Challenges and Opportunities for Using Immersive Technology: A Meta-Analysis of the Effectiveness of Cross-Country Studies

Maximus Tamur[1],* Yudi Wibisono[2], Alberta P. Makur[1], Kristianus V. Pantaleon[1]
{maximustamur@unikastpaulus.ac.id}

[1]Program Studi Pendidikan Matematika, Universitas Katolik Indonesia, Ruteng, Indonesia
[2]Program Studi Ilmu Komputer, Universitas Pendidikan Indonesia, Bandung, Indonesia

Abstract. The trend of using immersive technology with augmented reality as a didactic tool has enriched the learning process with various superior content. Previous studies have explored the aggregate effect of using augmented reality in education, but few have analyzed the comparative effectiveness of studies between countries as a categorical variable. Filling the previous gap, this work makes it possible to find the aggregate effect of the application of augmented reality by comparing study results between countries as a categorical variable. This work examined 52 independent comparisons for a total of 2,056 subjects. The analysis results assisted by CMA software showed that integrating immersive augmented reality technology in learning was associated with a positive and moderate effect ($g = 0.71$, $p < 0.005$) compared to other learning conditions. This impact is consistent and robust across primary studies. These results add empirical validity regarding the effectiveness of immersive technology, as it is necessary to understand the study in the context of future didactic development of Augmented Reality.

Keywords: Immersive Technology; Augmented Reality; Meta-Analysis; Categorical Variables.

1 Introduction

Immersive technology Augmented Reality (AR) has now become a new trend [1], which combines technology in teaching certain learning topics [2]. This technology is considered the latest discovery and innovation that facilitates sensory perception through digital objects [3], so it has the potential to be widely applied in the world of education [4], [5]. Virtual objects through the AR interface help teachers to visualize 2D and 3D geometric objects [6]–[8]. AR supports accessibility achieved through mobile devices and dynamic switching of gesture recognition [9]. AR allows students to interact with virtual objects easily and naturally, thus supporting their understanding of what they are learning and improving the quality of education.

AR technology helps teachers during the teaching and learning process as a tool that bridges closeness with the environment [10]. Augmented reality has become an important educational technology in teaching and learning. Technology-embedded learning provides increased perception of existing material [11]. The advantages of augmented reality include replacing existing objects, helping explain processes, helping simulations, getting attention, and describing abstracts. , explains space concepts, and replaces experiments [12].

ICEHHA 2023, December 15-16, Ruteng, Indonesia

DOI 10.4108/eai.15-12-2023.2345622

The advantages of AR have given rise to a flurry of studies specifically testing its effectiveness in learning. However, various previous empirical studies have provided varying and inconsistent results. Several studies have found that AR-based learning can increase students' interest in learning, thereby supporting the improvement of their academic abilities (e.g., [13]–[17]). In contrast, several other individual studies show different results that the use of AR has no or only a small impact on students' abilities (e.g., [18], [19]). Even the latest study [3] found that the impact of technology AR on students' academic abilities is still unclear or inconsistent.

Recent conditions have sparked a flurry of studies to discover the overall effectiveness of using AR in the classroom. This will help educators, practitioners, and stakeholders to consider the integration of AR in education. Meta-analysis can fill this gap by providing objective findings and categoric variables that can be identified for use in the context of [20]–[24].

Relatedly, in the current literature, many meta-analyses specifically aim to find the overall effect of using AR in education. For example, the meta-analyses that have been carried out by [25] and [26] only considered limited moderator variables. Likewise, meta-analysis studies conducted by [4] and [27] have analyzed the overall influence of AR technology in education but have yet to proceed by analyzing categorical variables that might clarify variations between primary study results. Of the various meta-analysis studies conducted, none has specifically considered comparing effectiveness between countries as a categorical variable. Besides aiming to analyze the overall impact of AR integration in education, this study fills the gap of previous work by considering comparisons of effectiveness between countries as a categorical variable. This contributes to the literature, teachers, lecturers, and stakeholders to consider the use of AR in education.

2 Method

This work uses a meta-analysis approach because of its strong decision-making position [28], [29]. This work begins with problem and hypothesis formulation, data tracking, data coding, and statistical calculations and closes with interpreting the results [30]–[35]. The following describes the details of these stages.

