Pegem Journal of Education and Instruction, Vol. 15, No. 2 , 2025 (pp. 52-62)

RESEARCH ARTICLE WWW.PEGEGOG.NET

Is the Research Conducted in Education about Augmented Reality Effective? Meta-Analysis Study

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Abstract

This research aims to examine the effectiveness of the studies conducted in educational institutions aimed at augmented reality. In general, the studies included in the study were included in *"web of science"* categories and published in journals with high impact size. This research was conducted on sixteen carefully selected studies. The total number of samples of these studies was three thousand two hundred and thirty-three and the data obtained formed the basis for a meta-analysis. First, a funnel plot diagram was drawn to check for publication bias. Then, statistics were calculated. As a result of these analyses, we found no publication bias in the studies. Then, we did a test for heterogeneity to choose a model. The results supported the meta-analysis's interpretation. It used the random effects model. A meta-analysis study has shown that research conducted in educational institutions related to augmented reality has greatly impacted overall. These results suggest that augmented reality has an important potential in education.

Keywords: Augmented Reality, Virtual Reality, Mixed Reality, Educational Institutions, Meta-Analysis

Introduction

Augmented reality (AR), by combining the real world with virtual elements, has great success potential in the field of education, as it provides students with more effective, visual, and meaningful educational experiences (Sholikan & Kom, 2021), has made a great impact on transforming learning experiences (Fleury & Richir, 2021). However, abstract and complex subjects have become more concrete and accessible with the application of augmented reality (Language, 2022). In this way, students in disciplines such as science, mathematics, engineering, and live 3D models (Sihinde et al., 2021) or were able to embody abstract concepts with interactive simulations (Araya, 2023). This helps students to understand the topics in more depth (Choudhury et al., 2023). In addition, providing students with control over the learning material (Lenox, 2023), contributes to students' ability to progress by their learning speed (Tom Dieck et al., 2021). It can respond to the needs of each student by providing customized learning experiences to students (Garvis & Keane, 2023) (Lv et al., 2022). On the other hand, the interaction of augmented reality with students (Maslankowski et al., 2023) and has great advantages in terms of cooperation (Jena et al., 2022). Students can collaborate on the same projects (Hammond, 2023) and interact with virtual classmates through augmented reality applications (Kaliraj & Devi, 2021). This situation can help students develop communication (Hawkridge, 2022) and cooperation skills (Geroimenko, 2022). In this way, students can explore different cultures and places around the world, having the opportunity to expand and embody their learning experiences (Parkerson & Parkerson, 2023) (Doerner et al., 2022). An important feature of augmented reality is the ability to provide instant feedback to students (Daniela, 2020). Students can receive quick and direct feedback through this application (Ma, 2023), so that they can also correct their mistakes (Cai et al., 2023). Augmented reality applications are also a great auxiliary tool for teachers (Bektic et al., 2020). It can help students monitor their learning progress (Sforcina, 2023) and create customized teaching materials (Simeone et al., 2023). From this point of view, we can state that students' learning experiences will become more fun (Shi, 2023) and interesting (Ris & Puvaca, 2023). Students can

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How to cite this article: Varlık S. Is the Research Conducted in Education about Augmented Reality Effective? Meta-Analysis Study, Pegem Journal of Education and Instruction, Vol. 15, No. 2, 2025, 52-62

Data Availability: The data that support the findings of this study are available from the authors, upon reasonable request.

Conflicts of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DOI:10.47750/pegegog.15.02.06

Received: 11.07.2024

Accepted: 23.12.2024 **Published:** 01.04.2025

enjoy the learning process more especially with gamification and interactive activities (Zaramenskikh & Fedorova, 2021). Contrary to all these positive situations, some points need to be taken into account to achieve success in education with augmented reality (Verma & Paul, 2022). Augmented reality technology and infrastructure should be developed in developed and developing world countries (Shivarkumar, 2023). Thus, all schools and students can access this application equally (Tacgin, 2020). Furthermore, teachers and educational institutions need to integrate augmented reality into their systems effectively (Sadiku, 2022), to direct their students to this technology and to pay attention to privacy and security issues (Mehler-Bicher & Steiger, 2022). However, in this way, this technology can be used as a sustainable and success-enhancing element (Badotra et al., 2023). The technological infrastructure related to augmented reality (Peddie, 2023), security (Fleury & Richir, 2021), and access (Maslankowski et al., 2023), we can say that this application will play an important role in the education of the future thanks to the solution of problems such as.

