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Meta-analysis of digital-based learning to improve learning outcomes

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Abstract: The learning process in the 4.0 revolution era has changed from conventional systems to digital. It causes every education component to use various features of digital technology as a learning medium. This study aims to determine and analyze the effectiveness and influence of digital-based learning media on learning outcomes in economics subjects in senior and vocational high school. The meta-analysis by examining the research results relevant to research variables from various research articles and theses is used in this study. Twenty-six studies examined digital-based cooperative learning media. The findings present that the effectiveness of digital-based learning media improves student learning outcomes. The quality of educators influences the effectiveness of using digital-based learning media in learning materials according to the tools or media used so that students' enthusiasm for participating in learning increases.
Keywords: digital learning; learning outcomes; meta-analysis

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INTRODUCTION

The growth of digital technology in the era of revolution 4.0 and society 5.0 affects the learning process from conventional systems to distance learning systems with the help of digital devices such as computers, mobile phones, and tablets (Ismiyati et al., 2021; Sholikah & Harsono, 2021). Learning with digital media provides more advantages than conventional ones, reducing costs and increasing student achievement (Arkorful & Abaidoo, 2015; Delgado et al., 2018; Lin et al., 2017; Suryani, 2016). In addition, the process of teaching and learning activities with a digital-based learning system is also considered adequate because it can be used anytime and anywhere (Korhonen et al., 2019). Thus, changes in the digital-based learning process significantly impact teachers, students, and schools.

The impact is that teachers and students must use various digital media as distance learning media. Understanding teachers and students are vital in achieving learning success. Similar to Wei & Chou (2020) and Yavuzalp & Bahcivan (2021), aspects of the ability of teachers and students in digital-based learning affect the success of online learning and student achievement. For this reason, the role of teachers and students is needed to improve the learning process and build effective communication to increase student satisfaction.

Appropriate digital learning media in online learning can bolster the relationship between lecturers and students to set off character changes for the surpass (Gray & DiLoreto, 2016). Several studies on using digital-based learning media have been widely studied. For example, Quealy & Langan-Fox (1999) found that Online learning can be effective if the media used is by the subject matter; besides that, mastery of the material by educators is also essential for the success and achievement of learning objectives (Quealy & Langan-Fox, 1999; Yavuzalp & Bahcivan, 2021). The results of other studies reveal that implementing digital-based learning media affects student learning outcomes (Ardiansyah & Diella, 2019).

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In research studies by Prestiadi et al. (2020), students tend to prefer learning online because the learning process is carried out concisely, and the learning media used are also very varied. In other research about the effectiveness of online learning as a learning medium, Ariesta (2019) and Lilis et al. (2020) concluded that the implementation of online learning is quite effective in supporting the success of In learning (Ariesta, 2019). However, different research results were found by Hsiao et al. (2019) in the short term, learning media-based digital is an insignificant effect, but in the long term, it is impactful because it can change student behavior.

Different results were also found by Kong et al. (2018), where students performed better when using traditional media than when using digital devices. Powered by Joosten and Cusatis (2019), the post-test results between distance learning and conventional learning students showed no significant difference. Thus, the main conclusion from the previous meta-analysis review found inconsistent results. Hence, it is crucial to amalgamate different studies (Dell et al., 2010; Paul & Jefferson, 2019). The synthesized study uses learning outcomes as variable indicators. Testing hypotheses in each selected study by comparing digital learning averages. Standard deviation was an indicator variable. The findings expose the actual improvement of digital-based learning and investigate its effect on learning outcomes. Meanwhile, the effect size is working to determine how effective the experimental class treatment is.