2.1 Literature Search

The online database is chosen as the location for searching for documents or journal articles resulting from research that will be included in the analysis. Next, the Publish or Perish (PoP) program was used to collect data on the influence of AR use in education. The use of PoP supports transparency and quality of data search [36]–[38]

2.2 Literature Inclusion Criteria

Primary research collected using the PoP application was selected using the following criteria: a). articles written in English and Indonesian and taken from online databases in the last six years. b) Provide adequate statistical data. Studies that did not provide statistical data such as (e.g., [2], [39], [40]). Were not included in the analysis c) Experimental research containing a treatment class and a control class. In this study, suggestions from [41], namely using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, were considered as data filtering in order to produce transparent and high-quality meta-analysis stages. Figure 1 presents the data filtering process.

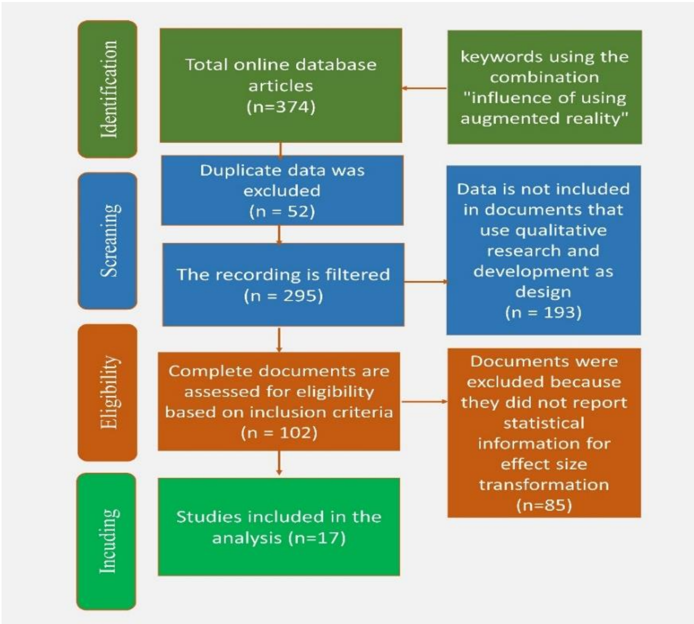

Fig. 1. Filtering data through PRISMA.

Based on Figure 1, 17 primary studies meet the inclusion criteria for analysis. However, some studies consisted of more than one comparison. As a result, this study involved 52 comparisons.

2.3 Data Coding

This work uses coding sheets to transform data into numerical information. Two coders were employed to examine the primary study and write down statistical data and information according to categorical variables. The agreement index is calculated using the Kappa formula [42] as follows:

$$k = \frac{Pr(a) - Pr(e)}{Pr(e)} \quad (1)$$

The actual observed level of agreement is Pr(a), and the chance agreement level is Pr(e). In this work, a value of 0.85 to 1 is interpreted as high agreement between the two coders [42]. From the calculation results, the index k = 0.96. This indicates that the instrument developed is valid and reliable because the index obtained is more than 0.85, which means there is a substantial to almost perfect match between the two coders.

2.4 Statistic Analysis

Effect size is chosen as a parameter to estimate the population. The effect size here is defined as the magnitude of the influence of AR integration in education on student learning outcomes. In this research, the CMA program was used to help calculate the effect size for each study, including finding statistical data such as p-values, Q statistics, and confidence intervals, funnel plots, and stem-leaf graphs. Hedges' g equation was chosen because some samples were considered to be small. Interpretation of effect sizes is based on classification [43], namely, less than 0.2 (negligible), 0.2 to 0.5 (small effect), 0.5 to 0.8 (medium effect), 0.8 to 1.3 (large effect), and more than 1.3 (very large effect). The random effects model was selected after satisfying the heterogeneity requirement. Decisions are taken by observing the p-value. If the p-value <0.05 means the effect size of each study is different or heterogeneous [44]. The next stage is checking for publication bias to prevent misrepresenting findings [45]. Determining the presence of publication bias uses a funnel plot, and the trim and fill stage is used to see the effect of publication bias on the aggregate effect size [44].

3 Results and Discussion

This research was conducted to analyze the overall effect of using AR in education, where the effect size is the research parameter. The results of the data screening showed that 52 independent comparisons were included in the analysis. Table 1 is a summary of the calculation results.

