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META ANALYSIS: THE EFFECT OF AUGMENTED REALITY ON STUDENTS' GEOGRAPHY LEARNING OUTCOMES IN SCHOOLS

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ABSTRACT

Geography learning outcomes reflect the success of the learning process, particularly in the cognitive domain. However, many students struggle to understand abstract geographical concepts that are ideally taught in natural settings. This study aims to analyze the impact of augmented reality (AR) as a learning medium on geography learning outcomes. Using a quantitative meta-analysis method, 14 ISSN-certified national journal articles were reviewed. The results show that AR significantly enhances geography learning outcomes, with an average effect size of 0.34, indicating a strong positive impact. he results show that AR significantly enhances geography learning outcomes, with an average effect size of 0.34. According to Cohen's criteria, this value is categorized as a large effect, signifying that AR has a substantial and meaningful impact on students' understanding of abstract geographical concepts. This effect size also surpasses that typically reported for conventional learning media, highlighting the innovative advantage of AR in geography education.

A. INTRODUCTION

Education is one way to improve the standard of human life by equipping people with knowledge and skills. One of the key indicators of success in the educational process is evident in the learning outcomes. Learning outcomes serve as a benchmark for measuring student competence after receiving instruction from teachers and educators, encompassing the affective, cognitive, and psychomotor domains (Hutapea, 2019). Student learning outcomes are influenced by teachers' teaching activities, where teachers' creativity in learning has a significant impact on student development (Moonti et al., 2021). To achieve good learning results, a learning process is needed that provides ample stimulation to students, one of which is through the use of learning

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media that align with the context of the material being taught (Anggraini, 2017).

The rapid development of technology supports the use of learning media now. Integrating technology and student-centred learning management is essential in 21st-century learning (Kerimbayev et al., 2023). Technological advancements are increasingly being utilised in various human activities, including the education sector. One of the things that supports teaching in education is the virtual environment, which includes augmented reality and virtual reality. In recent years, augmented reality has emerged as a transformative technology with a rapidly growing range of applications (Rauschnabel et al., 2022). The application of virtual environments in the Education sector shows that using virtual environment technology improves students' learning experience (Cevikbas et al., 2023).

The advantage of using a virtual environment for Education is that it differs from traditional teaching, providing convenience and reaching all specific physical locations that traditional teaching cannot access (Kumar et al., 2021). The use of Augmented Reality in the world of Education is no longer something new; teachers and students have the opportunity to use technology in packaging learning that is more interesting, creative, and visual to provide the main benefits obtained in the use of AR as a learning medium, namely, providing an immersive and interactive learning experience (Evanick, 2023). Augmented Reality is one of the technological innovations that can be effectively utilised to meet more meaningful learning criteria, presenting training relevant to daily practice and thereby fostering collaboration both locally and remotely, providing real-time feedback, and delivering improvements to the learning process (Osadchyi et al., 2021).

In geography learning, Augmented Reality (AR) presents opportunities to bridge abstract concepts with tangible experiences. Geography as a subject encompasses spatial, visual, and complex phenomena, such as topography, climate systems, and urban development, which can be challenging to grasp through conventional teaching methods (Volioti et al., 2022). AR can visualise these elements in three dimensions, allowing students to explore maps, landscapes, and environmental changes interactively. This visualisation enhances conceptual understanding and improves students' engagement and motivation, particularly in the cognitive domain. Students are more likely to retain information when they can see and interact with geographic phenomena in real-time simulations, rather than relying solely on textbooks or lectures.

Integration of AR in geography education aligns with the principles of experiential learning, where learners gain knowledge through active participation and reflection on their experiences (Dhaas, 2024). AR enables learners to manipulate virtual objects and scenarios that represent real-world geographic information, fostering higher-order thinking skills such as analysis, evaluation, and synthesis. This learning model is especially relevant for digital-native students who are accustomed to interactive and multimedia environments. Several studies have shown that AR-based learning significantly contributes to improved learning outcomes by accommodating diverse learning styles and needs, ultimately supporting more inclusive and effective education (Bos et al., 2022).

