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Meta-Analysis Study: The Effect of Augmented Reality on Student Learning Outcomes

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ABSTRACT
This study aims to determine the effect of Augmented Reality on student learning outcomes. This study consists of two variables: Augmented Reality as the independent variable and student learning outcomes as the dependent variable using quantitative meta-analysis research. The instrument used is an article coding sheet containing the data needed for meta-analysis in the form of mean data, the number of samples, and the standard deviation of control and experimental groups from articles that have passed the selection based on inclusion and exclusion criteria obtained through Google Scholar search. The results of the meta-analysis on 13 research articles obtained a summary effect (average effect size) of 0.541 which means that augmented Reality has a significant positive effect on student learning outcomes based on the effect size category set by Cohen. The results of the publication bias test show that the conclusion of the meta-analysis is not indicated by publication bias, as evidenced by the results of the funnel plot, egger test, and fail-safe N results. This study concludes that there is an effect of Augmented Reality on student learning outcomes.

INTRODUCTION

Technology has a great influence on all aspects of human life. Technology has many roles in the teaching and learning process; advances in science and technology greatly influence various fields of education that are inseparable from advancing science and technology. According to Rusman (2015), the technology role in student learning is guided to understanding how and where information can be obtained, how to package/process information, and how to communicate it. In addition to helping students in the learning process, technology also plays a role for teachers, especially in using facilities to enrich their teaching abilities. It indicates that the use of information technology in the learning process in the classroom has become a necessity in today's global era.

Learning media is a tool that can help the teaching and learning process and clarifies the meaning of the message conveyed by the communicator to the communicant. According to Grafe (Tulodziecki, 2012), the function of the media is to introduce cases or learning tasks, as a source of information and learning aids, as a tool for finding solutions to answers, a tool for feedback for the learning process, providing materials for their analysis or processing, an instrument organizing, store, organize knowledge resources and tools for communication and cooperation. Furthermore, by Bujokas (2014), educational media are media that can help create a learning environment where students become aware of the value of educational attainment. Effective learning media will encourage students to learn independently and form student-centered learning (Halimovna et al. 2021). For this reason, it is necessary to use technology to realize effective learning media. Virtual technology is one of the products

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of the industrial revolution 4.0 (Ma & Liu, 2016; Fajari & Meilisa, 2022). It was chosen because virtual technology can accurately represent real objects in providing information. Based on one example of virtual technology, Augmented Reality (Alzahrani, 2020). Media in learning helps students understand the concept of material that is considered difficult to explain using verbal language. Media use must be planned and systematic to the learning objectives (Fajari, Sarwanto & Chumdari, 2020). Media use depends on the media characteristics and the ability of teachers and students to understand how to use the media. Learning media in the learning process can arouse students' desires and interests, provide learning motivation, and significantly influence student learning activities (Aqib, 2013).

Learning media based on Augmented Reality (AR) is a media that combines components in Augmented Reality that are technological in the form of images, internet, video, and so on (Riyana, 2012). AR is an interactive technology that can unite something real and virtual to produce three-dimensional (3D) objects that can be seen on the user's smartphone layer (Fajari & Meilisa, 2022). The workings of augmented Reality can detect images or images called markers using a camera on a cellphone or smartphone. Augmented reality-based learning media is expected to assist when a teacher delivers teaching material so that it is more interesting. Based on what has been done by Halidi et al. (2015), augmented reality-based learning media is a pleasure for students because it helps students become more active during the learning process. so when it is recommended that teachers use this media to improve their students' learning outcomes. In addition, media students are helped to remember and manage information on teaching materials received. Media, in general, have been used, namely to clarify messages so that they are not verbal, overcome the limitations of space, time, energy, and senses, create a passion for learning, more direct interaction between students and learning resources, and help students become independent according to their talents, visual-auditory, and the visual kinesthetic (Fajari, Sarwanto & Chumdari, 2020).

