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The Effectiveness of IoT-Based Flipped Classroom Model on Students' Critical Thinking Skills: A Meta-Analysis

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Abstract: The research objective is to determine the effectiveness of the Internet of Things (IoT)-based Flipped Classroom model on students' critical thinking skills. This type of research is meta-analysis research. Data sources come from national and international journals. The inclusion criteria in this research are that research must come from journals and proceedings indexed by SINTA, WOS and Scopus; Research from journals published from 2019-2023; Research must use experimental or quasi-experimental methods; Data source searches must be from the G,oogle Scholar, Taylor & Francis, ScienceDirect, IEEE, and ERIC databases; and Research reports values (t), (r) and (f) and sample size > 20 students. Data analysis with the help of the JSAP application. The results of this study conclude that the summary effect size or mean effect size (rRE = 0.764; p < 0.001) has a high influence. In this meta-analysis, the author, year of publication, country of research, values (r), (t), and (f) are analyzed. These findings show that the Internet of Things (IoT) based flipped classroom model is effective in improving students' critical thinking skills.

Keywords: Critical thinking; Flipped classroom; Internet of things; Meta-analysis

Introduction

Critical thinking is a skill that students must have to face the 21st century (Temel, 2022; Elfira et al., 2023; Zulyusri et al., 2023; Farizi et al., 2019). Critical thinking skills are very important for students to solve a problem in the learning process (Arisoy & Aybek, 2021; Gültepe & Kılıç, 2021; Kiriktaş & Şahin, 2021). Critical thinking skills train students in formulating problems, planning and providing solutions in solving a problem (Leniati & Indarini, 2021; Etemadfar et al., 2020; Hacioglu, 2021; Ichsan et al., 2023; Saputra et al., 2019). Thinking skills include high-level thinking skills that have an important role in solving problems in life (Ayuningrum et al., 2015), as well as assisting students in encouraging cognitive abilities and retaining information in learning (Herzon et al., 2018; Nur et al., 2023; Hebebci & Usta, 2022). Efforts to improve students' critical thinking skills involve students actively and creatively in the learning process (Jamaludin et al., 2022).

However, in schools, the ability to think critically and solve problems is still low (Fitriyah & Ramadani, 2021; Putra et al., 2023; Supriyadi et al., 2023; Ramdani, 2016). The learning process does not actively involve students so that learning is teacher centered (Zubaidah et al., 2018; Listiqowati et al., 2022), so that student learning activities seem boring (Sofianora et al., 2023; Atwa et al., 2022; Razak et al., 2021). Furthermore, learning media and models that do not lead students to think critically (Astika et al., 2013), and students' science literacy in learning is still low (Rahim et al., 2021). The results of the 2018 PISA survey conducted by the OECD show that the level of science literacy of Indonesian students in critical thinking is low, only obtaining a score of 396, ranked 71 out of 78 participants (Nurtamam et al., 2023; Suryono et al., 2023; Nurlaeli et al., 2018). Students

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need to be encouraged by teachers in developing critical thinking skills at school. Efforts to develop critical thinking skills through the selection of appropriate learning models.

The flipped classroom model is a learning model that can develop critical thinking skills (Atwa et al., 2022; Diningrat et al., 2023; Nurfadillah et al., 2020; Widodo, 2022). The flipped classroom model is a learning model that utilizes technology to assist the student learning process (Ogden, 2015; Tang et al., 2017). The flipped classroom model is able to provide an active learning process for students in the classroom through collaboration (Ölmefors & Scheffel, 2023; Turan & Cimen, 2020). In the flipped classroom model of learning, the teacher provides learning materials through learning files or videos (Ramadhani et al., 2022; Taş et al., 2022; Aidoo et al., 2022; Pratiwi et al., 2022). Furthermore, the flipped classroom learning model can be connected to the Internet of Things (IoT).

Internet of Things helps students' learning activities become easier through the internet (Frydenberg, 2023; Francisti, 2023). Internet of Things-based learning helps students access learning information quickly (KÖzyer & Altınsoy, 2023; Rodrigues et al., 2023; Mershad & Wakim, 2018). In addition, the Internet of Things is able to help the student practicum process more effectively (Giwerc et al., 2020). Therefore, the flipped classroom learning model based on the Internet of Things encourages students to think critically.

Previous research results Kurnianto et al. (2020) The application of flipped learning model can improve students' learning outcomes and critical thinking skills. Research Mohamed et al. (2018) flipped classroom learning model affects students' cognitive ability. Flipped classroom learning is effective to increase students' interest and motivation to learn independently (Wallace, 2014). Therefore, this study aims at the effectiveness of the Internet of Things (IoT)-based Flipped Classroom model on students' critical thinking skills.

