

Technology-based learning effect on the learning outcomes of Indonesian students: a meta-analysis

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ABSTRACT

The utilization of information technology in education offers learners access to a variety of learning resources that are not restricted. It is expected that this use will enhance the success of the learning process and the attainment of educational goals. The purpose of this study is to examine the impact of information technology-based learning on the academic performance of students in Indonesia. This research adopts a meta-analysis design and utilizes a selection process based on established criteria to gather studies from the Google Scholar and Scopus databases. The study adheres to the PRISMA protocol. There were 51 studies included, comprising 44 academic journals and seven proceedings. The analysis technique applied is a meta-analysis using the random effect size model. The results of this study indicate that the utilization of information technology in education has a significant impact on the learning achievement of Indonesian students. The analysis of 51 studies, including 44 scientific journals and seven proceedings, showed that the effect sizes of the studies varied from -0.80 to 5.85, indicating heterogeneity in the studies analyzed. The effect size model used in this meta-analysis was a random effect size model, with the summary effect value showing a large effect size with a value of 1.285, a $p\text{-value} < 0.001$, and a confidence interval ranging from 1.012 to 1.559. Sub-group analysis also revealed a significant difference in the average effect size across different levels of education, including elementary, secondary, and tertiary education. The results of the study showed no evidence of publication bias.

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1. INTRODUCTION

The rapid transformations in various aspects of life demand that individuals possess the ability to continuously adapt to change. The success of this adaptation is dependent on both the individual's capability to adapt and the impact on the environment. To cultivate an evolved society, the capacity for adaptation and change is imperative [1]. The government, society, and educational institutions have a long-standing commitment to enhancing the quantity, quality, effectiveness, and efficiency of education. One of the initiatives aimed at achieving these goals is the integration of information technology in the educational

system, with the aim of improving the effectiveness and efficiency of the learning process. The use of information technology in education is seen as a trendsetter in this effort.

The growth of information technology is so rapid that the flow of information is so rapid. Following the first and second wave revolutions in agriculture and industry, Toffler dubbed the third wave revolution the rise of information technology [2]. The ramifications of information technology development in education include access to limitless sources of information via the internet network, which recognizes no bounds of space and time, both locally, nationally, and worldwide, allowing for remote learning [3], [4].

In contrast to traditional learning, which is centered in the classroom and requires face-to-face physical interaction between teachers and students, distance learning is designed with a learning system carried out outside the classroom and does not require face-to-face physical interaction between teachers and students [5]. Distance learning is now possible because of advancements in information technology [6]. Interaction between teachers and students can take place in real-time or indirect time (asynchronous). The use of information technology in education, such as gadgets and internet network, allows students to access a variety of learning resources and limitless learning materials. It is predicted that by utilizing this technology, it will be possible to boost the success of the learning process, minimize class absence and dropout rates, and provide an equal distribution of possibilities to get an education that reaches diverse levels of society from various locations [5].

The utilization of information technology is one of the keys to improving the quality and quality of education in Indonesia [7]. Stakeholders in the field of education must be fast and responsive in responding to these technological developments. The impetus to apply information technology in education is not just to follow global trends but is a strategic step in improving access and quality of education.

In the recent decade, the use of information technology in education has piqued the interest of educational experts and practitioners in Indonesia. Especially in the first half of 2020, when the coronavirus disease 2019 (COVID-19) pandemic affected the school industry, necessitating online learning. Many scholars and practitioners are investigating the effectiveness of learning using information technology. Previous research [8]–[14] has demonstrated information technology's favorable impact on the learning process. The use of digital learning media influences the interests and learning outcomes of students. Digital-based learning media provides advantages because it is easy to use, practical, effective, and implement the learning process [15]. The use of information technology also affects learning [16].