Table 1. Summary of Random Effects Model Analysis

Model	N	Hedges's g	SE	Test of null		Q	P
				Z-value	P-value		
Fixed-effects	54	0.69	0.03	22.23	0.00	327.18	0.00
Random-effects	54	0.71	0.07	9.04	0.00		

Table 1 presents a P value = 0.00 < 0.05, which indicates that the selected estimate is based on a random effects model. The aggregate effect size is 0.71, meaning that the use of AR has a moderate effect on students' academic abilities [43]. Second, publication bias checks were carried out using funnel plots. Figure 2 presents the research funnel plot extracted from the CMA application.

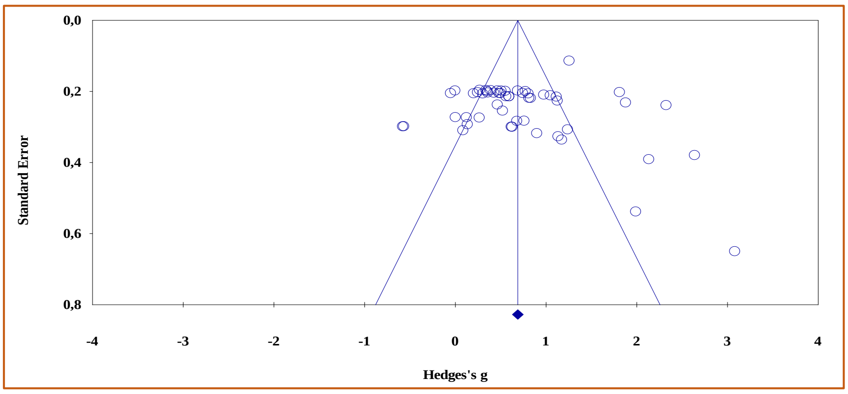

Fig. 2. Research funnel plot

Figure 2 clearly illustrates the asymmetric distribution of study effect sizes. Therefore, the inspection procedure for the impact of bias must be carried out by examining Trim and Fill. Table 2 presents the Trim and Fill results explored from the CMA application.

Table 2. Trim and fill analysis results.

	Studies Trimmed	Random-Effects Point Estimate	Lower Limit	Upper Limit	Q Value
Observed values		0.71	0.56	1.86	327.178
Adjusted values	0	0.71	0.56	1.86	327.178

Table 2 displays the trim and fill tests from left and right according to the random effects model. It was seen that Based on the random effects model, the point estimate and 95% confidence interval for the pooled studies was 0.71. Using Crop and Fill, these values do not change. This means there is no publication bias impact on this research's results. Thus, the overall effect size of the study was found to be 0.71, which is accepted as a large effect size that can be used to estimate the population.

Both of these studies consider the Comparison Between Countries as a categorical variable. A summary of the analysis results is presented in Table 3.

Table 3. Summary of Categorical Variable Analysis Results

Variable	Category	N	Hedge's g	Heterogeneity (Qb)	df(Q)	P
Comparison Between Countries	Indonesia	8	0.76	10.44	1	0.00
	Foreign Countries	44	1.01			

The analysis results gave an overall effect size of 0.71, categorized as a medium effect according to [43]. This result is similar to previous studies where the average effect size of studies on the influence of AR use in education is in the range of 0.6 to 0.8 (e.g., [4], [26]). This study also supports previous studies that state that integrating AR in educational environments helps improve students' academic achievement in collaborative learning environments and increases their retention and ability to translate it into other environments [13]–[15]. The analytical results also prove the superiority of the experimental group in general, not only in terms of cognitive but also in terms of student motivation (e.g., [46], [47]), cognitive development [48], student collaboration [49], and their learning experiences [50], [51]. Thus, these results support previous theoretical assumptions that immersive augmented reality technology can improve the quality of education [11], [47]. AR can also help students improve their focus through fun activities and immersive experiences [52], [53]. AR integration also satisfies students with various interesting content [54].

Furthermore, the analysis of categorical variables, as seen in Table 3, shows that the Comparison Between Countries is related to the study effect size ($P=0.00<0.05$). The analysis results show that AR integration is mostly implemented abroad (85%). Furthermore, the highest effect size was seen for the studies conducted in Indonesia. However, these results require further verification because the applied studies still need improvement. These results also provide useful space and information for educational practitioners to develop AR media that can be widely applied in Indonesia.