Technology is always developing from time to time. Along with these developments, one development is augmented reality technology or abbreviated as AR. According to Furh (2011), augmented Reality combines the virtual world with the real world created through a computer. For example, virtual objects can be in animation, text, 3D models, or videos combined with the real environment so that users feel that virtual objects are in their environment. According to Goel and Bhardawaj (2014), AR technology can normally run on mobile devices such as iPhones, IPads, smartphones, PCs, tablets, and others. For example, a smartphone can combine a three-dimensional (3D) object into a real environment with Augmented Reality technology. Furh (2011) stated that augmented reality (AR) is a technology that combines two-dimensional or three-dimensional virtual objects into a real environment and then projects these virtual objects in real-time.

Therefore, augmented Reality can play a role in growing student learning outcomes. For example, students can directly observe three-dimensional objects and learn more effectively than one- or two-dimensional images. Furthermore, three-dimensional objects generated from augmented Reality can improve students' analytical skills, making it easier for students to solve mathematical particle dynamics problems. In addition, this media can also motivate and arouse students' curiosity because the augmented reality learning system is different from existing learning; with this, it is hoped that student learning outcomes will be better (Furh, 2011).

Based on the importance of using augmented Reality, a comprehensive study is needed regarding the effectiveness of augmented Reality in the learning process. The meta-analysis method is a process in which the data of each study is processed and used to make statistical conclusions. These can be expressed in various measures that are calculated or searched in advance by formulas expressed by various mathematical equations, which are closely related to the research objectives of the analysis. Meta-analysis was performed (Pereira, 2019). This site is known as the effect size. The meta-analysis includes content analysis that encodes research characteristics, such as age, place of research, or certain domains in certain scientific fields. Then, effect sizes with the same characteristics are grouped and compared (Mueller et al., 2018). Based on the explanation above, it can be concluded that augmented Reality is a technique that combines two-dimensional and three-dimensional virtual objects into a three-dimensional (3D) real sphere and then projects in real time to create a big picture of augmented Reality with student learning outcomes across Indonesia. So a meta-analysis study is needed. So, this study aimed to determine the effect of augmented Reality on student learning outcomes (meta-analysis study).

METHODS

Research Design

The type of research used is quantitative meta-analysis. Quantitative meta-analysis is a statistical technique that combines two or more similar studies to obtain a quantitative data guide (Mueller et al., 2018). Based on the process, the meta-analysis is a retrospective observational study in that the researcher makes a data recapitulation without any experimental manipulation (Yusuf & Fajari, 2022). This data recapitulation comes from research publications on augmented reality and student learning outcomes.

Eligibility Criteria

The research publications studied in this study have several criteria in their selection with the aim that the results of this broad analysis can be more centralized. The studies that will be included in the meta-analysis depend on the intent of the meta-analysis (Tawfik et al., 2019). For this reason, the meta-analysis study hypothesis is very helpful in determining the inclusion and exclusion criteria that should be used from the outset to identify relevant studies (Higgins et al., 2018). The criteria for selecting research publications are as follows: (1) publications that can be searched for online journal search databases such as Google Scholer, (2) publications discussing augmented reality and learning outcomes; (3) publications must be in the range of 2014-2021; (4) publications have a value of (r), (t), or (F); and (5) research sample N > 20.

Data Coding

Coding in meta-analysis is the most important requirement to facilitate data collection and analysis (Malicki et al., 2021). Therefore, the instrument in this meta-analysis was carried out with a coding category. The data coding in this study clearly describes the publications' characteristics, such as the year of publication, country of origin, publication sample (N), correlation value (r_{xy}), t value, and F value.

