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The Effect of an Augmented Reality-Based Discovery Learning Model on Students' Language Proficiency: A Meta-Analysis

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Abstract
This study aims to determine the influence of augmented reality-based discovery learning models on students' language skills. This type of research is quantitative research with a meta-analysis approach. The eligibility criteria are that the research is published from 2021-2024, SINTA or Scopus must index the research, the research must be an experimental method or quasi-experiment, the research must be open access, and the research data must be complete to calculate the effect size value. Tracing data sources include Google Scholar, ERIC, Taylor of Francis, IEEE and Scopus. The data collection technique is observation through databases. The data in this study was filtered using the PRISMA 2020 method. Data analysis in the study by calculating the effect size value of each survey with the JSAP 0.8.5 application. The analysis of 22 studies concluded that the augmented reality-based discovery learning model significantly influenced students' language skills with a value of d = 1,029 in the high effect size category. This finding positively influences teachers to apply this model to encourage students' language skills in Indonesian learning.
Keywords: *Discovery Learning; Augmented Reality; Language Skills; Meta-analysis*

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Introduction
The development of educational technology has brought significant changes in the way the learning process is carried out (Lubis et al., 2019; Lestari et al., 2024). Technological advances are an important thing that cannot be separated from the world of education. These tools not only make it easier to access a wider range of learning resources, but they also transform the role of teachers and students in the classroom(Ristanto et al., 2022). If previously teachers were the only source of information, now students have the opportunity to search, understand, and explore various topics independently with the help of technology. One of the major impacts of this development is the increased involvement of students in the learning process, as technology allows for a more interactive and engaging learning experience (Li & Zhang, 2023; Hariyanto et al., 2023; Xavier, 2023).

In addition, technological advancements such as Augmented Reality (AR), Virtual Reality (VR), and artificial intelligence (AI) have enriched learning methods (Syawaludin et al., 2022; Anwar et al., 2023). This technology creates a more dynamic learning environment, where students can interact directly with learning materials through simulations, 3D visualizations, and interactive applications (Akihary et al., 2023); . The positive impact can be

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seen in increasing students' motivation and understanding of complex concepts. Technology also provides flexibility in learning, such as distance learning (online learning), which allows students to learn beyond the limitations of space and time. Thus, technological developments in education have opened up great opportunities to improve the overall quality of learning, provide more equitable access to education, and support the development of 21st-century skills (Siew & Chai, 2024; (Khafah et al., 2023; Alnajjar & Ibrahim, 2024);

Language learning faces various challenges that affect the development of students' language skills, both at the elementary and advanced levels (Wei, 2022). One of the main challenges is the difference in students' ability levels in understanding and using language. Within a class, students often have diverse backgrounds of knowledge and experiences, which affect their ability to speak, listen, read, and write (Yefang et al., 2024; Zahara et al., 2020). Teachers must face difficulties in providing materials that can accommodate the individual needs of students, without sacrificing the overall progress of the group. These difficulties often affect the speed of learning and the achievement of optimal results in language learning. In addition, the motivation of students to learn a language is often a challenge in itself. In language learning, the skills acquired cannot be immediately benefited in the short term, so students tend to lose interest and motivation to continue learning. Learning that is theoretical and less interactive can also reduce students' interest in developing language skills (Wei, 2022). The lack of opportunities to practice in real-life situations, such as discussions or everyday conversations, makes it difficult for students to apply their knowledge. As a result, speaking or writing skills often become weaker compared to reading or listening skills (Nurdin & Hafidzi, 2023; Myint et al., 2023);

Technological limitations in some situations are also an obstacle in language teaching(Syawaludin et al., 2022;Ristanto et al., 2022). Not all schools have access to technology tools such as language learning software, interactive apps, or Augmented Reality (AR) devices that can make learning more engaging and effective (Lim & Toh, 2024). On the other hand, even if technology is available, its less than optimal use or not adapted to the right teaching methods can reduce its benefits(Lim & Toh, 2024; Ma, 2024). Therefore, the challenges in language learning require a more creative and innovative approach, including utilizing technology and more student-centered learning methods to overcome various existing obstacles. Therefore, there is a need for a learning model that can improve students' language skills (Yefang et al., 2024).