However, some studies suggest otherwise. Research conducted by Prestiadi *et al.* using the meta-analysis method concluded that the effectiveness of online learning is still less effective when compared to conventional or face-to-face learning. It is influenced by several factors, including teacher competence in utilizing digital technology, instruments used in online learning such as gadgets and internet network support, and student behavior in online learning [17]. The problem in Indonesia is that using information technology or e-learning in the learning process is not yet optimal, especially in eastern Indonesia. It can be seen from the ineffective management of e-learning sites in several educational institutions such as schools and universities. The e-learning facilities provided have limited access, both in terms of resources and managing the website. The use of e-learning must be supported by various resources, including the readiness of educators and students to carry out learning that utilizes digital technology [8].

With diverse research findings connected to the effectiveness of using information technology in the learning process in Indonesia, it is necessary to perform a study that analyses the research findings in a meta-analysis framework. It is assumed that a meta-analysis study will be able to explain the reality that no research is free of faults or mistakes. Such meta-analytical research should also consider publication bias. As a result of this publication bias, the published literature may not be representative of all research undertaken on a topic, resulting in published studies reporting larger overall effect sizes.

In the last two decades, research on the effectiveness of information technology in education has been widely carried out. Machtmes and Asher conducted a meta-analysis study to examine the experimental research literature on the use of telecourses in adult learning and higher education. The study included experiments using both one-way and two-way video and audio. The purpose of this study was to review the evidence regarding the effectiveness of information technology-based telecourses. Variables that affect student achievement are the type of interaction, the type of course, and the type of remote site. Two-way interaction was found to be the best method of interaction between the learner and the instructor [18].

Furthermore, a meta-analysis of the literature comparing distance education (DE) between 1985 and 2002 was conducted. The study included 232 studies containing 688 respondents regarding independent achievement, attitude, and retention outcomes which were then analyzed [19]. The overall results show a zero-effect size on all three measures and wide variability. It shows that many students who use distance education platforms are doing well, and many are performing worse. Bernard *et al.* divide the achievements into synchronous and asynchronous DE forms, and produces somewhat different impressions. Generally, the average achievement effect size for synchronous applications favors classroom learning, while the effect size for asynchronous applications favors DE. However, significant heterogeneity remained in each subset [19].

Ozdemir *et al.* conducted another study to determine the effect of augmented reality (AR) applications on learning. An experimental study conducted in 2007-2017 on using AR in education was analyzed using the meta-analysis method to determine the effect of AR in the learning process. The articles analyzed were selected among publications in journals indexed in the social sciences citation index (SSCI). In this context, 16 studies were examined to identify the influence of AR applications in the learning process. The results showed that the AR application improved students' academic achievement in the learning process compared to traditional methods. The study explained that the use of AR did not show a significant difference in academic success in the learning process [20].

According to the preceding explanation, the researcher discovered a gap in prior studies, where there were inconsistencies in the conclusions on the effectiveness of information technology-based learning, particularly in Indonesia. As a result, using a meta-analysis methodology, it is critical to investigate the impact of information technology-based learning on the accomplishment of student learning outcomes in Indonesia. It is predicted that a meta-analysis study will be able to describe the findings of linked earlier investigations completely. This study was conducted to offer a theoretical contribution to the future advancement of Indonesian education in terms of the use of information technology in education.

2. RESEARCH METHOD

This research is a type of meta-analysis research [21]. Meta-analysis is a quantitative statistical method for compiling and analyzing descriptive data from relevant published and unpublished research results that explore and test the same research problems and hypotheses [22]. The stages of meta-analysis consist of i) formulating problems; ii) searching the literature; iii) collecting information and findings from individual studies; iv) evaluating the quality of studies; v) analyzing and interpreting study results; and vi) interpret the results or evidence [23]. In this meta-analysis, the data used are secondary data obtained from published research on the effectiveness of information technology-based learning on the achievement of student learning outcomes in Indonesia. Through a meta-analysis study, it is expected to be able to summarize the findings of previous related studies comprehensively. The literature reviewed in this study is journal articles and proceedings in Indonesian or English, and the research subjects are students. The year of publication of articles is limited to 2017 to 2021. Article searches are done by entering keywords in the Google Scholar and Scopus databases.

