped classroom model is a hybrid learning model with a new pedagogy in which students learn asynchronously (Bergmann & Sams, 2012; Baker, 2018). In this study, the flipped classroom model relates to the

interpretation of Cabi (2018) of a reverse learning model, with asynchronous videos and practice questions as learning activities at home and problem-solving-based learning as learning activities in class. The flipped classroom learning model was created to help students learn by eliminating direct instruction and maximizing interaction, allowing them to focus on the learning process (Johnson, 2009; Nurpianti & Wijaya, 2019). Supriatna (2021) and Kurnianto & Wiyanto (2019) conducted studies that support the application of the flipped classroom method in the high school physics curriculum in affecting levels of critical thinking skills and learning outcomes.

Based on this description, it is required to undertake an overall analysis of the numerous studies on the flipped classroom model using the meta-analysis approach, which summarizes the quantitative results of several similar studies (Anggreni et al., 2019). As a result, this meta-analysis study aims to determine the extent to which the flipped classroom model influences critical thinking skills and learning outcomes in high school physics learning. Ashari & Basuki (2021) conducted one of the meta-analysis studies on flipped classrooms based on the results of meta-analysis research that were completed from eight research publications indicating interactive learning using the flipped classroom learning model can affect student learning outcomes. As a result, the findings of this meta-analysis study will synthesize the findings of studies on the effect of the flipped classroom model on critical thinking skills and student learning outcomes in high school physics learning.

METHOD

This study was a meta-analytic study using descriptive linguistics to provide an analysis in the form of a review by

describing the findings of a study (Rukajat, 2018) that had been published nationally on the effect of the flipped classroom model on critical thinking skills and student learning outcomes in high school physics. The population of this study consisted of research articles published online between 2017 and 2022 about the flipped classroom learning model for critical thinking skills and learning outcomes in high school physics learning. The research sampling approach was purposive, and meaning samples were chosen explicitly for the study objectives (Sugiyono, 2017). The study sample categories chosen were experimental research articles and/or class action research published online, nationally, and in the Indonesian language from 2017 to 2022 about the effect of the flipped classroom learning model on critical thinking skills and learning outcomes in high school physics learning.

The data collection of this study conformed to the meta-analysis steps adopted from research by Littell et al. (2008). The steps include:

1. Determine the topic to be studied, namely the effect of the flipped classroom learning model on critical thinking skills and learning outcomes in high school physics learning.
2. Collection of research data:
 - a. Search and collect research articles (population).
 - b. Select research articles (samples).
 - c. Analyze and interpret the research sample.

3. Article coding (coding).
4. Process and analyze research data: Calculate the effect size value of each article using the formula for calculating the effect size, while the article's characteristic data on effect size values were analyzed according to the relevant statistical tests.
5. Interpretation.

The research instrument used data coding sheets. The variables used were adopted from research by Sulistri (2010), which included article code, researcher gender, year of publication, research university, research location, material, type of research, sample size in research, data collection instruments, statistical tests, and effect size.

Data analysis to calculate effect size values depends on statistical tests used in research articles such as Z test, t test, r-test/correlation, and F test (Sutrisno, 2007). Calculating effect size in experimental research for a single group/one group using Cohen's formula (Agung, 2010). Experimental research with two heterogeneous groups using the Glass formula (Glass, 2016).

In Table 1, the following statistical tests will be used to analyze research variables that were the characteristics of research articles on effect size.

Table 1 Characteristics of research articles and statistical tests

Characteristics of Research Articles	Statistical Tests
Gender of Researcher	t
Research University	t or F
Location	t or F
Physics Material	r or F
Type of Research	F
Sample Size	r
Data Collection Tool	t
Statistic Test	F

Source (Sulistri, 2010)

Cohen's reference was used in this study for the category of effect size values:
 Low effect : $0.2 \leq ES \leq 0.5$

Moderate effect : $0.5 \leq ES \leq 0.8$
 High effect : $0.8 \leq ES$

RESULTS AND DISCUSSION**The Large Effect Size of the Flipped Classroom Model on Critical Thinking Skills and Learning Outcomes in High School Physics Learning**

The flipped classroom model on critical thinking skills and learning outcomes in high school physics learning was summarized in this study. Table 2 displays the article data.