Research Problem

While explaining the pressure of solids, liquids, and gases in science class, I turned augmented reality applications into real experimental research. I observed that the students of the experimental group were highly motivated in the lessons, did not take absences, were looking forward to attending the lesson, and there was a significant increase in their academic achievements. For this reason, I have designed real experimental research on whether augmented reality applications in science teaching increase academic achievement and sent it to an international journal as an article. However, unfortunately, I was not convinced about whether the primary research I did and the research conducted on the subject were effective or not. Because tens of thousands of primary studies on augmented reality applications should be combined a decision should be reached on whether it works in practice (Chen & Peace, 2021; Riley et al., 2021). This situation creates a gap in the field of educational sciences in a scientific sense. The starting point of this research is to fill this gap. Because, when I examined the relevant literature on augmented reality, a large majority of the studies conducted (Bernarduzzi et al., 2021; Cai et al., 2017; Fidan & Tuncel, 2019; Garzon et al., 2017; Hassapopoulou, 2018; Mystatidis et al., 2022) remained the primary study, and I found that these studies could not go beyond the literature review. As is known, primary studies are original research and aim to produce new information in the scientific literature (Harrer et al., 2022). Such studies usually involve experimental design, data collection, and analysis processes and are carried out to test a new hypothesis or to correct a lack of information (Patole, 2021). In this way, they form the basis of important scientific advances in fields such as science and medicine (Khan, 2020). However, it would still be more correct to Decipher by combining and synthesizing the primary studies (Egger et al., 2022). In this respect, meta-analysis is used to examine the results of one or more scientific studies in depth (Simske, 2019) and to analyze the data of these studies collectively (Schmid et al., 2021). Combining the results of these studies aims to reach more powerful and reliable results (Cleophas & Zwinderman, 2017). Based on this, the main purpose of this research is to determine whether the research conducted in educational institutions related to augmented reality is effective in practice. In this way, by combining the results of the primary studies on augmented reality conducted in educational institutions, it will be possible to reveal a bigger picture and reach stronger results. This situation will also provide valuable information for those who study the scientific literature, decision-makers, academics, teachers who use the augmented reality application, and educational administrators, and it will also reveal whether this application is effective in practice. For meta-analytical analyses in line with the purpose of the research, "*H_a= The effect size of research conducted in educational institutions related to augmented reality is positive.*" the answer to the hypothesis has been sought.

Method

The Model and Paradigm of the Research

This research aims to determine the effect size of research conducted in educational institutions aimed at augmented reality. Meta-analysis is a method that brings together the results of many different studies (Cooper et al., 2019). These studies have been used to combine the results of research on augmented reality and to evaluate them statistically. This research has been carried out within the framework of a functional paradigm that treats and evaluates reality objectively. The functional paradigm argues that the social world is relatively fixed and analyzes the facts in an objective way (Gunbayi & Sorm, 2020).

Types of Meta-Analyses and Effect Size

Meta-analysis is a method that helps us to better understand a specific problem or topic by combining the results of many studies (Hanji, 2017). There are two types of meta-analysis: correlational meta-analysis and group comparison meta-analysis (Zoccai, 2018). Correlational meta-analysis is used to decipher the relationship between two variables (Rothstein et al., 2021). In other words, this method is used to understand how much one variable affects another (Harrer et al., 2022).

On the other hand, group comparison meta-analysis is used to compare the results of different groups (Hedges & Olkin, 1985). Effect size is a measure that measures the relationship between variables observed in a meta-analysis study or the effect of an application (Egger et al., 2022). In other words, it is a value that shows how large the effect of the independent variable on the dependent variable is (Ellis, 2010). The overall effect is the average effect obtained by combining the results of all studies (Chen & Peace, 2021). In meta-analysis studies, a diagram called a "forest plot" is used to graph the results (Cumming, 2012). In this diagram, the diamond-shaped symbol indicates how precise the predicted results are (Patole, 2021), while at the same time representing the effect size (Hartung et al., 2008). Effect sizes can be calculated by different methods such as mean differences, correlation coefficient, or probability ratio (Cleophas & Zwinderman, 2017). In this study, the average decency method was preferred to measure the effect size between two different groups.