3. RESULTS AND DISCUSSION

A total of 51 research articles were included in the meta-analysis. The 51 research articles consist of seven articles which are proceedings, and 44 articles are journals. These studies are extracted into a table containing information for each article. The table contains the researcher's name and year of publication, topic, research design, sample group, number of samples, mean, and standard deviation.

According to the publication year, the number of studies published in 2017 was three, while in 2018 it was six, in 2019 it was eight, in 2020 it was twelve, and in 2021 there were 22 studies published. A total of fifty-one studies were published between the years 2017 and 2021. When analyzing the studies based on the level of education, there were four studies conducted at the elementary school level, thirteen studies at the junior high school level, 27 studies at the high school level, and seven studies at the college level. Table 1 shows the database of researched literature [24]–[73].

3.1. Heterogeneity test

This heterogeneity test is needed to determine whether the combined effect size used is a fixed effect or a random effect. The fixed effect is used if the heterogeneity test shows no heterogeneity between study effect sizes, so the data is homogeneous. Conversely, if the heterogeneity test shows a heterogeneous value of the effect size of each study, the calculation of the combined effect size value uses the random effect method.

The heterogeneity test in this study used the help of JASP software. The heterogeneity analysis used several test models commonly used in meta-analysis. This study used Cochran's Q test to determine whether there was heterogeneity in the meta-analysis. Table 2 is the result of the heterogeneity test.

The analysis showed that the 51 effect sizes of the analyzed studies were heterogeneous, with a Q value=412.858 and a p-value<0.001. Thus, the random effect model is more suitable for estimating the mean effect size of the 51 analyzed studies. These results also indicate the potential to investigate the moderating variables that influence the independent and dependent variables [74].