4 Conclusion

This research analyzed 52 independent samples from 17 primary studies and found that using AR in education moderately affected student learning outcomes. This research also shows that Comparison Between Countries is proven to be an explanatory variable that influences the overall effect size of the study. These results are useful for literature, teachers, lecturers, and stakeholders in studying the advantages of each country.

Acknowledgments. We acknowledge financial assistance from the Ministry of Education of the Republic of Indonesia through a national research grant for the 2023-2024 fiscal year.

References

[1] M. Tamur, “Teknologi Immersive Augmented Reality Memfasilitasi Pembelajaran : Analisis Meta Perbandingan antar Subject Matters,” *Juring (Journal Res. Math. Learn.*, vol. 6, no. 4, pp. 361–372, 2023, doi: 10.24014/juring.v6i4.25813.

[2] N. Nordin, N. R. M. Nordin, and W. Omar, “The Efficacy of REV-OPOLY Augmented Reality Board Game in Higher Education,” *Int. J. Emerg. Technol. Learn.*, vol. 17, no. 7, pp. 22–37, 2022, doi: 10.3991/ijet.v17i07.26317.

[3] J. Buchner and M. Kerres, “Media comparison studies dominate comparative research on augmented reality in education,” *Comput. Educ.*, vol. 195, no. August 2022, p. 104711, 2023, doi: 10.1016/j.compedu.2022.104711.

[4] Z. A. Yilmaz and V. Batdi, “Meta-Analysis of the Use of Augmented Reality Applications in Science Teaching,” *J. Sci. Learn.*, vol. 4, no. 3, pp. 267–274, 2021, doi: 10.17509/jsl.v4i3.30570.

[5] Nurjanah, B. Latif, R. Yuliardi, and M. Tamur, “Computer-assisted learning using the Cabri 3D for improving spatial ability and self- regulated learning,” *Heliyon*, vol. 6, no. 11, p. e05536, 2020, doi: 10.1016/j.heliyon.2020.e05536.

[6] R. Leitão, J. M. F. Rodrigues, and A. F. Marcos, “Game-Based Learning: Augmented Reality in the Teaching of Geometric Solids,” *Int. J. Art, Cult. Des. Technol.*, vol. 4, no. 1, pp. 63–75, 2014, doi: 10.4018/ijacdt.2014010105.

[7] E. Demitriadou, K. E. Stavroulia, and A. Lanitis, “Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education,” *Educ. Inf. Technol.*, vol. 25, no. 1, pp. 381–401, 2020, doi: 10.1007/s10639-019-09973-5.

[8] A. Ü. Kan and E. Özmen, “The effect of using augmented reality based teaching material on students’ academic success and opinions,” *African Educ. Res. J.*, vol. 9, no. 1, pp. 273–289, 2021, doi: 10.30918/aerj.91.21.035.

[9] M. Sun, X. Wu, Z. Fan, and L. Dong, “Augmented reality based educational design for children,” *Int. J. Emerg. Technol. Learn.*, vol. 14, no. 3, pp. 51–60, 2019, doi: 10.3991/ijet.v14i03.9757.

[10] F. M. Zain, S. N. Sailin, M. Kasim, A. M. A. Karim, and N. N. Zameri, “Developing an Augmented Reality Immersive Learning Design (AILeaD) Framework: A Fuzzy Delphi Approach,” *Int. J. Interact. Mob. Technol.*, vol. 16, no. 11, pp. 65–90, 2022, doi: 10.3991/ijim.v16i11.30063.

[11] A. Yadav and K. P. Gupta, “Scope of the augmented reality applications in education sector: bibliometrik review,” *Inderscience Online*, vol. 15, no. 4, pp. 345–364, 2023, doi: 10.1504/IJLC.2023.132156.

[12] M. Romano, P. Díaz, and I. Aedo, “Empowering teachers to create augmented reality experiences: the effects on the educational experience,” *Interact. Learn. Environ.*, vol. 0, no. 0, pp. 1–18, 2020, doi: 10.1080/10494820.2020.1851727.