Selection and Determination of Outliers

Two different models, the "fixed effects model, and random effects model", are used in meta-analysis (Hunter & Schimd, 2004). The fixed effects model accepts that all studies are the same (Lipley & Wilson, 2001), while the random effects model accepts that each study is different (Riley et al., 2021). In this research, the universe sizes, sample sizes, standard deviations, and measurement tools used in the studies examined are different. Therefore, which model will be used is determined by the heterogeneity tests Q, I^2, and H^2. Outliers during the meta-analysis may harm the mean, variance, and other statistics. They are an issue (Stangl & Berry, 2000). The chance of finding outliers is quite high (Cheung, 2015). Initial studies usually only report results statistics (Sterne, 2009). So, it is hard to detect errors (Khan, 2020). There may be no obvious reason for the outliers (Kulinskaya et al., 2008). Thus, in this study, the study weights of all studies were calculated according to fixed and random effects models.

Data Collection and Inclusion Criteria

To collect the data and determine the inclusion criteria in the research, detailed research was conducted by meticulously complying with the criteria of "identification, separation, selection, inclusion". The research covers the period between March 14th and December 31, 2023. A flow diagram containing the details of the inclusion criteria of the studies included in the meta-analysis is presented in Table 1.

When the flow diagram containing the details of the inclusion criteria of the studies included in the meta-analysis was examined in Table 1, a detailed scan was made with the keywords "augmented reality, virtual reality, mixed reality" and the limitation "quantitative" in the databases "WEB OF SCIENCE, SCOPUS, ERIC, DOAJ, and SPRINGER". As a result of the search, a total of 17223 studies were found. Since it is thought that the time and affordability principle of working with such a large sample will be violated, the limitation of the year "2023" has been moved. It is not practically possible to review more than seventeen thousand articles. The 2023-year limitation has made research more manageable by narrowing the research pool. This is because the most recently published papers are generally expected to have better methodological standards and data analysis techniques. However, studies on augmented reality have not only been conducted in educational institutions. Augmented reality has become a focus of interest in many disciplines. When an in-depth review was conducted, it was seen that these studies were carried out in the form of literature reviews rather than experimental and descriptive survey studies. With the 2023-year limitation, when the selected studies are examined in detail, we can say that they reflect the innovations and developments related to augmented reality applications in the

Table 1: Meta-analysis flow diagram

IDENTIFICATION	Studies found in WEB OF SCIENCE, SCOPUS, ERIC, DOAJ, and SPRINGER databases with the keywords "augmented reality, virtual reality, mixed reality" and "quantitative" limitation (n=17223)	
SEPARATION	The number of remaining studies with the limitation of the year "2023" (n=904)	
	The number of studies remaining after the duplications were removed (n=723)	
	The number of remaining studies with the limitation of "education" (n=38)	
SELECTION	The number of studies evaluated for selection (n=38)	Conducted by qualitative research method (n=13)
		Performed by systematic review (n=7)
		The study that provided theoretical information (n=2) was excluded from the selection.
INCLUSION	The number of studies included in the meta-analysis (n=16)	