This study aims to confirm and generalize similar studies so that this research combines various literature studies. In addition, research with meta-analysis is also used to analyze previous studies, resolve problems entrenched in the literature, and identify critical conflicts for subsequent research (Delgado et al., 2018). In this study, researchers present the results of a meta-analysis that explores the effectiveness of digital-based learning on student learning outcomes. It is well known that researchers in any field cannot by themselves make satisfactory contributions to the development and testing of complex theories. Therefore, selecting meta-analyses can help summarize, integrate, and interpret findings from various studies (Creemers & Kyriakides, 2010; Kyriakides et al., 2014). In addition, by calculating the mean effect, meta-analysis can correct the distorting effect of different types of errors in sampling or measurement errors which usually result in conflicting findings, thereby biasing the actual basic pattern (Zhao, 2017). Thus, this research seeks to determine each study's effect size on the effectiveness of digital-based learning on learning outcomes.

METHODS

Research design

Descriptive research is the type of this research, namely the analysis presents the results of scientific research publications in electronic journals nationally related to digital-based learning media to improve economic learning outcomes. This study uses a pre-post contrast meta-analysis approach to combine and evaluate statistically based on findings about digital-based learning media to improve economic learning outcomes in senior and vocational high school. The pre-post contrast meta-analysis aims to compare and find out changes in a subject in certain variables the first time (T1) and the second time (T2) (Retnawati et al., 2018). Pre-post contrast is also called repeated measurement (Cheung & Hew, 2015; Retnawati et al., 2018).

Data Collection

Searching for the literature is the most critical step in a meta-analysis because, at this stage, the researcher must collect study materials in the form of research documents and correct the documentation of the results of previous research (Sahronih et al., 2019). In addition, this literature search was also used to find relevant research results. This study uses several electronic databases such as Scopus (Social Sciences and Humanities), dissertations and theses, Emerald, and Google Scholar. This study's search terms include online, digital, and learning outcomes. These terms are searched for as titles, abstracts, or keywords. In line with Card et al. (2012), the search for research results should focus on several disciplines, including research, assessment, practice, media studies, and instructional technology.

In this study, the researcher becomes the main instrument in the documentation and synthesis process of the previous findings. The focus of the research becomes clear; data will be collected from various sources, which are then developed into simple research instruments. The research results are

expected to complement and compare data from previous findings from this process. Data collection techniques use documentation from various similar research results. The sample in this research is purposive sampling assuming that the data obtained is adjusted to the research theme.

Coding

The next step is coding. The search results obtained 26 theses published online with complete data for the pre-post test scores. The next step is coding. The search results obtained 26 theses published online with complete data for the pre-post test scores. The coding comprised research, year, independent variable (learning outcome), sample size, average achievement, and standard deviation taken from the experimental class. This step is an important part that needs to be done before the statistical analysis process. The dependent variable in the research is digital-based learning.

Data Analysis

The effect size is a standard measure used in meta-analyses that determines the strength and direction of the relationship (Candra & Retnawati, 2020). So the data analysis technique in this research uses pre-post contrast analysis. Retnawati et al. (2018) pre-post contrast analysis procedures include: (1) calculating effect size, effect size variance, and standard error of effect size; (2) calculating summary for effect size, effect variance, standard error effect; (3) calculating confidence intervals; (4) test the hypothesis by calculating the value of Z, and p-value; and (5) make interpretations and conclusions of the results of the analysis. Retnawati et al. (2018), the flowchart of the pre-post analysis meta-analysis can be seen in Figure 1.