Table 1. Comparison of 13 studies based on N, r, t, F, value

Author	Year	Sample	N	r	t	F
Dharma, Sugihartini & Arhana	2018	Colleger	46		4,794	
Acesta & Nurmaylany	2018	Colleger	20	0,54		
Affandi, Suwarna & Hertanti	2014	Colleger	36		2,00	
Tasrif et al.	2020	Colleger	30	0,336		
Jami'ul & Rosid	2018	Colleger	20		4,1724	
Yuliono, Sarwanto & Rintayati	2018	Colleger	135		24,692	
Sono, Yanto & Rudi	2021	Colleger	29		7,240	
Adiansyah & Handayani	2017	Colleger	20		0,12	
Claudya & Lena	2021	Colleger	23		2,017	
Kamaruddin & Thahir	2021	Colleger	36		0,001	
Purnamasari, Suciati & Dwiastutu	2016	Colleger	22		0,846	
Aswan et al.	2019	Colleger	30	0,821		
Setiawan & Dani	2021	Colleger	20	0,98		

Data Analysis Technique

The software used in this research is JASP 0.8 4.0. The data analysis in this study was carried out through the following steps: (1) analysis of the characteristics of the research sample; (2) data coding; (3) conversion of t and F values to r correlation values. (4) heterogeneity test of effect size; (5) calculate summary effect or mean effect size; (6) create forest plots and funnel plots; (7) hypothesis testing and (8) check for publication bias. Analysis of the data used is a correlation meta-analysis. Effect sizes can

be categorized from 0 to 1 based on Cohen's effect size criteria (Chamdani et al., 2022; Yusuf & Fajari, 2022).

Table 2. Cohen's Effect Size Criteria

Value	Criteria
< 0+ /-1	Very weak effect
< 0+ /-3	Weak effect
< 0+ /-5	Medium effect
< 0+ /-8	Strong effect
≤ 0+ /-8	Very strong effect

RESULTS

Based on 13 research publications with specific criteria analyzed, various values of r, t, and F were obtained for each study. Before entering the heterogeneity test, for all research publications that do not have an r value, the t or F values listed will be converted to r values first. The results of the heterogeneity test are presented in table 3 below.

Table 3. Heterogeneity Test Result

	Q	Df	P
Omnibus test of Model Coefficients	7.026	1	0.008
Test of Residual Heterogeneity	4.188	12	0.980

Note. p -values are approximate.
Note. The model was estimated using the Restricted ML method.

Table 4. Residual Heterogenitas Estimates

		95% Confidence Interval	
	Estimate	Lower	Upper
τ^2	0.000	0.000	0.000
T	0.000	0.000	0.000
I^2 (%)	0.000	0.000	0.000
H^2	1.000	1.000	1.000

The results showed that the 13 effect sizes of each article analyzed were heterogeneous (Q = 4.188; p < 0.980). So it can be concluded that the 13 effect sizes of the analyzed studies are heterogeneous. Furthermore, an analysis of the estimated summary effect or mean effect size and a publication bias test were conducted using a random effects approach. The results of the analysis of the summary effect or mean effect size is presented in Table 5.

Table 5. Summary Effect or Mean Effect Size

					95% Confidence Interval	
	Estimate	Standard Error	z	P	Lower	Upper
intercept	0.541	0.204	2.651	0.008	0.141	0.940

Note. Wald test.

The analysis results with the Random Effect model show a significant positive correlation of the research data, namely 0.541, so it can be concluded that augmented Reality (AR) affects student learning outcomes. The big influence of augmented Reality on student learning outcomes was at the 95%

confidence level, with a p-value <0.541. Furthermore, it can be shown from the effect size of the 13 publications that are proven to be heterogeneous, have a positive correlation value, and are in the category of moderate effect with confidence (Z = 2.652; p < 0.008; 95% CI (0.141; 0.940).

Furthermore, the analysis results in this study are also presented using a visually attractive graphical method and are commonly referred to as forest plots. Forest plots allow us to estimate the combined effect depicted by plots (dots) at certain intervals simultaneously to make comparisons between studies clearer. The following is a chart of the forest plots of the 13 studies analyzed.