Discovery Learning is a learning model that puts students at the center of the learning process by encouraging them to independently discover knowledge through exploration, investigation, and problem-solving(Hariyanto et al., 2023; Akihary et al., 2023). In this model, students not only passively receive information from teachers, but actively seek and build their own understanding. Teachers act as facilitators who guide students through open-ended questions and challenging scenarios, so that they are more deeply involved in the learning process(Feridun & Bayraktar, 2024; Alnajjar & Ibrahim, 2024). Discovery Learning taps into students' natural curiosity and encourages them to take responsibility for their own learning, ultimately strengthening critical thinking skills and problem-solving abilities(Hains-Wesson et al., 2023; Dina & Ikhsan, 2019). The main advantage of *Discovery Learning* in education is its ability to increase student engagement and develop a deeper understanding of the subject matter. Because students are actively involved in discovering new concepts or information, they are more likely to understand and remember the material more effectively compared to passive learning(Baba et al., 2022; Hains-Wesson et al., 2023). In addition, this model increases learning motivation because students feel they have a greater role in the learning process. In the long term, Discovery Learning also helps students develop skills that are essential for 21st century students such as adaptability, collaboration, and creativity, all of which are essential foundations for success in the world of work and everyday life (Abumalik & Alqahtani, 2024; Permatasari et al., 2018; Ott et al., 2018);

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Discovery Learning and Augmented Reality (AR) technology have a close relationship in supporting student-centered, interactive learning(Li & Zhang, 2023; Lubis et al., 2019;(Feridun & Bayraktar, 2024; Yaiche, 2021). AR can enrich the Discovery Learning experience by providing an immersive learning environment, where students can explore abstract concepts through three-dimensional visualization and direct interaction with virtual objects. With AR, the discovery process in Discovery Learning becomes more concrete and interesting, as students can observe phenomena that are difficult to access in real life, such as biological simulations or physical phenomena (Dina & Ikhsan, 2019; Nusantari et al., 2021; Maarif, 2015). The combination of Discovery Learning with AR allows students to engage more actively, develop a deeper understanding, and increase motivation to learn, as this technology makes the process of exploration and discovery more fun and real (Simamora et al., 2018; Setiasih et al., 2023).

Research by Bacca et al. (2014); Wesson et al., 2023); Koto, 2020) found that the use of AR in learning environments can increase student motivation and facilitate the learning of concepts that are difficult to understand abstractly. Research by Cheng and Tsai (2013) shows that students who learn with the help of AR are better able to connect theory with practice, so their understanding of the material becomes better. In addition, this study also found that the integration of AR increases students' curiosity and interest in digging deeper into the material being studied. Another study by Liu et al. (2017) examined the influence of AR in the development of language skills, particularly in vocabulary learning and speaking. AR is used to visualize real-life conversational situations, where students can interact with simulated objects and environments directly. The results of this study show that students who use AR experience a better improvement in vocabulary mastery and speaking ability compared to students who learn through conventional methods. The study also notes that AR helps reduce awkwardness in speaking a foreign language, as students can practice in a more realistic and interactive environment. Therefore, this study aims to determine the influence of augmented reality-based discovery learning models on students' language skills through meta-analysis editing.

Methodology

Pada This research is a type of quantitative research with a meta-analysis approach. The meta-analysis aims to determine the influence of augmented reality-based discovery learning models on students' language skills. Meta-analysis is a research application that seeks an in-depth conclusion from the same research results (Dincer, 2014; Ulum, 2022). The procedures in meta-analysis research are 1) determining the subject and question of the research, 2) searching for research literature, 3) analyzing research that meets the inclusion criteria, 4) encoding data, 5) analyzing publication bias and 6) analyzing statistics for effect size (Borenstein et al., 2007; Öztop, 2023; Zulyusri et al., 2023).

Tracing the data sources in this meta-analysis is through the google scholar database; ERIC, Taylor of Francis, IEEE and Scopus. The keywords for data search are "discovery learning", "Augmented reality", "the influence of Augmented Reality-based Discovery learning", and "Students' Language Ability". From the results of the data search, 226 studies were obtained and continued at the data selection stage through the PRISMA 2020 method (figure 1.) consisting of identification, screening, and eligibility. The results of data selection were obtained from 22 studies that met the inclusion criteria set.