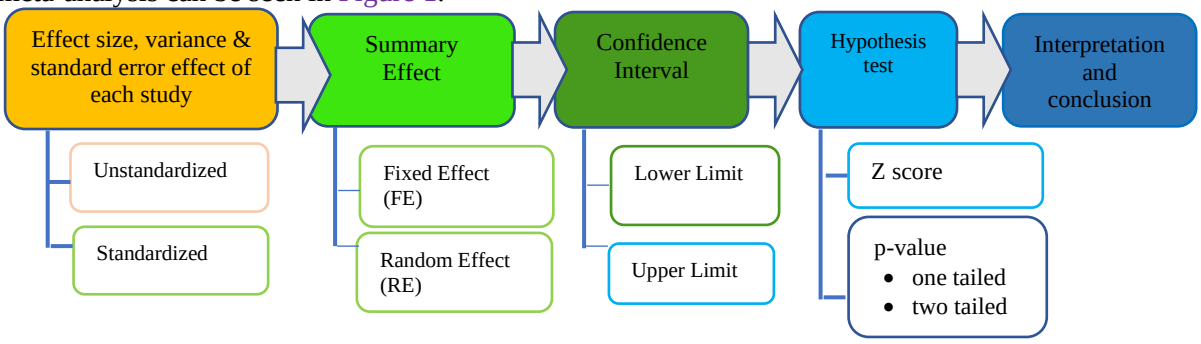

Figure 1. Pre-Post Contrast of Meta-Analysis Flowchart

Effect size analysis

After obtaining the average standard deviation data, the next step is transforming the average into the same scale to produce each effect size. In this study, the range of values is from 1-100. For this reason, the transformation carried out refers to a scale of 1-100. This transformation standardized the effect size of each study. This effect size standard is used to compare the mean of independent groups that are considered equal for each study of each of the two variables (Çiftçi & Yildiz, 2019).

Calculating summary effect size

The next step is to calculate the summary effect size. There are two models for calculating the summary effect size: the fixed-effect model and the random effect model (Retnawati et al., 2018). The way to determine the model is to test for heterogeneity using the Equation 1.

$$Q = \sum W_i \, ES_i^2 - \frac{(\sum W_i \, ES_i^2)}{\sum W_i} \quad \text{..... 1)}$$

Statistically, the decision-making criteria H_0 is rejected if the chi-square table is greater than the critical value. H_0 here states that the effect size between studies is homogeneous (Retnawati et al., 2018).

Data analysis

Data analysis includes summary effects, forest plots, funnel plots, and publication bias. The summary effect can be obtained using the Equation 2.

$$\overline{ES} = \frac{\sum W_i ES_i}{\sum W_i} \quad \text{..... 2)}$$

In addition to these equations, summary effects can be obtained using the JASP 0.11.1.0 program (https://jasp-stats.org/previous-versions/). With this program, researchers will also obtain forest lots and funnel plots. Furthermore, interpretation needs to be done to describe the summary effect output, forest plot, and funnel plot—furthermore, the analysis of publication bias using the JASP 0.8.4.0 program.

RESULTS AND DISCUSSION

Result

Based on the search results of research articles and theses, 100 articles have been found using the intervention model, furthermore selected and obtained 96 articles were. Afterward, the articles were examined by categorizing research, and 52 studies were preferred. In consonance with variables equally $\bar{x}$, SD, t-value, p-value, and a few samples, only 36 studies were reached. Then, the researcher investigated the research framework (pre-test, post-test, control) as an indicator variable, and 26 articles were selected.

Summary findings of 26 articles show 18 types of cooperative learning methods. The cooperative learning method with blog media and interactive CD is the most studied learning media (11.53%). Meanwhile, methods still rarely studied are wallcharts, Facebook, animation, educational games, fun spreadsheet quizzes, interactive monopoly, Edmodo, films, documentaries, firing lines, educative tax detectives, and educational games that want to be an account.

The results of the calculation of effect size (Appendix 1) show that the average value of the weighted effect (M*) is 16.97 with a variety of summary effects (VM*) of 0.050, while the standard error of summary effect (SEM*) is 0.223. For the confidence interval on the weighted mean effect (M*), the lower limit (LLM*) is 12.37, and the upper limit (ULM*) is 21.20. Thus the results of the summary effect are present in Figure 2.