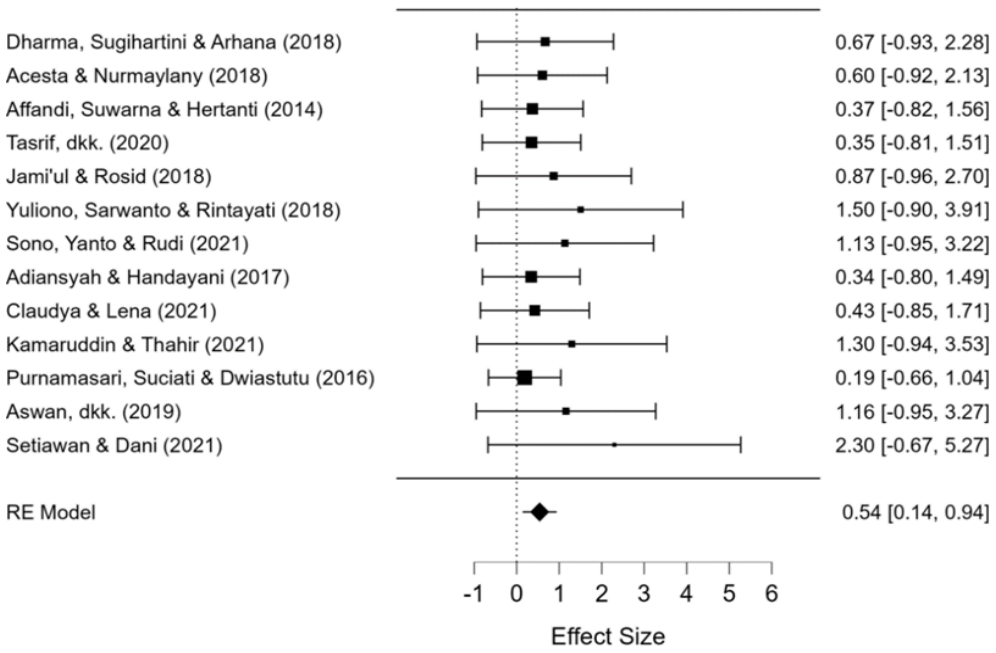

Figure 1. Forest Plot

Based on the forest plot graph is a summary of the results of our meta-analysis, which consists of each article's effect size, confidence interval, and summary effect results. So from the forest plot image, it can be observed that the effect size results of each analyzed article vary between 0.66 to 5.27. Furthermore, a funnel plot was made. The funnel plot is a scatter diagram used in meta-analysis to visually detect the possibility of publication bias (symmetrical or asymmetrical research sample). For example, the following is a funnel plot graph for the 13 studies analyzed.

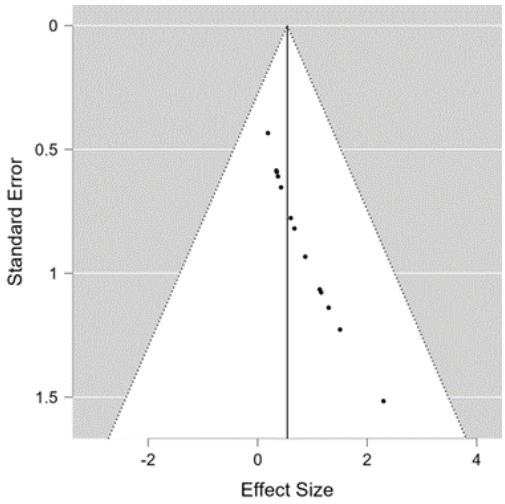

Figure 2. Funnel Plot

Based on the funnel plot graph results, there is no clear indication of publication bias because the model form can be said to be symmetrical, biased, and asymmetrical, so further analysis using the egger test is necessary. The egger test results are shown in the following table.

Table 6. Egger's Test Result

	Z	P
Sei	2.013	0.044

The analysis results in this table show Z = 2.013 with P > 0.04. So it can be concluded that the funnel plot formed from the random effects model is symmetrical. In other words, there is no evidence of publication bias in this meta-analysis study.