Table 1. Literature database

No.	Ref.	Method	Education level	Control sample	Exp Sample	Control mean	Control SD	Exp Mean	Exp SD
1	[24]	Research and development	College	34	35	86.97	4.26	91.14	4.16
2	[25]	Quasi-experimental	College	30	30	75.5	11.8	81.03	11.6
3	[26]	Pretest- posttest control group design	Senior high school	35	35	71.8	13.8	84.19	7.38
4	[27]	Research & development	Primary school	78	77	52.95	13.2	82.08	11
5	[28]	Experiment	Senior high school	25	26	64.8	11.4	71.04	11.7
6	[29]	Randomized pretest-posttest control group design	Primary school	39	39	53.33	32.5	65.89	18.9
7	[30]	Nonequivalent control group design	Junior high school	25	25	72.93	5.03	79.87	2.97
8	[31]	Experiment	Senior high school	39	39	54.05	16.9	68	18.3
9	[32]	Non-equivalent control group design	Primary school	22	22	71.59	7.75	79.54	8.43
10	[33]	Quasi experiment	Senior high school	35	35	79.05	6.36	85.97	9.08
11	[33]	Quasi experiment	Senior high school	35	35	75.6	13.7	84.62	10
12	[34]	Quasi experiment	Senior high school	64	64	77.46	4.6	78.15	4.09
13	[35]	Experiment	College	20	31	77.55	6.67	86.58	5.89
14	[36]	Quasi experiment	Senior high school	34	34	6.76	5.89	11.47	10.2
15	[37]	Non-equivalent control group design	Senior high school	35	35	48.31	12.7	80.37	11.2
16	[38]	Posttest-only, non-equivalent control group design	Senior high school	20	20	75.2	8.02	81.2	9.98
17	[39]	Pretest and posttest control design	Junior high school	25	28	65.6	15.3	75.71	16.2
18	[40]	Quasi experiment	College	24	24	19.46	9.42	29.4	10.5
19	[41]	Quasi experiment	Junior high school	24	25	59.4	11.7	72.8	5.6
20	[42]	Posttest-only control design	Senior high school	10	10	73.2	8.23	86.4	9.83
21	[43]	Pretest posttest control group design	Senior high school	20	20	74.15	4.12	80.25	2.44
22	[44]	Experiment with using pre and post test	Junior high school	36	36	78.47	4.1	89.03	6.19
23	[45]	Quasi experiment	Junior high school	31	31	76	9.68	84	7.8
24	[46]	Quasi experiment	Primary school	12	12	64.17	9	80.83	7.93
25	[47]	Pre-experimental	Senior high school	35	35	42.7	8.69	82.46	6.42
26	[48]	Quasi-experiment	Junior high school	18	18	26.67	7.29	40.28	8.13
27	[49]	True experimental	Junior high school	30	30	19.13	3.69	24.69	3.28
28	[50]	Pretest- posttest control group design	Junior high school	32	32	74	4	81	3
29	[51]	Non-equivalent control group design	Senior high school	20	20	61.75	8.62	86.75	6.54
30	[52]	Pretest- posttest control group design	Senior high school	31	32	70.65	8.73	84.53	6.52
31	[53]	Quasi experiment	Junior high school	25	25	68.9	10.3	88.5	6.21
32	[54]	Quasi experiment	Senior high school	29	33	76.44	4.64	77	5.32
33	[55]	Non-equivalent control group design	Senior high school	28	28	71.25	6.32	80.54	6.13
34	[56]	Quasi experiment	Senior high school	30	30	77.8	4.72	85.9	5.61
35	[57]	Research and development	College	25	25	81.92	8.5	85.12	8.45
36	[58]	Experiment	Junior high school	28	28	67.25	7.87	72.14	8.43
37	[59]	Experiment	Senior high school	34	34	73.2	14.9	80.6	15.4
38	[60]	Experimental non-equivalent control group design	Senior high school	25	25	84.5	6.65	90.1	6.12
39	[61]	Experiment	Senior high school	20	20	67.5	12.1	80.5	8.87
40	[62]	Experiment	Junior high school	36	36	75.4	5.29	78.94	9.67
41	[63]	Quasi experiment	Junior high school	29	28	17.52	3.03	23.43	2.64
42	[64]	Development	Senior high school	25	25	56.2	14.9	64	12.8
43	[65]	Pre-test-posttest control group design	Senior high school	20	20	75.2	7.29	90	5.86
44	[66]	Quasi experiment	Senior high school	20	20	68.15	7.03	75.51	3.91
45	[67]	Posttest-only non-equivalent control group design	Senior high school	32	32	75.16	16.7	77.66	18.6
46	[68]	Quasi experimental design	Senior high school	30	30	83.1	4.95	85.54	3.76
47	[69]	Quasi experiment	College	88	87	22.04	3.51	25.9	3.55
48	[70]	Quasi experiment	College	20	20	63.2	4.96	91.95	4.67
49	[71]	Posttest-only control group design	Senior high school	45	45	61.51	6.89	75.11	5.96
50	[72]	Posttest-only control design	Junior high school	36	35	47.83	17.3	66.07	18.8
51	[73]	Experiment	Senior high school	8	12	73.38	8.85	65	10.7

Table 2. Heterogeneity test

	Q	df	p
Omnibus test of model coefficients	84.777	1	<.001
Test of residual heterogeneity	412.858	50	<.001

Note: p-values are approximate; the model was estimated using restricted ML method

3.2. Summary effect size

The random effect size model is the effect size model used to estimate the summary effect. Estimation is performed using JASP software by providing the research's name, the effect size of each study, and the standard error of the effect size of each study. Table 3 shows the summary effect.

Table 3. Summary effect (Wald test)

	Coefficients		z	p	95% Confidence interval	
	Estimate	Standard error			Lower	Upper
Intercept	1.285	0.140	9.207	<.001	1.012	1.559

The analysis results show that the random effect size value shows the number 1.285 with a p -value < 0.001 and a confidence interval for the lower limit of 1.012 and the upper limit of 1.559. The p -value of 0.001 is smaller than the value of (0.05), so H_0 is rejected. So, it can be concluded that there is a significant effect of information technology-based learning on student achievement in Indonesia. An effect size of 0.20-0.49 suggests a minor effect, an effect size of 0.50-0.79 shows a moderate influence, and an effect size of 0.80 or higher indicates a significant effect, according to the Cohen value interval [75]. The calculation results show a cumulative effect size value of 1.285, indicating a significant effect. Thus, the impact of information technology-based learning on student achievement in Indonesia is significant.