[13] A. C. Silva, A. R. Calderon, M. G. Retuerto, and L. Andrade-Arenas, “Application of Augmented Reality in Teaching and Learning in Engineering Programs,” *Int. J. Interact. Mob. Technol.*, vol. 16, no. 15, pp. 112–124, 2022, doi: 10.3991/ijim.v16i15.31695.

[14] U. Cahyana, L. Roland, I. Lestari, I. Irwanto, and J. S. Suroso, “Improving Students’ Literacy and Numeracy Using Mobile Game-Based Learning with Augmented Reality in Chemistry and Biology,” *Int. J. Interact. Mob. Technol.*, vol. 17, no. 16, pp. 4–15,

2023, doi: 10.3991/ijim.v17i16.42377.
[15] J. Bin Whang, J. H. Song, B. Choi, and J. H. Lee, “The effect of Augmented Reality on purchase intention of beauty products: The roles of consumers’ control,” *J. Bus. Res.*, vol. 133, no. November 2019, pp. 275–284, 2021, doi: 10.1016/j.jbusres.2021.04.057.
[16] A. A. Eldokhny and A. M. Drwish, “Effectiveness of Augmented Reality in Online Distance Learning at the Time of the COVID-19 Pandemic,” *Int. J. Emerg. Technol. Learn.*, vol. 16, no. 9, pp. 198–218, 2021, doi: 10.3991/ijet.v16i09.17895.
[17] O. Aldalalah, Z. W. M. Ababneh, A. K. Bawaneh, and W. M. M. Alzubi, “Effect of Augmented Reality and Simulation on the Achievement of Mathematics and Visual Thinking Among Students,” *International Journal of Emerging Technologies in Learning*, vol. 14, no. 18. pp. 164–185, 2019. doi: 10.3991/ijet.v14i18.10748.
[18] R. M. Yilmaz and Y. Goktas, “Using augmented reality technology in storytelling activities: examining elementary students’ narrative skill and creativity,” *Virtual Real.*, vol. 21, no. 2, pp. 75–89, 2017, doi: 10.1007/s10055-016-0300-1.
[19] Y. C. Chien, Y. N. Su, T. T. Wu, and Y. M. Huang, “Enhancing students’ botanical learning by using augmented reality,” *Univers. Access Inf. Soc.*, vol. 18, no. 2, pp. 231–241, 2017, doi: 10.1007/s10209-017-0590-4.
[20] M. Franzen, “Meta-analysis,” in *Encyclopedia of Personality and Individual Differences*, H. V. Zeigler and T. . Shackelford, Eds., Springer, Cham, 2020, p. 5925. doi: 10.1007/978-3-319-24612-3_1326.
[21] M. Tamur, S. Ndiung, R. Weinhandl, T. T. Wijaya, E. Jehadus, and E. Sennen, “Meta-Analysis of Computer-Based Mathematics Learning in the Last Decade Scopus Database: Trends and Implications,” *Infin. J.*, vol. 12, no. 1, p. 101, 2023, doi: 10.22460/infinity.v12i1.p101-116.
[22] D. Juandi, Suparman, B. A. P. Martadiputra, M. Tamur, and A. Hasanah, “Does Mathematics Domain Cause the Heterogeneity of Students’ Mathematical Critical Thinking Skills through Problem-Based Learning? A Meta-Analysis,” *AIP Conf. Proc.*, vol. 2468, no. December, 2022, doi: 10.1063/5.0102714.
[23] D. Juandi, M. Tamur, B. A. P. Martadiputra, Suparman, and V. S. Kurnila, “A meta-analysis of a year of virtual-based learning amidst the COVID-19 crisis : Possible solutions or problems ?,” in *AIP Conference Proceedings*, AIP Conference Proceedings, 2022, pp. 1–6.
[24] Y. Yunita, “Studi Meta-Analisis: Pembelajaran Berbasis Digital Dan Kontribusinya Terhadap Kemampuan Matematis,” *EDUMAT J. Edukasi Mat.*, vol. 13, no. 1, pp. 47–57, 2022, doi: 10.53717/edumat.v13i1.343.
[25] M. Ozdemir, C. Sahin, S. Arcagok, and M. K. Demir, “The effect of augmented reality applications in the learning process: A meta-analysis study,” *Eurasian J. Educ. Res.*, vol. 2018, no. 74, pp. 165–186, 2018, doi: 10.14689/ejer.2018.74.9.
[26] Y. Lin and Z. Yu, “A meta-analysis of the effects of augmented reality technologies in interactive learning environments (2012–2022),” *Comput. Appl. Eng. Educ.*, vol. 31, no. 4, pp. 1111–1131, 2023, doi: 10.1002/cae.22628.
[27] H. Altinpulluk, “Determining the trends of using augmented reality in education between 2006-2016,” *Educ. Inf. Technol.*, vol. 24, no. 2, pp. 1089–1114, 2019, doi: 10.1007/s10639-018-9806-3.
[28] H. M. Cooper, *Research Synthesis and Meta-Analysis : A Step-by-Step Approach*, Fifth. Los Angeles: SAGE Publications, 2017. doi: 10.4135/9781071878644.
[29] F. L. Schmidt and J. E. Hunter, *Methods of Meta-Analysis: Correcting Error and Bias in Research Findings*, Third. 55 City Road, London: 55 City Road, London: SAGE