DISCUSSION

Based on 13 research results that were analyzed through this meta-analysis study, found a positive and significant relationship (p-value < 0.04). The value (Q = 4.188; p < 0.980) was obtained using the heterogeneity test using Q-statistics. So it can be concluded that the effect size results of the 13 articles analyzed differ for various populations. The results of the Summary effect calculation obtained from the JASP application in the table show the results of the summary effect using the random effects model method. The results are 0.541, with a 95% confidence interval ranging from 0.141 to 0.940. The results are not much different from the calculation results manually by using equations 3.20 to 3.27, which shows the result M* 0.541. Because the confidence interval contains 1, there is strong evidence of the positive effect of the treatment given to students to improve student learning outcomes. It is also reinforced by the testing results of the null hypothesis (H_0 = 0), where we have to reject the hypothesis because the summary Z effect is 2.651 with a p-value smaller than the value of a (0.08). In this case, the true effect size is not equal to 0. so it can be concluded that there is a significant positive effect on student learning outcomes. Furthermore, it can be seen in the summary or combined effect (M = 0.541). Therefore, the conclusion that can be drawn based on the random effect model is that there is a significant positive effect of 0.541 on improving student learning outcomes.

Based on 13 research results analyzed through this meta-analysis, a positive and significant relationship was found to student learning outcomes. The impact augmented reality-based learning media affects student learning outcomes. Augmented reality learning media is a new media for students. This media combines virtual objects into a real three-dimensional environment and displays them in real time so that the image seems alive and real in front of us. There is an effect size test showing the magnitude of the effect of a treatment or the strength of the relationship between two variables which is the most important part of the meta-analysis procedure because it can provide information and summary results. By determining the effect size of each study, overall, it can be found and determined how much influence a treatment has. The effect size calculation is carried out on the raw data contained in the statistical data of the journal. The results of this calculation become the basis for the meta-analysis process (Tawfik et al., 2019; Higgins et al., 2018).

Based on the results, the Forest plot is a graphical display of the estimation results of several articles used in the meta-analysis to understand the summary effect, also called the aggregation's effect size. This forest plot consists of elements including the effect size of each article, the variable line in the middle containing a square of different sizes whose width indicates the magnitude of the weighting, and its position states the location of the effect size of each study using a certain level of significance assigned to it. Determined by the researcher. If using the 5% level, the confidence interval is 95%. In addition, the forest plot also presents a summary effect or effect size resulting from the aggregation, which is located at the very bottom in the form of a diamond (diamond) whose breadth states the total area of the total weight of each study and its position states the magnitude of the summary effect (Chamdani et al., 2022; Yusuf & Fajari, 2022). In Figure 2, the results of the summary effect are shown with the label RE Model. The summary effect value of 0.541 indicates that student learning outcomes are 54%. If the summary effect is 0, it can be interpreted that there is no difference in the influence of the two groups in improving student learning outcomes. If the summary effect is greater than 0, it can be concluded that augmented reality media has an effect on student learning outcomes, and if the summary effect is smaller than 0

means that there is no effect of augmented reality media on student learning outcomes. Other information that can be obtained from the forest plot in Figure 2 is regarding the consistency of the effect size of the 13 articles and the cause of the summary effect to be significant, namely, 13 research articles have an effect size that falls in the interval > 0.5 so that the results of the summary effect are significant in the medium category. Based on the description of the research findings obtained through statistical analysis using JASP above, it can be concluded that there is a significant positive effect "The effect of augmented reality on student learning outcomes" with the average effect size generated in the medium category, namely 0.54 in Cohen's criteria (Chamdani et al., 2022; Yusuf & Fajari, 2022).