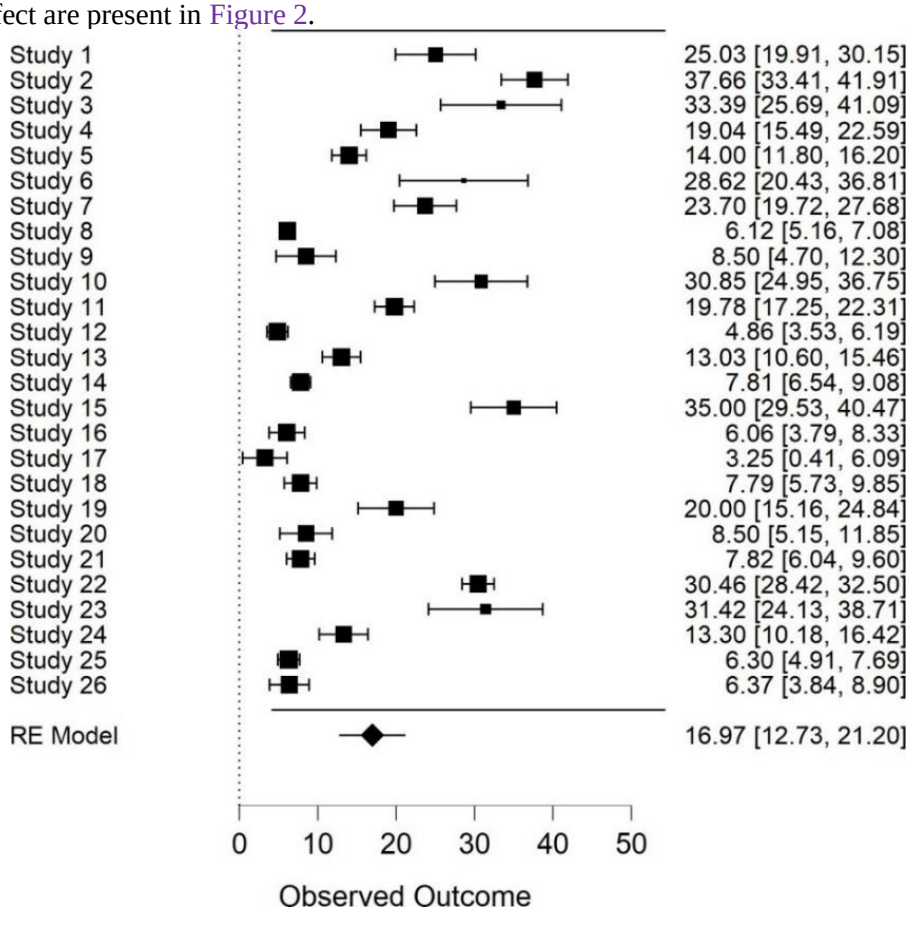

Figure 2. Forest Plot

The forest plot in Figure 2 shows that the black box is the effect size value in each study. The number in brackets is the limit value of the confidence interval with 95% significance, and the number outside the brackets is the correct value. Meanwhile, the black diamond is the effect size of all studies. The horizontal line on each effect size is the boundary value of the confidence interval. It can be seen in the vertical line, which is the confidence interval's acceptance limit. The study is insignificant if the horizontal line exceeds or crosses the vertical line. If the effect size value is on the left side of the dotted vertical line, then the study is negative. Then, if the effect size value is just above the dotted vertical line, the value is zero and positive.

Furthermore, to test the hypothesis, the p-value and z-value are calculated to determine the acceptance and rejection of the null hypothesis H0: true effect $\theta = 0$). Based on the calculation, the value of Z (M* / SEM*) is 76,119, while the p-value using Microsoft Excel with the formula = 1-NORMSDIST for the p-value one-tailed test and 2 [1-NORMSDIST] for the p-value two-tailed test which is less than ($p < 0.05$). The analysis results using the RE (Random Effect) model can be seen in Table 1.

Table 1. Random Effect Analysis Results

Mean and precision		
Main effect	M8	16.97
Variance	VM*	0.050
Standard error	SeM*	0.223
Confidence intervals		
Lower limit (95%)	LLM*	12.37
Upper limit (95%)	ULM*	21.20
Test of the null that M=0		
Z for the null	Z*	76.119
p-value (1-tailed)	P*1	0
p-value (2-tailed)	P*1	0

Because the p-value < (0.05), then H0 is rejected; in this case, the actual effect size is not equal to 0. Thus, digital-based learning is "effective" when viewed from student learning outcomes based on research results from 2011 to 2019 (9 years). Next, the process of detecting publication bias from 26 articles to obtain missing research information (unpublished) and evaluate research conclusions that conclude that digital-based learning is effective for improving learning outcomes in economics subjects. Detection of research publication bias using JASP software with the results in Table 2.