Publications, Ltd, 2015. doi: 10.4135/9781483398105.
[30] M. Borenstein, L. V Hedges, and H. R. Rothstein, *Introduction Meta-Analysis*, no. January. John Wiley & Sons, 2009.
[31] M. Tamur, V. S. Kurnila, E. Jehadus, S. Ndiung, J. Pareira, and S. Syaharuddin, "Learning from the Past : Meta-Analysis of Contextual Teaching-Learning of the Past Decade," *Int. J. Educ. Curric. Appl.*, vol. 4, no. 1, pp. 1–10, 2021, doi: 10.31764/ijeca.v4i1.3981.
[32] Y. K. Sari, D. Juandi, M. Tamur, and A. M. G. Adem, "Meta-Analysis: Mengevaluasi Efektivitas Problem Based Learning pada Kemampuan Pemahaman Matematis Siswa," *J. Honai Math*, vol. 4, no. 1, pp. 1–18, 2021, doi: 10.30862/jhm.v4i1.144.
[33] M. Tamur, K. Mandur, and J. Pereira, "Do Combination Learning Models Change The Study Effect Size? A Meta-Analysis Of Contextual Teaching And Learning," *J. Educ. Expert*, vol. 4, no. 1, pp. 1–9, 2021, doi: 10.30740/jee.v4i1p1-9.
[34] Yohannes, D. Juandi, and M. Tamur, "The Effect of Problem-Based Learning (PBL) Model On Mathematical Communication Skills of Junior High School Students – A Meta-Analysis Study," *J. Pengukuran Psikol. dan Pendidik. Indones.*, vol. 10, no. 2, pp. 142–157, 2021, doi: 10.15408/jp3i.v10i2.17893.
[35] D. Juandi, M. Tamur, and Suparman, "Formulating Best Practices for Digital Game-Based Learning: A Meta-analysis study," *AIP Conf. Proc.*, vol. 090003, no. 1, pp. 1–7, 2023, doi: 10.1063/5.0155520.
[36] M. Tamur, L. L. Jedia, R. Kurniyati, and M. A. Banggut, "Analisis Bibliometrik Penggunaan Geogebra dalam Meningkatkan Kemampuan Pemecahan Masalah Matematis Siswa Dekade Terakhir," *Suska J. Math. Educ.*, vol. 8, no. 2, pp. 75–86, 2022, doi: 10.24014/sjme.v8i2.19868.
[37] M. Tamur, F. E. Men, K. E. Ermi, A. M. Muhut, R. Nunang, and O. A. Lay, "Penggunaan ICT dan Pengaruhnya terhadap Kemampuan Penalaran Matematis Siswa: Sebuah Analisis Bibliometrik," *Juring (Journal Res. Math. Learn.*, vol. 5, no. 4, p. 261, 2022, doi: 10.24014/juring.v5i4.19991.
[38] Y. N. Deda, H. Disnawati, M. Tamur, and M. Rosa, "Global Trend of Ethnomathematics Studies of The Last Decade: A Bibliometric Analysis," *Infin. J.*, vol. 13, no. 1, pp. 233–250, 2024, doi: 10.22460/infinity.v13i1.p233-250.
[39] S. Oueida, P. Awad, and C. Mattar, "Augmented Reality Awareness and Latest Applications in Education: A Review," *Int. J. Emerg. Technol. Learn.*, vol. 18, no. 13, pp. 21–44, 2023, doi: 10.3991/ijet.v18i13.39021.
[40] M. Tezer, E. P. Yildiz, A. R. Masalimova, A. M. Fatkhutdinova, M. R. Zheltukhina, and E. R. Khairullina, "Trends of augmented reality applications and research throughout the world: Meta-analysis of theses, articles and papers between 2001-2019 years," *Int. J. Emerg. Technol. Learn.*, vol. 14, no. 22, pp. 154–174, 2019, doi: 10.3991/ijet.v14i22.11768.
[41] T. D. Pigott and J. R. Polanin, "Methodological Guidance Paper: High-Quality Meta-Analysis in a Systematic Review," *Rev. Educ. Res.*, vol. 90, no. 1, pp. 24–46, 2020, doi: 10.3102/0034654319877153.
[42] M. L. McHugh, "Lessons in biostatistics interrater reliability : the kappa statistic," *Biochem. Medica*, vol. 22, no. 3, pp. 276–282, 2012, doi: 10.11613/BM.2012.031.
[43] L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education*, 8th ed. London: Routledge, 2017. doi: 10.4324/9781315456539.
[44] M. Borenstein, L. V Hedges, J. P. T. Higgins, and H. R. Rothstein, *Introduction to Meta-Analysis*. UK: John Wiley and Sons, 2009.

