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Augmented Reality Technology in Language Learning: A Meta-Analysis of Experimental Studies (2015–2025)

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Abstract. This meta-analysis systematically evaluated experimental and quasi-experimental research examining the impact of augmented reality (AR) technology on language learning between 2015 and 2025. In this study, journal articles were searched in three electronic databases: Web of Science Core Collection, Scopus, and ERIC. The 47 studies included in the meta-analysis and an effect size of 83 involving 2450 participants showed that AR-assisted language teaching had an overall high level of impact (g = 1.227). This finding indicates that AR applications significantly support the development of language skills. Moderator analysis revealed that language type (L1/L2), target language, and intervention duration significantly affected the effect sizes. AR was found to have stronger results in second language (L2) learning and increased the effectiveness of long-term interventions. On the other hand, no significant difference was found in moderators of different education levels and the type of device used (mobile/computer). The results obtained show that AR improves learner performance by providing interactive, contextual, and multisensory learning experiences in language teaching. Therefore, it can be stated that AR-supported activities have more pedagogical potential, especially in foreign language teaching and long-term instructional designs.

Keywords: augmented reality; language learning; meta-analysis; technology; technology-enhanced language learning

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1. Introduction and Background

Rapid developments in information and communication technologies have radically transformed education processes and enabled learning to have a flexible structure independent of place and time. Electronic communication tools, internet-based applications, mobile devices, and online learning environments have become basic components of educational activities today; this has brought about a significant paradigm shift from the traditional classroom-centered approach to technology-assisted learning (Bećirović et al., 2021). This change has also been reflected in the language education process (Palacious Hidalgo, 2020).

In literature, the use of technology in the language education process is addressed within the framework of computer-assisted language learning (CALL), mobile-assisted language learning, and technology-assisted language learning approaches. In addition to the numerous technologies examined (Lim & Aryadoust, 2021; Zhang & Zou, 2022a), it has been revealed that these approaches are perceived positively by students, increase students' motivation, participation in the lesson, and self-confidence, make the learning process more permanent and effective, and have significant effects on language learning (Asllani & Paçarizi, 2021; Elaish et al., 2019; Gillespie, 2020; Shadiev & Wang, 2022; Wei, 2022).

Especially in the context of language teaching, the integration of technology into teaching processes has significantly contributed to the development of basic language skills such as phonetics, vocabulary, grammar, reading, writing, listening, and speaking (Shadiev & Yang, 2020; Tseng, 2019; Zhang & Zou, 2022b). In this context, it is stated that the range of digital technologies that students routinely use has expanded considerably in this period, when the use of technology in education is rapidly advancing (Edwards et al., 2018; Yuen et al., 2011). Augmented reality (AR) is one of the new digital technologies that has recently come to the fore, especially due to its functionality in education (Hassan et al., 2021).

Augmented reality (AR) combines the real world and virtual images by allowing simultaneous interaction between them (Azuma, 1997; Klopfer & Sheldon, 2010). This technology entered the education field in the early 2000s, becoming a more visible research area in language teaching, especially with the widespread use of mobile devices (Zhang, 2018). Augmented reality (AR) applications have been used most frequently in language learning for vocabulary teaching, providing learners with the opportunity to more quickly grasp target words through concrete audiovisual stimuli (Parmaxi & Demetriou, 2020).

Augmented reality (AR) technologies have diversified over time to contribute to the development of other language skills such as speaking, listening, reading, and writing (Ghanizadeh et al., 2015; Liu, 2009; Qaddoura et al., 2026; Shadiev & Yang, 2020; Şimşek & Direkçi, 2023; Wedyan et al., 2022; Zhang & Zou, 2022b). However, AR applications are also used at different levels of education. In fact, a wide range of students, from preschool children to university students, use AR applications, and this technology is considered adaptable across age groups (Klopfer & Squire, 2008; Shadiev et al., 2017; Şimşek, 2024a). The literature reveals that AR applications increase students' motivation and engagement, promote learning in authentic contexts, and provide collaborative learning opportunities (Bacca et al., 2014; Bacca et al., 2018; Di Serio et al., 2013; Fombona et al., 2017; Godwin-Jones, 2016; Liu & Chu, 2010; Phon et al., 2014). Today, while AR applications are widespread, especially in learning English as a foreign language, they are increasingly included in research on teaching other languages (Goksu et al., 2022; Shadiev & Yang, 2020).

Increasing studies of AR applications have revealed that augmented reality enriches the learning experience by increasing students' motivation, engagement, and learning performance (Bacca et al., 2014; Fan et al., 2020; Neo, 2025; Parmaxi & Demetriou, 2020; Pauccar et al., 2025; Safitri et al., 2025). However, technical limitations of AR applications, issues concerning users' familiarity, and integration difficulties in the classroom environment have also been reported in the literature (Akçayır & Akçayır, 2017; Garzón et al., 2019). Bibliometric analyses in the literature show that AR applications are widely used in education, but the effect sizes specific to language learning have not been adequately examined (Cai et al., 2022; Wu et al., 2024).