Table 2. Rank Asymmetry Test Correlation for Funnel Plot

	Rank	Sei
Kendall's τ	0.493	-
p	< 0.001	< 0.001
Z	-	5.436

Rank asymmetry test correlation for funnel plot is used to see whether the study includes publication bias based on Kendall's value and the value of the regression correlation coefficient with variance. The research criteria included publication bias if the p-value <0.05 and vice versa. From Table 2, the analysis results obtained based on the rank correlation method are 0.493 with a p-value of 0.001, while the regression method is 5.436 with a p-value of 0.001. It means that the research includes publication bias. This study also uses a funnel plot to detect publication bias, as shown in Figure 2.

Figure 2 is a graphical way to determine whether there is a tendency for publication bias from a synthesized research article or not (Yuwono & Sujono, 2018). Determination of whether or not there is publication bias can be observed from the triangles depicted in the funnel plot. Symmetrical triangles indicate that there is no publication bias. Meanwhile, the asymmetrical triangle shows a tendency for publication bias. Regarding the results in Figure 2, there is a tendency for publication bias. This publication bias occurs due to over-intervention in small studies with low methodological quality. In addition to using funnel plots, other methods for detecting publication bias can also use fail-safe N. For clarity, the results of the fail-safe N method are presented in Table 3. Retnawati et al. (2018), the

tolerance level equals 5k+10, so the result above shows 5*26+10 = 140. Therefore, the fail-safe value N (24598.000) >140. It shows that there is an influence of publication bias.

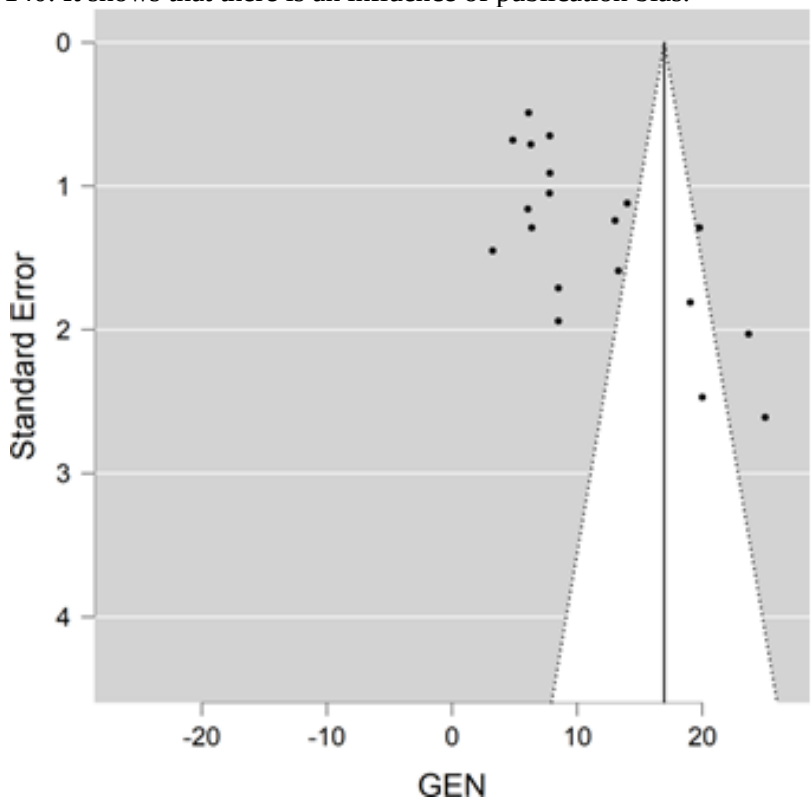

Figure 2. Funnel plot

Table 3. Results of the Analysis of the Fail-Safe N

Fail-save N	24598.000
Target sig.	0.050
Observed sig.	< 0.001

Discussion

Based on the results of a meta-analysis of 100 articles related to digital-based learning, it can be seen that the purpose of research on digital-based learning is mainly to determine the effectiveness of learning. The results showed that digital-based learning was proven to be "effective" in improving the learning outcomes of high school and vocational high school students. It is indicated by the value of Z=76,119 with a p-value less than = 0.05. The average weighted effect (M*) of the 26 studies is 16.97. Therefore, learning improves student learning outcomes not only from the learning model but also from other factors.