Table 2 Articles data

No	Article Code	Author and Year	Effect Size	Category
1	01KBK	Moh. Risam Hidayatulloh (2021)	1.38	High Effect
2	02KBK	I Made Yadnya Tresna Putra (2019)	3.31	High Effect
3	03KBK	I Putu Mas Ariadi (2020)	0.65	Moderate Effect
4	04KBK	Anak Agung Mela Andani (2020)	1.55	High Effect
5	05KBK	Seli Nurpianti, Sutrisno, Agus Fany Chandra Wijaya (2020)	2.93	High Effect
6	01HB	D Lidinillah, Y Dirgantara, R D Agustina (2019)	3.21	High Effect
7	02HB	Stefiana Lenisa, Muhammad Syafi'I, M. Rahmad, Yati Gusneli (2019)	3.56	High Effect
8	03HB	Anisa Rahmayani (2020)	1.02	High Effect
9	04HB	Magdalena Ferlina Rere Djogo (2021)	1.52	High Effect
10	05HB	Mariana Peni Manuk (2019)	0.98	High Effect

This study presented the findings of ten articles, five of which used the flipped classroom model to improve critical thinking skills in high school physics learning and had an average effect size of 1.964 (high effect category). Students were expected to participate actively in debating and discussing using the flipped classroom format. Students could also communicate and summarize the outcomes of discussion and analysis. As a result, the average score of students' tests and scores on the indicators of critical thinking skills rose. This outcome was consistent with the research findings of Putra (2021) that the flipped classroom model could affect critical thinking skills.

Meanwhile, five articles with an average effect size of 2.058 (high effect category) on the effect of the flipped classroom learning model on learning outcomes in high school physics learning have been published. These findings suggested that the flipped

classroom model could influence student learning outcomes in high school physics. According to the findings of this study, the flipped classroom learning method could influence student learning outcomes in high school physics.

The flipped classroom model benefits high school physics learning because students interact with teachers and students under conducive conditions, resulting in higher cognitive domain learning outcomes scores. This study was consistent with Ashari & Basuki (2021) findings, which found that active learning with the flipped classroom learning model can affect student learning outcomes based on a meta-analysis of eight journals.

Analysis of the Characteristics Effect of the Flipped Classroom Model Articles on Critical Thinking Skills in Physics Learning

Several statistical tests, including the t-test, F-test, and r-test, were used to

calculate the influence of the flipped classroom model article's characteristics

on critical thinking skills in high school physics learning, as shown in Table 3.

Table 3 Analysis of the characteristics of the flipped classroom research article model on critical thinking skills in high school physics learning

Research Characteristics	Statistical Tests	Result
Gender of Researcher	t	$t_{\text{count}} = 0.401 < t_{\text{table}} = 3.18$
Research University	F	$F_{\text{count}} = 0.4013 < F_{\text{table}} = 215.7$
Location	t	$t_{\text{count}} = 1.51 < t_{\text{table}} = 3.18$
Physics Material	F	$F_{\text{count}} = 0.2 < F_{\text{table}} = 19.00$
Type of Research	F	$F_{\text{count}} = 0.014 < F_{\text{table}} = 19.00$
Sample Size	r	$r_{\text{count}} = 0.902 > r_{\text{table}} = 0.576$
Data Collection Tool	t	$t_{\text{count}} = 0.02 < t_{\text{table}} = 3.18$
Statistic Test	F	$F_{\text{count}} = 0.288 < F_{\text{table}} = 19.00$

Analysis of the characteristics of the sample size used using the r-test showed that the value of $r_{\text{count}}(0.902) > r_{\text{table}}(0.576)$. The value of r_{count} was bigger than r_{table} , indicating that r_{count} and effect size were related in the study of the effect of the flipped classroom model on critical thinking skills in high school physics learning. The qualities of research articles for large research samples impacted critical thinking skills development. The mean and standard deviation obtained were highly probable as research samples increased (Alwi, 2015). The findings of this study was in line with Sulistri (2010), who revealed a positive correlation r_{count} , implying that the characteristics of research articles based on the sample size used should be taken into account in conducting research.

Analysis of the characteristics of the research articles according to the gender of the researcher used the t-test showed the value of $t_{\text{count}}(0.401) < t_{\text{table}}(3.18)$. The findings of these calculations showed that there was no difference in the value of the effect size. This characteristic had little to do with the research's methodology. According to Fuad et al. (2017), the gender of students influences their critical thinking skills. The findings of this study were in line with Nurhasanah (2017), who revealed that

the results of the t-test calculations for the researchers' gender characteristics indicated no difference in effect size.

Analysis of the characteristics of the research articles according to the research university showed the value of $F_{\text{count}}(0.4013) < F_{\text{table}}(215.7)$. This indicated the effect size value did not differ. This characteristic did not affect increasing critical thinking skills. The effect size value used in calculating the F-test did not show the mean and standard deviation with high probability. This result was in line with the findings by Sulistri (2010), who stated that the F-test calculation results showed no difference in effect size.