Method

This research is a type of meta-analysis research. Meta-analysis is a type of quantitative research that analyzes previous research that can be analyzed statistically (Bagus et al., 2022; Yıldırım, 2022; Razak et al., 2021; Santosa et al., 2021; Diah et al., 2022). The meta-analysis aims to investigate the effect of the Internet of Things-based flipped classroom model on students' critical thinking skills. According to Badawi et al. (2023) The steps in conducting a meta-analysis consist of: determining inclusion criteria; literature search and data coding process; evaluating each study; statistical analysis and data interpretation. Clearly can be seen in Figure 1.

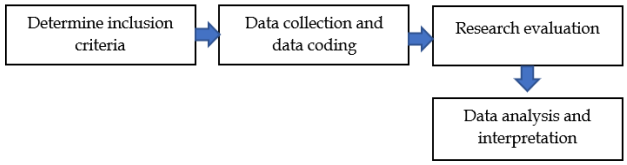

Figure 1. Meta-analysis steps

Data Souerces

Data sources in this meta-analysis came from national and international journals. The process of searching data sources through google scholar, ERIC, Plos ONE, Wiley and ScienceDirect databases. The keys to search for data sources are "flipped classroom learning", "Internet of Things", Internet of Things-based flipped classroom", and "flipped learning model on critical thinking skills". The process of selecting data sources through the database can be seen in Figure 2.

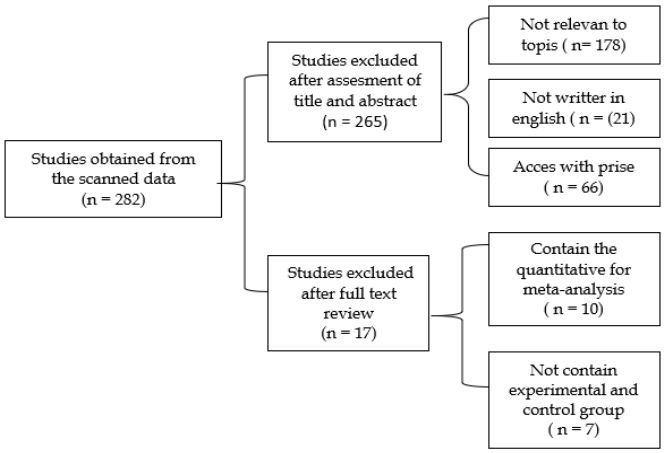

Figure 2. Data selection flow chart

Inclusion Criteria

The inclusion criteria in this meta-analysis study are that the research must come from journals and proceedings indexed by SINTA, WOS and Scopus; Research from journals published from 2019-2023; Research must use experimental or quasi-experimental methods; Data source searches must be from Google Scholar, Taylor & Francis, ScienceDirect, IEEE, and ERIC databases; and Research reports the value of (t), (r) and (f) and a sample size of 20 students.

Data Analysis Procedures

Data analysis with the help of JSAP application to calculate standard deviation, sample size (N), heterogeneity test, and effect size value of the whole study. According to (Cohen, 1988) The effect size criteria in meta-analysis research are Cohen's d < .20 negligible;

20 ≤ Cohen's d < .50 low criteria; .50 ≤ Cohen's d < .80 medium criteria; and Cohen's d ≥ .80 high criteria.

Publication Bias

Publication bias is very important in conducting meta-analyses because. This is due to selecting published studies and only presenting significant results (Kaçar et al., 2021). Therefore, unpublished studies such as these, theses and dissertations are included to prevent publication bias. Determination of publication bias in this study using funnel plot and fail safe N (FSN) test.

Result and Discussion

Results

From the analysis of 282 studies on the Internet of Things (IoT)-based Flipped Classroom model on students' critical thinking skills, there were 10 studies that met the inclusion criteria. Furthermore, studies that have met the inclusion criteria are analyzed based on research characteristics consisting of the researcher's name, journal code, sample size (N), value (t), (r) and (F). The results of sample analysis based on research characteristics can be seen in Table 1.