The study results of 26 articles show that the weighted average effect (M*) has a positive value from 0.49 to 37.66. This value indicates a difference between the post-test scores and the pre-test scores. The difference in values indicates that the post-test is higher than the pre-test. According to Figure 1, the slightest weighted average effect (M*) is 0.49. This research was conducted by Darmawan (2016), Mufidah & Roifah (2020), and Taqwa & Sandi (2019), where research is carried out with the type of Research and Development research (R&D) by using vlogging development media for learning media.

According to Biel & Gatica-Perez (2013) and Maulidah & Prima (2018), the use of vlogs as a learning medium can involve all students in learning and, at the same time, teach other students. Vlogging or video is a medium that can present audio and visual forms containing learning messages in the form of concepts, principles, procedures, and application theories to help understand a learning material. Meanwhile, the highest mean weighted effect (M*) is 37.66. This research was conducted by Chomariyah (2019), where the research was conducted with the type of experimental research. The learning model used is the Interactive CD (Compact Disk) media. The same thing was done by

research by (Kustyarini et al., 2020; Pernanda et al., 2018; Rusilanti & Nurlaila, 2017; Yasmi et al., 2017). By using Interactive CD (Compact Disk) media, Interactive CD (Compact Disk) is very useful for students and can attract attention in the learning process in class (Kustyarini et al., 2020; Pernanda et al., 2018; Rusilanti & Nurlaila, 2017; Yasmi et al., 2017). The benefits are convenience in learning, overcoming teacher limitations and overcoming problems in delivering teachers to students.

Based on the results of research from 26 articles, it can be seen that the average value of the weighted effect (M*) and it is seen that each study has a different value. Internal and external factors cause differences in research results obtained by each study. Internal factors include talent, interest, condition of students when collecting research data, and intelligence. External factors include classroom conditions, school environment, and society (Prestiadi et al., 2020). In addition, even though using the same type of learning media in the teacher's learning process, it is possible to implement it in different learning to affect student learning outcomes.

Meanwhile, from the detection of publication bias, from these 26 studies using three methods of detection of publication bias, it is shown that there is publication bias. Factors that cause high bias in effect size are language bias, availability bias, cost bias, familiarity bias, publication bias, and citation bias (Retnawati et al., 2018). Twenty-six studies were taken from the university's repository and library and published online for this meta-analysis research. So this is one of the cost biases because researchers looking for research are selective in choosing research that is available for free). In addition, there is also an availability bias, where researchers are selective in choosing research that is more accessible online. The impact of publication bias by Card et al. (2012) and Retnawati et al. (2018) is that the resulting information becomes inaccurate because the published literature may not represent the research that has been done on a topic. It becomes a challenge for further research to take the repository or library results. However, take advantage of other search sources.

CONCLUSION

Based on the results and discussion that has been carried out regarding meta-analysis studies of digital-based learning media to improve economic learning outcomes, it can be concluded that the calculation of the effect size obtained by the weighted average effect (M*) is 16.97 with a variety of summary effect (VM*) of 0.050 while the standard error from summary effect (SEM*) is 0.223. For the confidence interval on the weighted mean effect (M*), the lower limit (LLM*) is 12.37, and the upper limit (ULM*) is 21.20. This value indicates a difference between the post-test scores and the pre-test scores. In this research, of course, there are still limitations and things that still need to be studied and developed, namely one strategy in implementing learning media either directly or online by using learning media that are easily understood by students and can overcome the problem of delivering material between teachers and students, to improve student learning outcomes.

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