best way. Because it is critical to examine the most up-to-date data in order to accurately analyze the latest innovations and current situation in this field. However, the innovations and developments in augmented reality in 2023 may be different from the studies conducted in previous years. Therefore, the 2023 timeframe may provide a better understanding of the current technological situation and practices. In addition, we can think that the 2023-year limitation enables us to analyze the data of recent studies that are compatible with current educational policies and practices. This is because academic research requires efficient and effective use of resources. Since it is thought that analyzing more than seventeen thousand studies would violate the principles of time, economy, and innovation, we can state that resources are used more effectively and efficiently with the 2023-year limitation. As a result of this limitation, there are 904 studies left available. Since this research is carried out in educational institutions, another limitation has been made with the "education" sub-category. It was determined that 38 studies remained with this limitation. In general, the importance of these studies being in journals with high effect size, SSCI, and SCI-E categories has been given. When the remaining studies were examined meticulously, it was found that there are usually qualitative and literature-related studies related to augmented reality. When these studies were eliminated, this research was conducted on 16 carefully selected studies. In this study, the total number of samples was determined as n=3233. The focus of the studies included in the meta-analysis is that "the studies were conducted in educational institutions or used augmented reality applications with a focus on education and training". Ahmed & Latifeh (2023), the effect of augmented reality on the educational environment; Al-Amri et al., (2023), the use of augmented reality in course content; Anil & Batdi (2023), the use of augmented reality in science education; Baumann et al., (2023), augmented reality applications in map reading in earth sciences course; Cheng (2023), virtual reality application for narrative reading; Delgado-Rodriguez et al, (2023), the design of an educational model based on the use of augmented reality; Ghobadi et al., (2023), augmented reality applications in education; Koparan et al., (2023), the integration of augmented reality in mathematics teaching; Marin-Diaz & Requena, (2023), teachers' use of mixed reality in the classroom; Marin-Marin et al, (2023), teachers' use of augmented reality; Medina & Gomez, (2023), the effect of augmented reality on vocabulary acquisition and student; Moran & Lizarraga, (2023), the effect of augmented reality on students' learning; Ozeren & Top, (2023), the effect of augmented reality on students' academic achievement; Sat et al, (2023) focused on teachers' use of augmented reality applications; Wen et al., (2023) focused on the use of augmented reality in science courses; Yoon et al., (2023) focused on the effect of augmented reality on educational performance.

Publication Bias

Publication bias is a problem that arises when the research in the scientific literature does not accurately reflect the entire society (Cooper, 2017). In other words, when the results of existing research show deviations from the actual results of all studies in a given area (Littell et al., 2008), there may be a risk that this kind of research will mislead readers and critics (Simske, 2019). This can sometimes lead to serious consequences, such as cases where an ineffective or dangerous treatment method is mistakenly evaluated as safe and effective (Schmid et al., 2021). Publication bias is a potential danger in all research fields, even if it uses analysis methods such as meta-analysis (Rosenthal, 1987). In recent years, the increasing prevalence of methods such as systemic examination and meta-analysis has contributed to making this problem even more important (Borenstein et al.,2019). This situation means that as the review methods become more scientific and quantitative (Leandro, 2005), the review and synthesis of the research are as important as the research in the first degree (Dias et al., 2018). In this research, various methods have been used to detect publication bias. Among these methods are "funnel plot" diagram drawing, "rank correlation", "trim and fill method", "regression constant" and "protected N method". Through these methods, the presence or absence of publication bias has been tried to be determined.

Coding Process

The studies selected for meta-analysis were evaluated by the main objectives of the research and their compliance with the research criteria was checked. Each study was recorded in a coding form with information such as sample size, average values, and standard deviation values. To prevent errors during the coding process, the encodings were re-examined by five experienced meta-analyzers, and a Fleiss Kappa reliability analysis was performed to evaluate the reliability between decoders. According to the analysis results, the reliability coefficient between decoders was [K=.943, z=16.757, p=.001 (.833-1.053] has been obtained. According to Gwet (2021), this value has shown that the reliability value between decoders is significantly high.

Analysis of the Data

In this research, it is aimed to examine the effectiveness of the studies conducted on augmented reality education. The studies included in the review include the scores obtained from different scales. So, Card (2012) calculated the effect

sizes in the studies by standardizing using Hedges' g coefficient. Harrer et al. (2022) based their analyses on a 95% confidence level and a p<.05 significance level. The obtained effect magnitudes "d=.20" a small effect, "d=.50" a medium-sized effect, "d=.80" represents a major influence (Egger et al., 2022). The studies are of different sizes and do not represent the same universe. So, we calculated the overall effect size with the random effects model. Also, we made a "forest plot" diagram. It shows the link between effect sizes and study weights. It checks for outliers between the effect sizes of each study. A heterogeneity test was applied to determine whether there is heterogeneity in the results of the included studies.