Analysis of the characteristics of the research articles according to the research locations showed the value of $t_{\text{count}}(1.51) < t_{\text{table}}(3.18)$. It proved the effect size value did not differ. This characteristic did not affect increasing critical thinking skills. The research locations were divided into cities and districts (Nurhasanah, 2017). There were four research articles from the city and one from the district. The effect size value used in the t-test calculation did not show the mean and standard deviation with high probability. This result was consistent with the findings of Nurhasanah (2017), who found that the

results of t-test calculations did not differ in the effect size value.

Analysis of the characteristics of the research articles according to the type of research using the F-test showed the value of $F_{\text{count}}(0.014) < F_{\text{table}}(19.00)$. The calculated findings demonstrated no difference in the effect size value. This characteristic did not affect increasing critical thinking skills. Since the F-test is calculated using only five research articles, the value of F_{table} is bigger than the value of F_{count} . This conclusion was consistent with the findings of Nurhasanah (2017), which revealed that the F-test calculation results showed no change in the effect size value.

Analysis of the characteristics of the research articles according to the data collection tool using the t-test showed the value of $t_{\text{count}}(0.02) < t_{\text{table}}(3.18)$. The value of t_{count} was bigger than t_{table} , meaning there was no difference in the effect size value. Data collection tools used in research are divided into two: research that only used tests and those that used tests and questionnaires. Data collection tools were used to acquire the information needed to meet research objectives (Alhamid & Anufia, 2019). As a result, it had little to do with developing students' critical thinking skills.

Analysis of the characteristics of the research articles according to the physics material using the F-test showed

the value of $F_{\text{count}}(0.02) < F_{\text{table}}(19.00)$. These findings implied that the effect size value for this characteristic did not differ. This characteristic did not affect increasing critical thinking skills. The number of research articles used in calculating the F-test was only five, so the calculation obtained by the F_{table} value was bigger than the F_{count} value.

Analysis of the characteristics of the research articles according to the statistical tests using the F-test showed the value of $F_{\text{count}}(0.288) < F_{\text{table}}(19.00)$. These findings implied that the effect size value stayed the same. This characteristic did not affect increasing critical thinking skills. A statistical test is a statistical method for determining the probability distribution to achieve a hypothesis conclusion (Anam, 2020). This conclusion was consistent with the findings of Nurhasanah (2017) that there was no change in the effect size value for the statistical test characteristics.

Analysis of the Characteristics Effect of the Flipped Classroom Model Articles on Learning Outcomes in Physics Learning

The t-test, F-test, and r-test were employed in the analysis of research data to illustrate the calculation of the characteristics effect of the flipped classroom model research articles on learning outcomes in high school physics learning, as shown in Table 4.

Table 4 Analysis of the characteristics of the flipped classroom model article on learning outcomes in high school physics learning

Research Characteristics	Statistical Tests	Result
Gender of Researcher	t	$t_{\text{count}} = 4.162 > t_{\text{table}} = 3.18$
Research University	F	$F_{\text{count}} = 0.63 < F_{\text{table}} = 215.7$
Location	t	$t_{\text{count}} = 1.28 < t_{\text{table}} = 3.18$
Physics Material	F	$F_{\text{count}} = 19.77 > F_{\text{table}} = 19.00$
Type of Research	F	$F_{\text{count}} = 0.22 < F_{\text{table}} = 19.00$
Sample Size	r	$r_{\text{count}} = 0.902 > r_{\text{table}} = 0.576$
Data Collection Tool	t	$t_{\text{count}} = 8.52 > t_{\text{table}} = 3.18$,
Statistic Test	F	$F_{\text{count}} = 0.157 < F_{\text{table}} = 19.00$

Analysis of the characteristics of the research articles according to the gender of the researcher using the t-test showed the value of $t_{count}(4.162) > t_{table}(3.18)$. The collected data revealed that the value of the effect size varied. These characteristics affected learning outcomes. The researchers in the five research articles examined were all female. The estimated t-test value has a high probability mean and standard deviation. Furthermore, researchers in their research acted like teachers where. This conclusion was consistent with the findings of Sulistri (2010), which revealed that the results of t-test calculations showed a difference in effect size.

Analysis of the characteristics of the research articles according to the research university using the F-test showed the value of $F_{count}(0.63) < F_{table}(215.7)$. The effect size value used in the F-test calculation did not reliably show the mean and standard deviation. This characteristic did not affect improving learning outcomes. The average effect size for UIN Sunan Gunung Djati, University of Riau, UIN Syarif Hidayatullah, and University of Santa Dharma was 1.26; 0.81; 1.02; and 1.25 respectively. This conclusion was consistent with the findings of Sulistri (2010), which showed that the F-test calculation results showed no significant difference in effect size.