The analysis of data in this study is to calculate the effect size value of the research with the help of the JSAP application. The data analysis procedures in this meta-analysis are 1) calculating the effect size of each study, 2) conducting a heterogeneity test, 3) calculating the summary effect size and 4) checking the publication bias. Furthermore, the effect size criteria in this study are guided by (Cohen's, 2018) table 1. Before doing the summary effect, a heterogeneity test is carried out. The heterogeneity test uses the parameter Q. The decision-making criterion is that if the p-value < 0.05, then the measurement model used to calculate

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the effect size is random effect. If the p-values > 0.05, then the measurement to calculate the effect size value is fixed effect (Sen & Yildirim, 2020; Kahraman, 2023; Balemen & Keskin, 2018). The publication bias test in this study is the Rosenthal Fail Save N test. If the FSN value is greater than 5k + 1, then there is no publication bias.

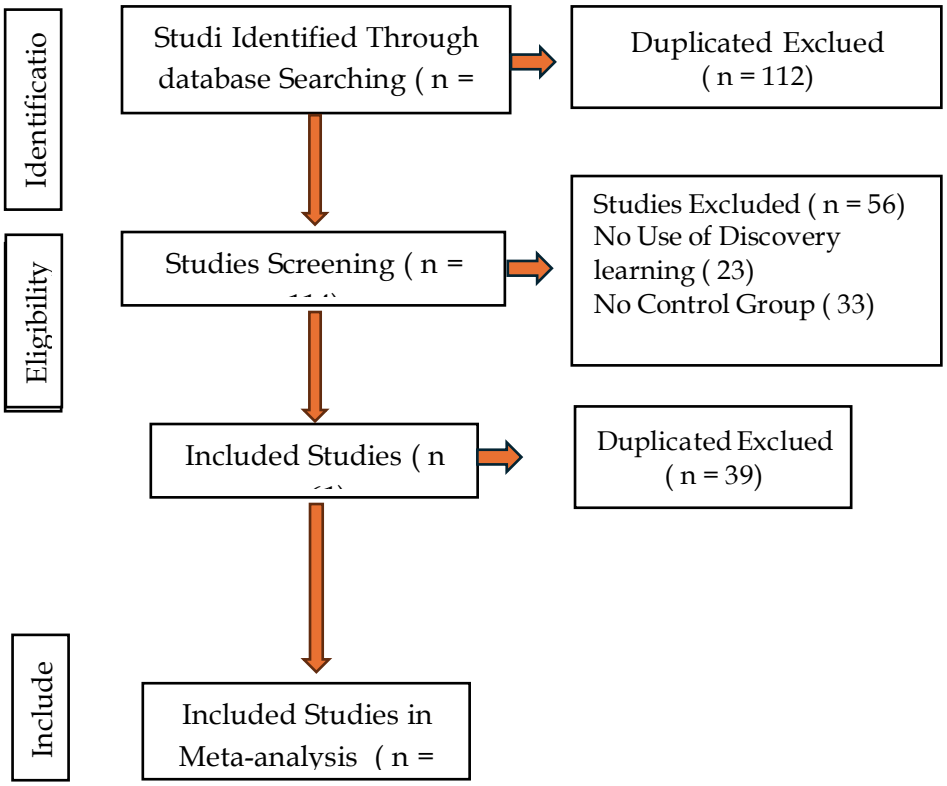

Figure 1. Data Screening Through PRISMA 2020

Table1. Criteria Nilai Effect Size Cohen's

Classification	Interval
No Effect	0.00≤ES≤ 0.19
Small Effect	0.19 < ES ≤ 0.49
Medium Effect	0.49 < ES ≤ 0.79
High Effect	0.79 < ES ≤ 1.29
Very High Effect	ES > 1.29

Result and Discussion

From the results of a search of the google scholar database, ERIC, Taylor of Francis and IEEE obtained 22 studies that met the inclusion criteria. Furthermore, the effect size and standard error can be seen in Table 2.