JAMOVI 2.4.2 package program was used in the data analysis.

Findings

Findings Related to Publication Bias

Publication bias is a very important concept in scientific studies (Harrer et al., 2022). This refers to the situation when the results of the research are not presented objectively or there is a tendency to emphasize certain results (Egger et al., 2022). In particular, if a study shows that a particular effect is not statistically significant or finds an effect that is the opposite of what was expected (Harrer et al., 2022), may be less likely to publish these results. This is important in terms of the reliability and validity of the studies (Borenstein et al.,2019). We created Figure 1, a "funnel plot" diagram, to visually represent the results of the studies included in the meta-analysis.

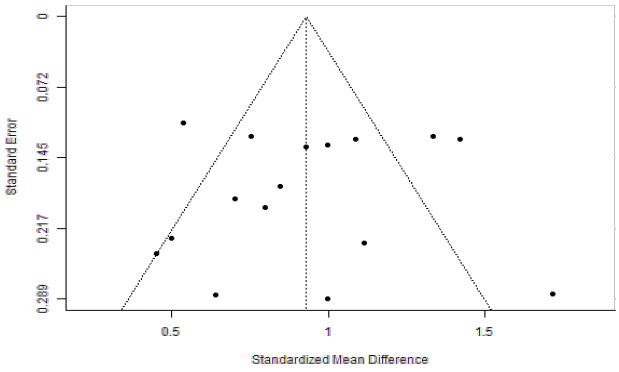

Fig. 1: Funnel plot diagram

This diagram shows the standard error and effect size values of the studies (Rothstein et al., 2021). These analyses help to assess how variable the results of studies are and the evidence of publication bias. In other words, approaching the results of the research from an objective point of view, it ensures that attention is paid to potential biases that may affect the results of a scientific study (Schmid et al., 2021). A method frequently used to detect publication biases in meta-analysis studies is the drawing of funnel-shaped graphs that provide the first impression to researchers (Dias et al., 2018). In the graph in Figure 1, the X axis represents the g effect sizes of Hedges, which measure the impact of studies conducted on augmented reality education, and the Y axis represents the standard errors of the studies evaluated in the meta-analysis. The studies at the top of the chart represent those with large samples (Harrer et al., 2022). When the funnel plot diagram shows the broadcast bias, it causes the points to take the shape of an asymmetric funnel. This situation indicates that there are incomplete studies (Patole, 2021). However, it is observed that the publications of the studies included in this research show a symmetrical distribution and this distribution does not indicate publication bias. Nevertheless, it is insufficient to rely only on the funnel plot diagram to come to a definite conclusion in the meta-analysis (Simske, 2019), so statistical calculations have also been performed. The results of the statistical analysis are presented in Table 2.

Table 2: Publication bias assessment

Test Name	*Value*	*p*
Fail-Safe N	2967.000	.001
Begg and Mazumdar Rank Correlation	.117	.564
Egger's Regression	.309	.757
Trim and Fill in the Number of Studies	1.000	-

Note. Fail-safe N Calculation Using the Rosenthal Approach

Rosenthal's safe N method showed that more than 2967 studies with zero or negative effects are necessary for this research. Also, Rosenthal's safe N method found the z value to be >1. This means future studies did not change the meta-analysis results. Also, the study had no bias in publication (Rosenthal, 1987). The Begg ranking correlation method is a statistical method that evaluates the relationship between the ranking of effect sizes and the variances of these sizes (Chen & Peace, 2021). The Begg ranking correlation method is a statistical method that evaluates the relationship between the ranking of effect sizes and the varying decencies of these sizes. Begg and Mazumdar's rank correlation analysis found that the main studies in this meta-analysis were not chosen wrongly. The correlation was weak [Tau=.117, p>0.05]. Researchers use Egger regression analysis to test for publication bias in the data in the meta-analysis (Egger et al., 2022). Rothstein et al. (2021) regress the standard normal deviation against its certainty in this analysis. The results of regression show that there is no publication bias in this meta-analysis. They provide the p>0.05 condition (Cleophas & Zwinderman, 2017). The Duval and Tweedie trim-and-fill analysis is used

to estimate the number of incomplete studies (Riley et al., 2021). This analysis is aimed at correcting the effects rather than detecting publication bias. This meta-analysis shows that there is no publication bias in the research (Patole, 2021). In general, these analyses are based on the results of different statistical methods used to assess the reliability of the meta-analysis study and whether there is publication bias (Schmid et al., 2021). All the findings show that this meta-analysis research is reliable and does not have publication bias.