Urgency of using Augmented Reality (AR) in geography education continues to grow in line with the demands of 21st-century learning, which emphasises the integration of technology and interactive, contextual teaching approaches. Geography, as a subject involving many abstract and spatial and concepts, requiring instructional media that can effectively visualise such phenomena in a concrete and immersive manner. AR offers an innovative solution to enhance students' understanding of material, encourage active engagement, and create more meaningful learning experiences. Amid the ongoing shift toward digital education, it is essential to evaluate the actual impact of technologies like AR on student learning outcomes, particularly in the context of school-based geography instruction.

However, a research gap remains in comprehensively understanding the effectiveness of AR on student learning outcomes, primarily through a meta-analytic approach that can synthesise findings from various empirical studies. Previous research remains fragmented, often employing diverse methodologies and yielding inconsistent results, necessitating a systematic and integrative review. Therefore, this study aims to fill this gap by providing a comprehensive synthesis of the effectiveness of AR in improving students' geography learning outcomes through meta-analysis. The results are expected to offer practical recommendations for the development and implementation of AR-based learning media in the future.

B. METHOD

To minimise bias in this meta-analysis, article selection was carried out systematically based on strict inclusion criteria, namely, only including accredited national journals with complete statistical reporting. The quality and risk of bias in each study were assessed independently by two reviewers, using indicators such as internal validity, clarity of intervention, and completeness of results reporting.

Furthermore, publication bias was evaluated by examining the distribution of effect sizes and conducting a qualitative inspection of the funnel plot. This step ensures that the conclusions drawn are robust and not overly influenced by the presence of bias in individual studies.

The analysis focused on calculating the effect size (η^2) to determine the magnitude of the influence of AR on learning outcomes. The formula used for calculating the effect size is:

$$\eta^2 = r^2 = \frac{t_o^2}{t_o^2 + db} \qquad (1)$$

Where:
t_o : t-obtained value from the article
db: degrees of freedom

Interpretation of effect size :
After calculating the effect size for each study, the results are interpreted using the following criteria:

- Small Effect: $0.01 < \eta^2 < 0.09$
- Medium effect: $0.09 < \eta^2 < 0.25$
- Significant effect: $\eta^2 > 0.25$

C. RESULT AND DISCUSSION

C.1. RESULT

The research results on the use of augmented reality in learning outcomes yielded diverse data, with an average effect size of 0.34, which, according to Cohen's criteria (1988), falls into the category of a significant effect ($\eta^2 > 0.25$). This suggests that incorporating augmented reality into learning yields a substantial and statistically significant improvement in learning outcomes. The effect size obtained is also higher than that generally reported for conventional learning media, further confirming the added value of AR in geography education.

The effect size obtained is also higher than that generally reported for conventional learning media, further confirming the added value of AR in geography education. To see the detailed results of the influence of Augmented reality on Geography learning outcomes (Table 1).

Overall, the effect *size* of using augmented reality on geography learning outcomes falls into a large category. There are five articles for medium effects, and 1 article for minor effects. Table 2 explains that the various effect *size* values of the impact of augmented reality on learning outcomes.

The effect size is variable based on the year. For clarity on the effect size of the use of augmented reality in learning outcomes (Table 3).

Table 1. Data Analysis: The Effect of Augmented Reality on Geography Learning Outcomes (Meta Results)

Name and Year	n	n1	n2	r^2	t count	n^2	Independent Variable	Dependent Variable	Code
Mulyani & Masniladevi (2021)	30	15	15		2,490	0,18	AR	Learning outcomes of building a cube and beam space	AR1
Kusumo & Afandi (2021)	29				5,457	0,52	AR	Social Studies learning outcomes for elementary schools	AR2
Aini & Zulfadewina (2024)	60	30	30		6,361	0,41	AR	Science learning outcomes	AR3
Khotimah (2019)	72	36	36	0,036		0,19	AR	Student Learning Outcomes	AR4
Susena et al. (2024)	64	32	32		7,100	0,45	AR	Social Studies learning outcomes for junior high school	AR5
Dewi et al. (2024)	46	22	24		2,337	0,11	AR	Science learning outcomes	AR6
Tania et al. (2023)	68	34	34		2,680	0,10	AR	Student Learning Outcomes of statistical materials	AR7
Sholikhah et al. (2023)	63	32	31		6,687	0,42	AR	Student learning outcomes	AR8
Zuana & Aziz (2023)	61	30	31		3,958	0,21	AR	History learning outcomes	AR9
Anggraini et al. (2024)	40	20	20		5,774	0,47	AR	Critical thinking skills	AR10
Masri et al. (2023)	35			0,411		0,64	AR	Student Learning Interest	AR11
Parung et al. (2024)	44	22	22		1,875	0,08	AR	Student learning outcomes and student PPP	AR12
Kumalasari & Ridwan (2023)	30				-6,967	0,63	AR	Cognitive learning outcomes	AR13
Acesta & Nurmaylan (2018)	41	21	20		4,830	0,37	AR	Student learning outcomes	AR14
Mean						0,34			