Table 2, the effect size values of 22 studies ranged from 0.41 to 2.13. According to Cohen's (2018) effect size criteria, 22 studies were obtained, 5 (22.73%) studies had medium effect size values, 8 (36.37%) studies had high effect size values, and 9 (40.91%) studies had high effect size values. Next, an estimation model was determined to analyze the mean effect size of the 22 studies analyzed. The analysis of mean effect size through random and fixed effect models can be seen in Table 3.

Based on Table 3, the results of the Q value analysis of 207.15 are higher than the value of 76.47 with a confidence degree of 95% and a p value of <0.001. These results can be concluded that the 22 effect sizes analyzed are heterogeneously distributed. The model that is suitable to be used to analyze the average of 22 effect sizes is the random effect model.

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Table 2. Effect Size dan Standard Error

Journal Code	Years	Dependent Variable	Effect Size	Standard Error
PL1	2022	Language skills	1.12	0.41
PL2	2022	Language skills	0.42	0.23
PL3	2024	Language skills	0.96	0.37
PL4	2024	Language skills	1.19	0.61
PL5	2023	Language skills	2.13	0.49
PL6	2023	Language skills	2.07	0.53
PL7	2023	Language skills	1.16	0.49
PL8	2024	Language skills	1.09	0.35
PL9	2023	Language skills	0.82	0.33
PL 10	2022	Language skills	0.74	0.12
PL 11	2022	Language skills	0.92	0.25
PL 12	2024	Language skills	1.34	0.44
PL 13	2024	Language skills	1.62	0.51
PL 14	2022	Language skills	0.69	0.39
PL 15	2022	Language skills	0.41	0.18
PL 16	2024	Language skills	1.56	0.61
PL 17	2023	Language skills	1.67	0.44
PL 18	2023	Language skills	2.17	0.42
PL 19	2022	Language skills	0.84	0.29
PL 20	2024	Language skills	0.66	0.17
PL 21	2024	Language skills	0.73	0.20
PL 22	2022	Language skills	1.40	0.43

Table 3. Random dan Fixed Model

	Q	df	P
Omnibus test of Coefficients Model	76.47	1	< 0.001
Test of Residual Heterogeneity	207.15	21	< 0.001

Note. p-value are approximate

Furthermore, it determined the publication bias check of the 22 studies analyzed. To find out whether or not there is publication bias through funnel plot analysis and Rosenthal Fail Safe N test (Tamur and Junadi, 2020; Zulkifli et al., 2022; Zulyusri et al., 2023; Hariyadi et al., 2023; Borenstein et al., 2007). The results of the funnel plot analysis can be seen in Figure 2.

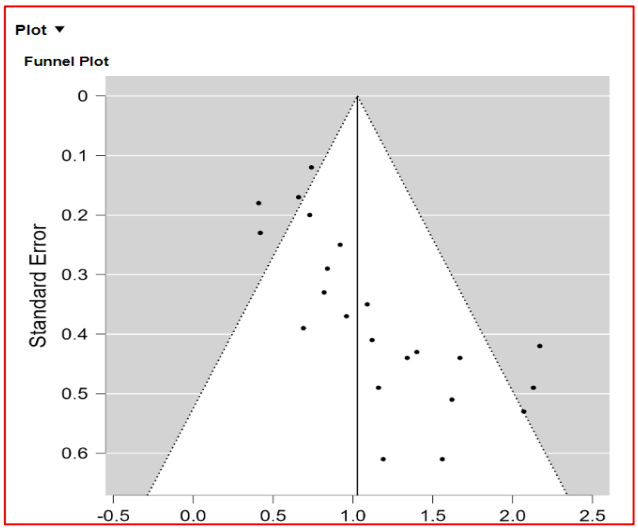

Figure 2. Funnel Flot Random Effect Model

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Figure 2, explains that the results of the effect size analysis through the funnel plot cannot be known whether the curve is symmetrical or asymmetrical. Therefore, it is necessary to do the Rosenthal Fail Safe N test. The results of the Rosenthal Fail Safe N test can be seen in Table 4.

Table 4. Fail Safe N

File Drwaer Analysis			
	Fail Safe N	Target Significance	Observed Significance
Rosenthal	1823	0.050	< 0.001

Table 4, the results of the Rosenthal Fail Safe N test are 1823 with a significance value of 0.050 and $p < 0.001$. The value of K = 22 then 5k + 10 = 5.22 + 10 = 120. Because the FSN value is > K, in the analysis of the 22 effect sizes in the meta-analysis, there is no publication bias and can be scientifically accounted for. The next step is to determine the mean effect size through a random effect model which can be seen in Table 5.