The results of the analysis also contain a forest plot as shown in Figure 1. The forest plot represents each study's effect size and its contribution to the combined effect size (weight). In the forest plot, the effect size representation is visualized as a line in the center of the plot. This visualization shows the estimated study points on the x-axis. This point estimate is complemented by a line representing the range of confidence intervals calculated for the observed effect size. A square surround the point estimate. The weight of the effect size determines the size of the square. Studies with larger weights form larger squares, while studies with lower weights have smaller squares.

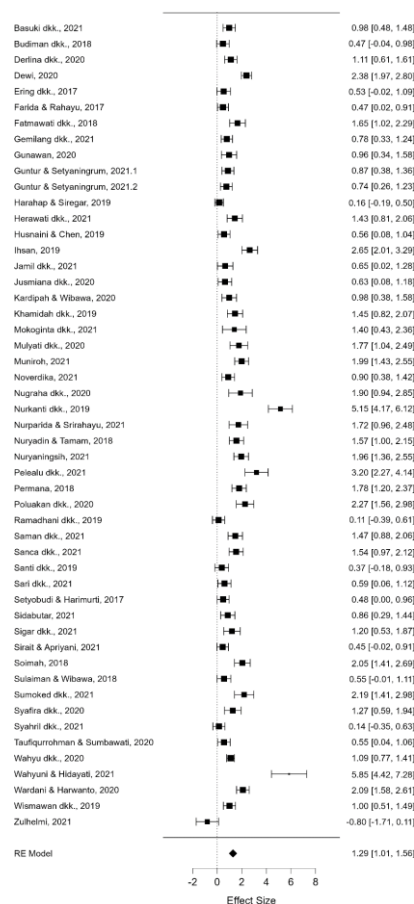


Figure 1. Forest plot

3.3. Subgroup analysis

The study of heterogeneity in the meta-analysis is essential in identifying the appropriate combined effect size model and determining whether the variance affects the combined effect size results. From the previous explanation, it has been explained that the results of the heterogeneity test of the meta-analysis of

the observed studies show a high/substantial heterogeneity value. For this reason, it is essential to do a post-hoc test based on the high heterogeneity test results. The post-hoc test in meta-analysis is to perform sub-group analysis or commonly called moderator variables. In this subgroup analysis, a different approach is used to identify why specific patterns of heterogeneity can be found in the observed study data. The subgroup analysis assumes that the heterogeneity of the study effect size is not a disturbance but an interesting variation that can be explained through scientific hypotheses. In this study, education level is a moderating variable that causes heterogeneity in the effect size of the observed studies.

The subgroup test was carried out with the help of JASP software by entering effect size data and standard errors for each study that had been grouped by education level. The level of education is divided into four groups, namely: i) elementary school (SD); ii) junior high school (SMP/MTS); iii) senior high school (SMA/SMK/MA); and iv) college (PT). The data needed to test the hypothesis are summary effect data, overall Q value, the effect size for each group, and the Q value for each group. Table 4 summarizes the data.

Table 4. Summary of effect size and Q

Group	Effect size	Q
Elementary school	1.414	41.523
Junior high school	1.515	46.313
Senior high school	1.261	263.709
College	1.673	51.744
Overall	1.285	412.858

After acquiring the data, as mentioned earlier, the statistical value of Q is examined by computing Q_{within} (1) and $Q_{between}$ (2) with $df = k - 1$ to determine the p-value. Table 5 shows the subgroup test summary. The p-value obtained is smaller than 0.05, so it can be concluded that there is a significant difference in the average effect size at the level of education between elementary, junior high school, senior high school, and college. These differences can also be observed in the forest plots of each group.

$$\begin{aligned}
 Q_{within} &= Q1 + Q2 + Qi \\
 Q_{within} &= 41.523 + 46.313 + 263.709 + 51.744 \\
 Q_{within} &= 403.289
 \end{aligned} \tag{1}$$

$$\begin{aligned}
 Q_{between} &= Q_{overall} - Q_{within} \\
 Q_{between} &= 412.858 - 403.289 \\
 Q_{between} &= 9.569
 \end{aligned} \tag{2}$$