(Source: Compiled from various educational journal articles (2018-2024))

Table 2. Criteria Effect Size

Code	Category Effect Size	Total
AR12	Small	1
AR1, AR4, AR6, AR7, AR9	Medium	5
AR2, AR3, AR5, AR8, AR10, AR11, AR13, AR14	Big	8
Total		14

(Source: Data processed from 14 AR research (2018–2024))

Table 3. Augmented Reality Impact by Year

Code	Year	Effect Size	Total
AR14	2018	0,37	1
AR4	2019	0,19	1
AR1, AR4	2021	0,7	2
AR7, AR8, AR9, AR11, AR13	2023	0,4	5
AR4, AR5, AR6, AR10, AR12	2024	0,304	5
Total			14

(Source: Data processed from 14 AR studies (2018–2024))

C.2. DISCUSSION

The Effectiveness of Augmented Reality in Enhancing Learning Outcomes

The findings from this meta-analysis suggest that the use of Augmented Reality (AR) in learning processes significantly enhances student outcomes, particularly in subjects such as geography, science, and social studies. The average effect size recorded is 0.34, which falls into the high-effect category, demonstrating that AR can serve as an effective pedagogical tool in enhancing learning comprehension and performance. This is reflected in the works of researchers such as Aini & Zulfadewina (2024) and Kusumo & Afandi (2021), who reported large effect sizes of 0.41 and 0.52, respectively, in science and social studies learning outcomes.

Notably, the high effect sizes observed in studies by Susena et al. (2024) and Sholikhah et al. (2023) with 0.45 and

0.42, respectively, strengthen the claim that AR encourages better engagement and mastery of learning material. The immersive and interactive characteristics of AR make it possible to explain complex spatial concepts, like landform structures or historical developments, with clarity. These aspects are particularly relevant in geography education, where spatial understanding is fundamental. Students benefit from real-time visualisations that enhance cognitive connection to the material.

However, the results also reveal considerable variation in the impact of AR, depending on factors such as subject matter, year of publication, and the specific design of the AR intervention. For example, Dewi et al. (2024) and Parung et al. (2024) reported lower effect sizes of 0.11 and 0.08, respectively. These variations highlight that AR's effectiveness is not solely determined by the technology, but also by how well it is integrated into classroom instruction, the alignment with the learning material, teacher readiness, and the educational context. Additionally, differences in student grade levels and institutional support also contribute to the observed disparities in effect size. This finding aligns with broader educational research that stresses the importance of pedagogical fit and implementation quality for technology-mediated learning.

Poor alignment between content and AR tools, limited teacher training, or technical issues might contribute to reduced effectiveness in such cases. AR media also offers significant contributions to the affective domain. Zuana & Aziz (2023) A study on history learning reported an effect size of 0.21, which emphasised how AR increased student enthusiasm and emotional engagement with the material. When learners experience the lesson through a vivid, simulated environment, they tend to develop a greater interest and emotional attachment, which in turn translates into better retention and increased participation in the classroom. Additionally, Acesta & Nurmaylany (2018) it highlights the strength of AR in supporting students' autonomy in the learning process.