Based on the results, Funnel plots are visible results used to investigate publication bias in the meta-analysis in the form of Funnel plots of the distribution of the estimated treatment effects of individual studies on study sizes. In Figure 3, the X axis shows the effect size range, the Y axis shows the standard error value, and the center line shows the magnitude of the summary effect. Based on the funnel plot results, the points scattered at the top of the graph indicate studies with a larger sample size, while the points scattered at the top and bottom of the graph indicate studies with a smaller sample size due to studies with smaller sample sizes. Has a larger standard error in effect size (Basu, 2017). In this study, a funnel plot was made using JASP software to evaluate whether the conclusions about augmented reality's effect on student learning outcomes formed.

Figure 3 shows that most research articles sampled in the meta-analysis are studies with relatively medium sample sizes, seen from the scattered points above and below. If you pay attention to the 13 studies that are symmetrically distributed, it can be interpreted that there is no potential for publication bias regarding the conclusions from the meta-analysis results. However, interpretation or visual assessment cannot be used as a reference. There is a strong evidence base to say that the funnel plot is symmetrical or asymmetrical, so a statistical approach is needed to test the symmetry using the egger test and Fail Safe-N.

Based on the fail-safe N calculation results with the help of JASP software which shows the fail-safe N value of 36.00. It means that 36.00 nonsignificant, unpublished (missed) studies needed to be added to the meta-analysis to reduce the overall statistically significant observations to insignificant. According to Rosenthal (2008), if the value of fail-safe N is relatively small, there is a possibility of publication bias against the observed results. However, if the value of fail-safe N is relatively small, publication bias towards the observed results is possible. However, if the value of fail-safe N is relatively large, it can be assured that although the observed treatment has a significant effect on the exclusion of some studies, it will not make it null or change the conclusion. At the same time, Rosenthal (2008) does not provide specific guidance on the number of studies that may be considered “large” enough to provide confidence that the analysis results do not indicate publication bias. Therefore, it offers a general guideline that fail-safe N showing results equal to or more than five 5K + 10 will show strong meta-analysis results against the threat of publication bias (Rothstein et al., 2005). Therefore, the fail-safe N value is 36.00 will compare with the value of 5K + 10, where K = 25, to obtain a value of 135. This result is smaller than the fail-safe N value, meaning publication bias does not influence our conclusions.

Publication bias is one of the important stages in the meta-analysis, as this can threaten the conclusions obtained from the results of the systematic review with the meta-analysis, according to Kyndt et al. (2013). Stating that publication bias is a term used for any study in the published literature that is systematically unrepresentative of the population of completed studies. In this direction, the case where the journal only publishes articles whose results lie they should be statistically significant. As a result, the effect size may be too large (Kyndt et al., 2013).

Ahn & Kang (2018) also said that publication bias refers to the distortion of meta-analysis results because the probability of publication of a statistically significant study is higher than that of an insignificant study (Ahn & Kang, 2018). If the results of the meta-analysis research do not indicate publication bias, then the studies on the funnel plot will be distributed symmetrically regarding the summary effect because the sampling error is random. On the other hand, if the meta-analysis results indicate publication bias, a symmetrical pattern is formed, some studies are lost in the middle, and more studies are lost at the bottom. The methods used to investigate, evaluate and deal with publication bias in the meta-analysis results in this study are Funnel plot, rank correlation, regression method, fail-safe N, trim, and fill.

CONCLUSION

The following conclusions can be drawn based on the data analysis and discussion described previously in this study. First, augmented reality's effect on student learning outcomes can be said to be effective. Augmented reality media is used as a learning medium for student learning outcomes to get an average percentage of attention indicators and a good category. It means AR media can attract students' attention during the learning process. Second, the publication bias test results show that the meta-analysis results do not indicate publication bias. It is based on the results of several methods, such as the results of the symmetrical funnel plot. Furthermore, the fail-safe N method shows that this meta-analysis is not influenced by publication bias, in addition to the results of forest plots and funnel plots before and after analyzed by trim and fill. Third, overall it can be concluded that the meta-analysis conducted on several studies on using augmented reality media showed a moderate effect on student learning outcomes.

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The authors declare no funding and conflicts of interest for this research.

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