Findings on Heterogeneity and Effect Size

One of the first goals of meta-analysis studies is to examine the results of the research in more depth (Borenstein et al., 2019) and to take into account how the effect of the intervention may vary in different sample subgroups (Simske, 2019) or how the results of observational studies may differ between different people (Khan, 2020). Heterogeneity is one of the concepts underlying this study (Hartung et al., 2008) and helps us to understand the reasons for the differences in research (Hunter & Schimdt, 2004). Heterogeneity focuses on the main difference between the fixed effects model and the random effects model (Cooper, 2017. This difference plays a critical role in the selection of models that give weight to the results of research (Leandro, 2005). If the Cochran Q statistic gives a significant result ($p<0.05$), it is (Dias et al., 2018), which means that the effect sizes in the studies differ and there is an effect of regulatory variables. The analysis found that the effect sizes of the studies in the meta-analysis vary. The results are in Table 3.

Table 3: Heterogeneity statistics

Tau	*Tau²*	*I²*	*H²*	*df*	*Q*	*p*
.262	.0688	72.810 %	3.677	15.000	61.824	.001

When examining the analysis results in Table 3, we find that the Tau2 value is .0688 and we found the Q value to be 61.824. This value shows that the effect sizes have a heterogeneous distribution according to the random effects model (Hedges & Olkin, 1985). The Higgins I^2 parameter represents the ratio of the actual heterogeneity to the total observed variance (Ellis, 2010). This parameter shows how different the results of the studies are, regardless of the location or spread of the actual effects (Littell et al., 2008). Therefore, I^2 should be more appropriately evaluated as an indicator that measures the inconsistency of results between studies, not the heterogeneity between actual effects (Cheung, 2015). Decolonization is a decolonization of the results between studies. Also, the I^2 and Q statistic is a measure of inconsistency that is not directly affected by the number of studies included in the analysis; this (Kulinskaya et al., 2008), explains the variability in impact estimates caused by heterogeneity instead of sampling error. The analysis showed that the sizes of the effects in the studies varied. The I^2 value was 72.81%. This shows that 72.81% of the observed variance is due to real differences between studies and can therefore be explained by common variables at the study level. That is, it seems that the differences between studies are largely due to actual heterogeneity. On the other hand, the H^2 value was found to be 3.677. The H^2 value is usually used as a heterogeneity statistic. If there is heterogeneity in a meta-analysis, this indicates that the differences between studies are high and may mean that the results should be interpreted Decently. The value of H^2 takes a value between 0 and 1 (Harrer et al., 2022). Ideally, as the H^2 value approaches 1, the differences between studies Decelerate, meaning that a large part of the actual effect is due to the results (Rothstein et al., 2021). As the H^2 value approaches zero, the differences between the studies increase and the effect of random variance becomes greater (Egger et al., 2022). Based on these findings, we decided to use the effect size value of the random effects model in this research. Table 4 provides the analysis results of the random effects model.

Table 4: Random effects model

Model Type	*ES*	*SE*	*Z*	*p*	*CI Lower Bound*	*CI Upper Bound*
Random Effects Model	.930	.0800	11.600	.001	.773	1.087

The effect size is extremely important for a meta-analysis study (Riley et al., 2021). Meta-analysis attempts to reach a more general conclusion by combining the results of a series of studies (Chen & Peace, 2021). Calculating the effect size of each study helps us to understand how significant and effective these results are (Borenstein et al., 2019). When Table 4 is examined, the overall effect size.it is calculated as .930. This shows that the application has a great and positive impact. The statistical significance of the studies included in the study is also quite strong. The Z value gives significant results within the 95% confidence interval and at the significance level of .05. The findings show that the studies in the meta-analysis had a big, positive effect on the application's effectiveness. They were statistically significant. Therefore, this study shows that the augmented reality applications applied in educational institutions have a significant impact and are generally successful. In this meta-analysis, the effect sizes obtained from the studies are the lowest. It has 450 and the highest values at 1,710. This shows that each study has different effect sizes. Figure 2 shows the forest plot diagram for the studies included in the meta-analysis.