Table 1. Sample Analysis Based on Research Characteristics

Author	N	r	t	F
Listiqowati et al. (2022)	30	1.43		
Chi et al. (2022)	110	0.97	2.15	
Yerizon et al. (2022)	48	0.72		
Koes et al. (2020)	24	0.63		4.20
Asmara et al. (2018)	24	0.91		
Inayah et al. (2021)	22	0.86		5.14
Alfina et al. (2021)	180		2.61	
(Atwa et al. 2022)	385	2.18		3.17
Al-zoubi (2021)	54		1.16	
Aslan (2022)	68		2.70	

Based on table 1 explains the data analysis based on the characteristics of the researchers where the articles analyzed were published from 2018-2023 and the sample size (N) ranged from 30-262 students. Furthermore, before conducting hypothesis testing, you must first conduct a heterogeneity test of each research effect size. The results of the heterogeneity test can be seen in Table 2 and Table 3.

Table 2. Heterogeneity Test Results

	Q	df	p
Omnibus test of Model Coefficients	69.521	1	< 0.001
Test of Residual Heterogeneity	4240.671	9	< 0.001

Note. p value are approximate

Table 3. The Residual Heterogeneity Test Result

	Estimates	Lower bound	Upper Bound
τ^2	0.563	0.321	0.810
τ	0.641	0.5872	0.979
I^2 (%)	97.620	94.190	99.316
H^2	34.140	24.120	52.150

Tables 3 and 4 explain that the 10 studies are heterogeneously distributed. This can be seen from the p value <0.001; Q = 69.521; τ^2 or t> 0 and I2 (%) = 97.620 close to 100%. The next step is to calculate the summary effect value or mean effect size of the entire research sample. The results of the summary effect size test or mean effect size can be seen in Table 4.

Table 4. Summary Effect Size or Mean Effect Size test

	Estimates	Standard Error	z	p	Lower bound	Upper bound
Interce pt	0.764	0.230	9.007	< 0.001	0.610	1.322

Based on Table 4 explains that the p value <0.001. This result shows the Flipped Classroom model based on the Internet of Things (IoT) on students' critical thinking skills. Furthermore, the results can be categorized as moderate effect based on the estimated standard error value of 0.764 (0.610; 1.322). In addition, the effect size summary analysis test can be illustrated by the forest plot in Figure 3.

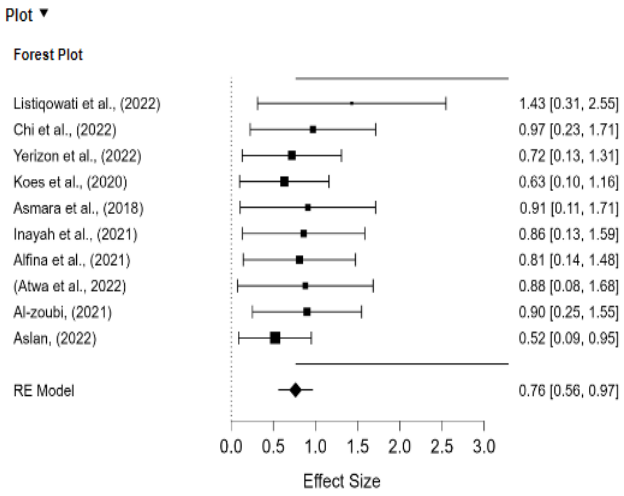

Figure 3. Forest plot

Based on Figure 3, explains that the overall effect size of the study has a significant effect. Furthermore, knowing the publication bias of each study. In this meta-analysis research, publication bias can be known by using funnel plot. Funnel flot effect size of the entire study can be seen in Figure 4.

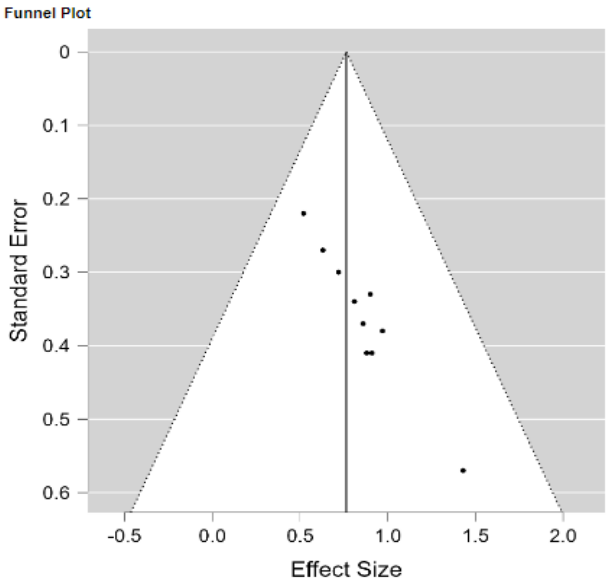

Figure 4. Funnel plot standard error

Based on Figure 4, explains that the points of the study that are extended domina are in the middle of the curve. This shows that the effect size is accurate but it is difficult to determine whether this meta-analysis is symmetrical or asymmetrical, so the Egger test is needed. The Egger test results can be seen in Table 5.