By using AR, learners are given the flexibility to explore content at their own pace and in their own style, thereby fostering critical thinking and problem-solving skills. The effect size of 0.37 in Acesta's study indicates a substantial improvement in learning outcomes when AR is used as an exploration tool rather than just a demonstration medium. Not only that, Masri et al. (2023) but we also found an exceptionally high effect size of 0.64 when investigating the influence of AR on students' learning interest. This finding underscores how AR media improve knowledge acquisition and drive motivation and intrinsic interest, two essential components for lifelong learning. When students are emotionally and intellectually engaged, their academic performance tends to increase significantly.

Despite these promising findings, this meta-analysis has limitations. The included studies exhibit variations in research methodology, reporting standards, and contextual factors such as school infrastructure and teacher expertise. These differences may affect the comparability of effect sizes and the generalizability of results. Future studies should aim for more standardised reporting and explore the contextual factors influencing the successful adoption of AR in classrooms.

Factors Influencing the Impact of Augmented Reality in Learning

While most studies confirmed the benefits of AR, the degree of its impact varied based on several influencing factors. One of the primary factors is the year of publication, which correlates with but technological development and pedagogical adaptation. For instance, older studies such as that by Acesta & Nurmaylany (2018) reported a respectable effect size of 0.37, but more recent research from Kusumo & Afandi (2021), Susena et al. (2024), and Anggraini et al. (2024) revealed higher and more consistent effect sizes, indicating better integration of AR as the technology matures. Another key variable is the targeted subject matter.

Research focusing on visual-intensive disciplines such as geography, science, and history tended to produce better outcomes with AR integration. Aini & Zulfadewina (2024) and Dewi et al. (2024), both focusing on science learning, achieved different results, 0.41 and 0.11 respectively despite similar subjects. This suggests that other underlying factors, such as content alignment and instructional design, strongly influence effectiveness. Meanwhile, Anggraini et al. (2024) with an effect size of 0.47, demonstrated how AR can enhance higher-order thinking skills like critical thinking.

Moreover, student level and educational background appear to play a role. Kusumo & Afandi (2021) and Susena et al. (2024), who worked with elementary and junior high school students, saw strong learning gains, possibly because younger students are more visually oriented and responsive to interactive content. In contrast, Kumalasari & Ridwan (2023), although reporting a high effect size of 0.63 in cognitive learning, did not specify the educational level, leaving questions about contextual generalizability.

The quality of teacher facilitation and institutional support also influence the success of AR integration. For instance, in studies with high effect sizes like AR2, AR3, and AR5, there is an implication that

AR was not only available but also effectively used, perhaps supported by teacher training and pedagogical planning. On the other hand, the low effect sizes found in AR6 (Dewi et al., 2024) and AR12 (Parung et al., 2024) might reflect inadequate teacher preparation or lack of institutional readiness to support AR-based learning.

Technical design and application interactivity also contribute to learning impact. Studies like those of Sholikhah et al. (2023) and Zuana & Aziz (2023) which utilized interactive AR apps tailored to specific subject needs, produced higher effect sizes than those that simply overlaid static 3D objects. These findings suggest that pedagogical intentionality in AR design, how interactive, immersive, and relevant the content is matters significantly in achieving learning goals. Differences in research methodologies influence the reported outcomes. Studies using experimental designs with clear control and treatment groups (Aini & Zulfadewina (2024); Sholikhah et al. (2023) are more likely to report precise and reliable effect sizes than those using quasi-experimental or descriptive designs.

D. CONCLUSION

The results of the meta-analysis indicate that the use of Augmented Reality (AR) in education generally has a significant positive impact on learning outcomes, with an average effect size of 0.34, which falls into the high category. AR has been proven effective in enhancing conceptual understanding, emotional engagement, and student motivation, particularly in visually oriented subjects such as geography, science, and social studies.

However, the effectiveness of AR is influenced by various factors, including content relevance, application design quality, teacher readiness, and implementation strategies in the classroom. To optimize the potential of AR in education, it is crucial for educators to receive adequate training in integrating AR into their teaching, ensuring alignment with curriculum and learning objectives. Policymakers should provide institutional support in the form of infrastructure, funding, and professional development to facilitate the effective use of AR.

Collaboration among educational stakeholders, technology developers, and government agencies is recommended to create a sustainable ecosystem for digital learning. Future research should focus on standardizing implementation models and further investigating the impact of AR on affective and higher-order cognitive domains across various educational settings.

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