Tabel 5. Summary Effect Size

Coefficient					**95% Confidence Interval**	
	Estimate	Standar Error	Z	P	Lower	Upper
Intercept	1.029	0.107	9.638	< 0.001	0.819	1.238

Based on Table 5, the result of the summary effect size is 1,029 with a confidence level of 95% with a lower limit of 0.819 and an upper limit of 1,238. These findings conclude that the augmented reality-based discovery learning model has a significant influence on students' language ability with a high effect size category with a value of Z = 9.638 and $p < 0.001$.

Discussion

The use of Augmented Reality (AR) helps enrich the student learning experience by combining visual, auditory, and kinesthetic elements that are able to increase student engagement in the learning process (Baba et al., 2022). Additionally, AR also allows students to interact directly with learning materials, which encourages deeper exploration and understanding. The results of the study are in line with Sreejun & Chatwattana (2023) the application of augmented reality can encourage students' creative thinking and language skills in learning. Selanjutnya, Discovery Learning integrated with AR encourages students to be more independent in discovering language concepts through fun learning experiences. Students are actively involved in the learning process, where they are challenged to find solutions or answers through a series of explorations and experiments (Wei, 2022; Özeren & Top, 2023). This process helps improve students' critical and analytical thinking skills in understanding language structures. In addition, this approach allows students to learn according to their pace and learning style, which ultimately improves overall language proficiency (Simamora et al., 2018; Alotaibi, 2020).

The use of Augmented Reality (AR) in language learning has also been proven to be able to strengthen students' motivation to learn. With real-time visualization of concepts, students become more interested and motivated to participate in learning(Yaiche, 2021). This motivating factor plays an important role in improving language skills, as students are more eager to practice and apply the knowledge they have acquired. In addition, AR also allows for the provision of quick and interactive feedback, so students can immediately correct mistakes and improve their understanding(Wibowo, 2023; Myint et al., 2023); Nusantari et al., 2021). The effect of AR on language skills also includes improved listening and speaking skills. Through AR-based simulations, students can practice listening and speaking skills in a more

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realistic context. For example, AR can simulate everyday communication situations that force students to hear, understand, and respond in the target language (Jibril & Çakir, 2023). This helps students develop confidence in speaking, as well as improve their listening comprehension skills through more authentic experiences

Furthermore, the improvement in reading and writing skills was also seen in students who learned with the Augmented Reality-based Discovery Learning model. AR-based discovery learning models are able to display text, images, and animations that help students understand the context and meaning of the text they read (Dina & Ikhsan, 2019; Nurdin & Hafidzi, 2023). In the context of writing skills, AR can help students visualize the structure of sentences or paragraphs, as well as provide examples of the appropriate use of language in various situations. It helps students improve their writing skills more effectively.

Conclusion

From the results of this study, it can be concluded that the augmented reality-based discovery learning model has a significant influence on students' language ability with a value of d = 1,029 in the high effect size category. This finding has a positive influence on teachers in applying this model to encourage students' language skills in learning Indonesian. Research contributes to the world of education in Indonesia and future researchers. This research provides important insights for educators and curriculum developers regarding the effectiveness of augmented reality (AR)-based learning models combined with discovery learning to improve students' language skills. The implementation of this model can encourage students to be more active in the learning process through exploration and in-depth interaction with visual-based materials and AR technology. Thus, educators can use this approach to create more engaging and meaningful learning experiences, especially in language teaching that requires active student involvement to improve reading, speaking, listening, and writing skills. AR technology provides an immersive and interactive learning experience, making it easier for students to understand the material through independent exploration supported by concrete visualizations. Based on these findings, it is recommended that schools integrate the AR-based Discovery Learning model into language learning by providing adequate technology devices, training for teachers to design AR-based learning, and developing interactive modules that suit the needs of students. The application of this model is expected not only to improve learning outcomes, but also to prepare students to face the challenges of the digital era more adaptively and creatively.

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