Table 5. Egger Test Results

Egger Test Results	
Intercept	-2.052
% 95 lower limit	-5.235
% 95 upper limit	2.160
t value	0.758
df	9
p value (tag-1)	0.120
p value (tag-2)	0.284

Based table 5,on the value (p-value > 0.05; t = 0.758), the funnel plot distribution is symmetrical. Funnel plot shows there is no publication bias in this study. Furthermore, to increase the validity of publication bias, it is necessary to conduct the Fail Safe N (FSN) test. The results of the fail safe N test can be seen in Table 6.

Table 6. Fail Safe Test Results N

Fail Safe N	
z value	7.351
p-value	0.00
Alpha	0.05
Z for alpha	1.08
N	10
p>number of missing studies	203

Based on table 6, the fail safe N (FSN) value is 203. Furthermore, the value of fail-safe N is compared with the value of k = (5.10) + 10 = 60. Therefore, the value of fail-safe N 203/60 = 3.83 > 0.05, so there is no publication bias in this meta-analysis.

Discussion

From the analysis of 10 studies that have met the inclusion criteria, it illustrates the significant effect of the Internet of Things (IoT)-based flipped classroom learning model on students' critical thinking skills. This can be seen from the summary effect size or mean effect size of the entire study (p < 0.001; 0.764 [0.610; 1.322]). Research results Nugraheni et al. (2022) the application of the Internet of Things (IoT)-based flipped classroom model effectively develops students' critical thinking skills. Next, Mandasari et al. (2019) Flipped classroom learning is able to create student cooperation and encourage the development of student knowledge. The Internet of Things (IoT)-based flipped classroom model trains students to think at a higher level in learning. (Alsowat, 2016; Oktarina et al., 2021; Yurniwati & Utomo, 2020).

The flipped classroom model helps students learn independently and creatively, encouraging critical thinking skills (Betihavas et al., 2016; Nugroho & Maryono, 2020; Jdaitawi, 2019). In addition, the flipped classroom model based on the Internet of things can improve students' learning outcomes and skills in solving a problem (Al-Samarraie et al., 2020; Yavuz & Ozdemir, 2019). The flipped classroom learning process based on the Internet of Things (IoT) is carried out by utilizing technology that students can access in the form of files, videos, and others (Çevikbaş & Argün, 2017; Putri et al., 2022; Katz, 2015).

Furthermore, the application of Internet of Things (IoT)-based learning can help students access learning information faster (Frydenberg, 2023; Francisti, 2023; Du et al., 2021). Furthermore, the utilization of the Internet of Things can develop student and teacher competencies in the learning process (Jiwandono et al., 2021; Rodrigues et al., 2023; Gangi et al., 2023). Furthermore, learning through the Internet of Things (IoT) can develop students' knowledge (Samsugi et al., 2020). Therefore, the utilization of the flipped classroom model in learning is very effective in supporting the improvement of students' critical thinking (Kong, 2014; Afzali & Izadpanah, 2051).

Furthermore, in this meta-analysis study, the calculation of publication bias used funnel plot, Eggers test and Fail safe N. In the funnel plot analysis, the effect size of the study was on a curve. Furthermore, the Eggers test shows that the curve is symmetrical. To test the validation of publication bias, the fail safe N test was conducted (Polat, 2022; Yildirim & Kurt, 2022). The

results of the fail safe N test show that there is no publication bias. Publication bias is very important in meta-analysis tests testing hypotheses (Aybirdi, 2023). So, the flipped classroom model based on the Internet of Things has a moderate effect on students' critical thinking skills.

Conclusion

From the meta-analysis research, it can be concluded that the summary effect size value or mean effect size (rRE = 0.764; p < 0.001) has a high effect. This meta-analysis analyzes the author, year of publication, country of research, (r), (t) and (f) values. This finding shows that the flipped classroom model based on the Internet of Things (IoT) is effective in improving students' critical thinking skills. The flipped classroom model based on the Internet of Things (IoT) helps students learn more independently and creatively so as to encourage critical thinking skills.

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Author Contributions
Syafruddin and Ika Agustina collected research data from national or international journal databases; Jimmy and Komari contributed to the selection process of data-based journals, Tomi Apra santosa analyzed and interpreted the research data.

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Conflicts of Interests
No Conflicts of interest.

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