Analysis of the characteristics of the research articles according to the research locations using the t-test showed the value of $t_{count}(1.28) < t_{table}(3.18)$. The calculation results showed no change in the effect size value. This characteristic did not affect learning outcomes. The research locations were divided into cities and districts (Nurhasanah, 2017). There were three city research articles and two district research articles. This conclusion was consistent with the findings of Nurhasanah (2017), which revealed that

the t-test calculation results showed no significant difference in effect size.

Analysis of the characteristics of the research articles by the type of research showed the value of $F_{count}(0.22) < F_{table}(19.00)$. These findings indicated that there was no shift in the value of the effect size. This characteristic did not affect learning outcomes. The number of research articles considered in the F-test calculation is merely five. The average effect size for pre-experimental, quasi-experimental, and CAR was 3.38; 0.247; 1.02; and 1.25; respectively. Between the mean and the standard deviation, there was no probability. This conclusion was consistent with the findings of Nurhasanah (2017), who discovered that the F-test calculation results showed no significant variation in effect size.

Analisis pada karakteristik besar sampel yang digunakan dengan menggunakan uji-r menunjukkan nilai $r_{hitung}(0.902) > r_{tabel}(0.576)$. Hasil tersebut menunjukkan bahwa adanya korelasi r_{hitung} terhadap *effect size* pada penelitian pengaruh model *flipped classroom* terhadap hasil belajar peserta didik pada pembelajaran fisika SMA. Karakteristik artikel penelitian untuk besar sampel penelitian memberikan pengaruh terhadap peningkatan hasil belajar. Karena semakin besar jumlah sampel penelitian yang digunakan, maka mean dan standar deviasi yang didapat mempunyai probabilitas yang tinggi (Alwi, 2015). Hasil ini sejalan dengan temuan oleh Sulistri (2010), menunjukkan bahwa adanya korelasi positif r_{hitung} , sehingga karakteristik artikel penelitian menurut besar sampel yang digunakan perlu diperhatikan dalam melakukan penelitian.

Analysis of the characteristics of the research articles according to the data collection tool using the t-test showed the value of $t_{count}(8.52) < t_{table}(3.18)$, showed that there was a difference in the effect size value. These characteristics

influenced improving learning outcomes. The data collection tools used in the study were categorized into two: research that only used tests totaling two articles and research that used tests and questionnaires totaling three articles. The effect size calculation produced an average effect size of 1.173 (sd=0.3) for those using the test, and 3.38 (sd=0.247) for those using the test and questionnaire. There was a probability between the mean and the standard deviation. As a result, the t_{count} value is bigger than t_{table} value. Therefore, the characteristics of research articles according to data collection tools needed to be considered.

Analysis of the characteristics of the research articles according to the physics material using the F-test showed the value of $F_{\text{count}}(19.77) < F_{\text{table}}(19.00)$. The calculation results showed a difference in the effect size value. These characteristics influenced improving learning outcomes. This result was in line with the findings by Sulistri (2010), who stated that there was a difference in the effect size value.

Analysis of the characteristics of the research articles according to the statistical tests using the F-test showed the value of $F_{\text{count}}(0.288) < F_{\text{table}}(19.00)$. The calculation results demonstrated that the effect size value was the same. This characteristic did not affect improving learning outcomes. A statistical test is a technique to see the probability distribution to reach a hypothesis conclusion (Anam, 2020). As a result, it had nothing to do with learning outcomes.

CONCLUSION

Based on the findings of the meta-analysis of ten articles and the calculation of the effect size using the effect size calculation formula, the average effect size of the flipped classroom model on critical thinking skills in high school physics learning was 1.964, and the average effect size of

the flipped classroom model on learning outcomes in high school physics learning was 2.058. In general, it could be concluded that the flipped classroom approach had a high effect on the degree of critical thinking skills and learning outcomes in high school physics learning (Chen, 2019; Özdemir, A., & Şentürk 2021).

Findings on the effect of flipped classroom model characteristics on critical thinking skills in high school physics learning and sample size analysis had a positive link with effect magnitude. Meanwhile, there was no significant variation in effect size based on the researcher's gender, university of origin, study location, data collection tools, research type, physics material, or statistical test. As a result, examining it in the study was unnecessary.

The findings on the analysis of the characteristics effect of the flipped classroom model of research articles on learning outcomes in high school physics learning, including the gender of the researcher, sample size, data collection tools, and the physics material used, showed that the effect size was significantly affected by the gender of the researcher, sample size, data collection tools, and the physics material used. In comparison, the research location, statistical test, university of origin, and type of research did not significantly vary in effect size. As a result, it did not require immediate attention.

Researchers who intend to do meta-analytic research are expected to employ a large number of research articles because the greater the number of samples used in meta-analytic research, the easier the selection process and the higher the quality of the research.

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