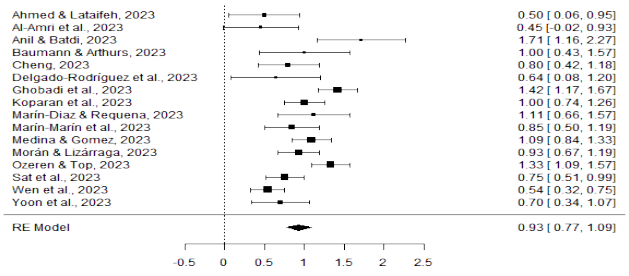

Fig. 2. Forest plot diagram

The research weights in the meta-analysis are in Figure 2. The lowest is 4.20% and the highest is 7.92%. These results show that studies generally have weights close to each other. When we combine these findings, we can conclude that studies in schools on augmented reality are very effective. They have a large positive effect size. For this reason, *"H_a= The effect size of research conducted in educational institutions related to augmented reality is positive."* it seems that his hypothesis is supported.

Discussion, Conclusion and Recommendations

Publication bias in meta-analysis is a very important concept in scientific studies. This refers to the situation where the results of a study are not presented objectively or tend to emphasize certain results. It is also important for the validity and reliability of the research (Borenstein et al., 2019; Egger et al., 2022; Harrer et al., 2022). A funnel plot diagram was drawn to visualize the results of the studies included in the meta-analysis. This diagram shows the standard error and effect size values of the studies (Rothstein et al., 2021). When the funnel plot diagram was examined superficially, it gave the impression that there was no publication bias. However, it is still insufficient to make a decision only by looking at the funnel plot diagram to reach a definite conclusion in meta-analysis (Simske, 2019). Therefore, statistical calculations were made to determine whether there was publication bias. Rosenthal's safe N method showed that more than 2967 studies showing zero or negative effects were necessary for this research (Rosenthal, 1987). Begg and Mazumdar's rank correlation analysis results indicate that the primary studies included in the meta-analysis study were not biased (Chen & Peace, 2021). In addition, regression constant, Duval and Tweedie's trim and fill analysis showed that there was no publication bias (Cleophas & Zwinderman, 2017; Patole, 2021; Riley et al., 2021). After it was understood that there was no publication bias in the study, a heterogeneity test was conducted. Accordingly, when Tau^2, Q and I^2 values were analyzed, it was concluded that the effect size should be based on the random effects model (Cheung, 2015; Hedges & Olkin, 1985; Egger et al., 2022; Ellis, 2010; Kulinskaya et al., 2008; Littell et al., 2008; Rothstein et al., 2021). The overall effect size calculated according to the random effects model was .930 and the confidence interval was [.773-1.087]. The calculated overall effect size is quite high. Effect sizes are generally classified as 0.2 "small", 0.5 "medium" and 0.8 "large" (Cooper, Hedges & Valentine, 2019). The calculated effect size shows that the implementations of augmented reality in educational institutions have a significant and positive effect. The calculated confidence interval shows the reliability of the effect size (Egger, Higgins & Smith, 2022). This interval indicates that the actual effect size is within these limits with ninety-five percent confidence (Schmid, Stijnen & White, 2021). This means that there is a statistically significant finding (Cleophas & Zwinderman, 2017). Because even the lower limit calculated indicates a large effect size (Harrer et al., 2022). In other words, the calculated confidence interval shows that the effect of augmented reality in education is consistently high and there is not a large variability between different studies. These results show that augmented reality technology has a great impact when used in educational institutions and that this technology positively improves learning and teaching processes (Krug et al., 2023; Mena et al., 2023). It indicates that augmented reality technology should be considered more in educational policies and program development processes (Taggart et al., 2023). When these results are taken together, it has shown that the impact of the studies conducted in educational institutions for augmented reality is great (Lytvynova & Soroko, 2023). Therefore, the hypothesis "Ha= The effect size of studies conducted in educational institutions on augmented reality is positive." was accepted.