[45] D. Juandi and M. Tamur, *Pengantar Analisis Meta*, 1st ed. Bandung, Indonesia: UPI PRESS, 2020.
[46] N. Atalay, "Augmented reality experiences of preservice classroom teachers in science teaching," *Int. Technol. Edu cation J.*, vol. 6, no. 1, pp. 28–42, 2022.
[47] J. H. Djibril and H. Çakir, "Students' Opinions on the Usage of Mobile Augmented Reality Application in Health Education," *J. Learn. Teach. Digit. Age*, vol. 8, no. 1, pp. 10–24, 2023, doi: 10.53850/joltida.1076286.
[48] E. P. Yildiz, "Augmented Reality Applications in Education: Arloopa Application Example," *High. Educ. Stud.*, vol. 12, no. 2, p. 47, 2022, doi: 10.5539/hes.v12n2p47.
[49] M. C. Costa, A. Manso, and J. Patrício, "Design of a mobile augmented reality platform with game-based learning purposes," *Inf.*, vol. 11, no. 3, pp. 1–20, 2020, doi: 10.3390/info11030127.
[50] L. E. Reeves *et al.*, "Use of augmented reality (Ar) to aid bioscience education and enrich student experience," *Res. Learn. Technol.*, vol. 29, no. 1063519, pp. 1–15, 2021, doi: 10.25304/rlt.v29.2572.
[51] J. Jesionkowska, F. Wild, and Y. Deval, "education sciences Active Learning Augmented Reality for STEAM Education — A Case Study," *Educ. Sci.*, vol. 10, no. 8, pp. 1–15, 2020.
[52] A. D. Samala and M. Amanda, "Immersive Learning Experience Design (ILXD): Augmented Reality Mobile Application for Placing and Interacting with 3D Learning Objects in Engineering Education," *Int. J. Interact. Mob. Technol.*, vol. 17, no. 5, pp. 22–35, 2023, doi: 10.3991/ijim.v17i05.37067.
[53] J. Cardenas-Valdivia, J. Flores-Alvines, O. Iparraguirre-Villanueva, and M. Cabanillas-Carbonell, "Augmented Reality for Quechua Language Teaching-Learning: A Systematic Review," *Int. J. Interact. Mob. Technol.*, vol. 17, no. 6, pp. 116–138, 2023, doi: 10.3991/ijim.v17i06.37793.
[54] D. Karagozlu, N. N. Kosarenko, O. V. Efimova, and V. V. Zubov, "Identifying students' attitudes regarding augmented reality applications in science classes," *Int. J. Emerg. Technol. Learn.*, vol. 14, no. 22, pp. 45–55, 2019, doi: 10.3991/ijet.v14i22.11750.