Table 5. Subgroup test summary

Q_{within}	$Q_{between}$	df	p-value
403.289	9.569	3	0.0226085

3.4. Publication bias

Publication bias arises when the results affect a study's likelihood of publication. For this reason, a publication bias test is needed to determine whether the data from the observed study are publication bias. The publication bias test in this meta-analysis study used two publication bias tests. The funnel plot test and the file drawer analysis test are the two publication bias tests or Rosenthal's fail-safe N model [23]. The results of the two publication bias test methods are described.

3.4.1. Funnel plot

The sample size and standard error are closely related in this experimental research. A standard error larger than the effect size results in a wider confidence interval and increases the likelihood that the effect is not statistically significant. Therefore, it is reasonable to assume that the effect of the small study will largely affect the study with a larger standard of error. The funnel plot is the most used analysis of publication bias. With the help of JASP software, the following funnel plots are obtained as shown in Figure 2. The funnel plot shows a symmetrical distribution, so it can be said that there is no publication bias in this meta-analysis study.

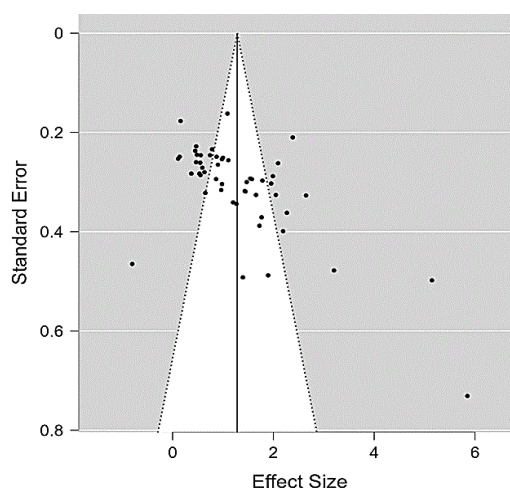


Figure 2. Funnel plot

3.4.2. File drawer analysis

File drawer analysis in this meta-analysis uses the Rosenthal model. The value of the save file N obtained is 15,917, with a target significance of 0.05 and $p < 0.001$. Table 6 shows the results of the file drawer analysis.

According to Mullen's formula, assuming $N/(5K + 10)$ is greater than 1, the publication bias is certainly low [76], [77]. While the value of $5K+10$ with $K=51$ obtained a value of 265. The result of $15,917/265=62.1$ is greater than 1, so it has a relatively low meta-analysis publication bias. So, it can be concluded that there is no publication bias problem in this meta-analysis study.

Table 6. File drawer analysis

	Fail-safe N	Target significance	Observed significance
Rosenthal	15917.000	0.050	<.001

4. CONCLUSION

The results of the study demonstrate that the effect size of the studies analyzed in this meta-analysis varies from -0.80 to 5.85. The findings indicate the presence of heterogeneity, and as a result, a random effect size model was employed in this meta-analysis study. The findings indicate that the utilization of information technology in education significantly enhances student learning outcomes in Indonesia. The impact of information technology-based learning on student learning outcomes falls within the large category of 1.29. The results of the study reveal a significant discrepancy in the mean effect size at the school level between elementary school, junior high school, senior high school, and higher education. Based on these findings, it can be concluded that there are disparities in the effectiveness of information technology utilization in enhancing student learning outcomes, contingent upon the level of education. This meta-analysis found no evidence of publication bias.

This study has significant implications for further research on the utilization of information technology in education to enhance the quality of instruction. The results of this study highlight the significance of incorporating information technology in education, particularly in Indonesia. This study supports previous research findings on the effectiveness of information technology-based learning and encourages the advancement and implementation of information technology in education. However, it should be noted that this meta-analysis has several limitations, including the restriction to open-access studies available through the Scopus database, and the possibility of bias in the article selection process as it was performed by a single researcher rather than multiple individuals.

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