Augmented reality is a technology in which objects and images in the real world are combined with digital content (Serin, 2022). This technology is increasingly being used in education, especially to enrich the learning experience of students (Henne et al., 2024). Research conducted on augmented reality also states that the use of this technology shows positive results in education (Gervasi et al., 2023). The studies included in the research show that augmented reality boosts students' learning (Lazo-Amoda et al., 2022). It helps with their motivation and attitudes (Angrawan et al., 2023). In this research, it was also concluded that the size of the effect of the primary research in schools on augmented reality is large and positive. This result shows that augmented reality has an important potential in education (Kamińska et al., 2023; Nikou et al., 2023). Chin & Wangs (2021) that the effect of augmented reality technology on the learning performance of university students is positive; Fidan & Tuncel (2019) that

the integration of augmented reality into problem-based learning positively affects learning success and attitude in physics education; Gnidovech et al., (2020) that augmented reality is important for teaching the human circulatory system to secondary school students; Tosik & Atasoy (2017) that augmented reality positively affects the spatial abilities and academic achievement of elementary school students; Kirikkaya & Başgül (2019) that the use of augmented reality applications has positive effects on the academic achievement and motivation of seventh graders; Lai et al., (2019) that an augmented reality-based learning approach to improving students' science reading performance will be effective from the perspective of cognitive load theory; Lee (2020) that augmented reality positively affects students' achievement in mobile gaming and foreign language education; Önal & Önal (2021) that augmented reality positively increases the level of astronomy achievement and interest of gifted students; Singh et al., (2019) that the effect of augmented reality learning environment on the electronic laboratory skills of engineering students is positive; Su (2019) found that the behavioral intentions of augmented reality users in education have a positive effect on gamification; Turan et al., (2018) have shown that mobile augmented reality has positive effects on geography education. These results show similarities with the research results. Throughout these studies, it has been found that students using augmented reality have higher performance in different disciplines compared to students studying using traditional methods, and that students using augmented reality have more motivation and are more interested in classes than students studying using traditional methods. Although these results are based on, there are several reasons why the effect of augmented reality in education is positive. Firstly, augmented reality makes students' learning experience more realistic and engaging. Thanks to augmented reality, students can see and experience objects and events in the real world more closely. This situation makes the students' learning process more meaningful and permanent (Akçayır & Akçayır, 2017). Secondly, augmented reality allows students to determine their learning speeds and styles (Karagözlü, 2021). Augmented reality applications allow students to adapt learning materials according to their own needs (Arici et al., 2019). This situation makes the students' learning process more efficient (Mystakidis et al., 2022). Third, augmented reality helps students develop cooperation and teamwork skills (Yu et al., 2022). Augmented reality applications allow students to work together and create joint projects (Algarni, 2021). This situation helps students to develop their social and communication skills. Of course, it should also be remembered that the effect of augmented reality in education is not always positive (Akçayır & Akçayır, 2017). Augmented reality applications can be distracting and costly (Zaramenskikh & Fedorova, 2021). In addition, for augmented reality applications to be used effectively, teachers need to have sufficient knowledge about augmented reality (Doerner et al., 2022). As a result, it can be said that augmented reality has a positive effect on education. Augmented reality is an effective technology that can be used to enrich the learning experience of students and make the learning process more efficient. However, for augmented reality applications to be used effectively, they need to be carefully planned and implemented. With the development of augmented reality technology, it is expected that the use of augmented reality in education will become more widespread and effective. In this research, the following suggestions have been developed for decision-makers, academics, teachers, and education managers to further increase the impact of augmented reality in education based on the research results.

- The content of augmented reality applications can be made more high-quality and interactive.
- Augmented reality applications can be adapted according to different learning styles and needs of students.
- Augmented reality applications can be designed in a way that makes them easier for teachers to use.
- Augmented reality applications can be integrated into textbooks through educational programs.

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