Studies conducted on a global scale show that AR applications are compatible with contemporary educational approaches such as constructivism, sociocultural theory, and task-based learning in language teaching, emphasizing that this technology offers unique, contextual, and immersive experiences to learners (Godwin-Jones 2016; Parmaxi & Demetriou 2020; Wu 2021). Thus, global research trends reveal that while AR technology holds strong potential in language learning, more meta-analysis and pedagogical integration studies are needed in this field.

When the relevant literature is examined, it is evident that several meta-analytic studies have focused on the effects of AR applications on language teaching (Cai et al., 2022; Wu et al., 2024; Yang & Zang, 2025). The present meta-analysis differs from previous studies in terms of the range of years it covers. As AR technology continues to advance and AR-based language learning applications become increasingly rich in instructional content, these developments may influence the outcomes reported in more recent research.

For this reason, the time span adopted in the current study not only substantially increased the number of primary studies included compared to earlier meta-analyses but also enabled the incorporation of data from the most up-to-date research (Cai et al., 2022; Wu et al., 2024). This, in turn, strengthened the reliability of the findings. Moreover, several of the moderators considered in the present meta-analysis (e.g., language type and device) were not examined in earlier reviews (Yang & Zang, 2025). Consequently, notable differences emerged in the pattern of results across studies.

Augmented reality (AR) applications have been addressed in different dimensions of language education, and various research has been carried out within this framework. However, the findings of the studies carried out do not show homogeneity; they point to different orientations. In fact, while some studies pointed out that AR contributes significantly to the development of reading skills (Bursalı & Yılmaz, 2019; Çetinkaya Özdemir & Akyol, 2021; Danaei et al., 2020; Ebadi & Ashrafabadi, 2022; Liu et al., 2024; Nasongkhla & Sujiva, 2023; Şimşek & Direkçi, 2023; Şimşek, 2024a), in other studies, it was reported that there was no difference between the experimental and control groups (Tobar-Muñoz et al., 2017). A similar situation is seen in studies focusing on listening, writing, speaking skills, and vocabulary teaching with different results being noted (Allagui, 2021; Belda-Medina & Marrahi-Gomez, 2023; Chaidir et al., 2024; Chen et al., 2017; Fitayanti, 2024; Ibrahim et al., 2018; Kelpšienė, 2020; Li, 2022; Li et al., 2023; Liu & Tsai, 2013; Suwancharas, 2016; Uiphanit et al., 2020; Wang, 2017).

In addition, the variation in the effect sizes reported in each study makes the diversity among the findings more visible. However, a wide range of target groups can be observed ranging from preschool children to university students, and this diversity leads to differentiation of basic research results and impact sizes (Belda-Medina & Marrahi-Gomez, 2023; Chen et al., 2017; Fitayanti, 2024; Hsieh & Lee, 2008; Kelpšienė, 2020; Li, 2022; Liu et al., 2024; Suwancharas, 2016; Şimşek & Direkçi, 2023; Şimşek et al., 2025; Şimşek, 2024a; Şimşek, 2024b; Ustun et al., 2022; Yilmaz, 2016).

In addition, variables such as language type (L1/L2), target language, and intervention duration are addressed in different ways in research, increasing the heterogeneity of the results and leading to different effect sizes (Chen et al., 2017; Hsieh & Lee, 2008; Izzaty et al., 2019; Kelpšienė, 2020; Li et al., 2023; Şimşek & Direkçi, 2023; Şimşek et al., 2025; Şimşek, 2024a; Şimşek, 2024b; Uiphanit et al., 2020). This diversity in research findings revealed that the effect sizes were not homogeneous; therefore, it was necessary to consider moderator variables such as language type, target language, target language skills, learner educational level, device, and intervention duration.

Considering the above, this meta-analysis aimed to investigate the impact of AR interventions on learners' language skills from a holistic perspective. In this context, the following two research questions guided this study:
1. What is the overall effectiveness of AR interventions in language learning?
2. How do moderator variables affect the effectiveness of AR interventions in language learning?

2. Methodology
In the present meta-analysis, we followed a rigorous research process to collect, evaluate, and summarize the empirical evidence. We used Comprehensive Meta-Analysis (version 2.2.064) to make the calculations within the scope of the research. We carried out the meta-analysis process through the following steps: identifying potential target studies; developing a codebook based on the conditions and characteristics of the identified studies; calculating the overall effect size for each of the conditions; and testing the effects of potential moderators under each condition. Detailed information about these steps is explained below.

2.1 Search and Retrieval of Studies

In the current research, we searched journal articles in three electronic databases: Web of Science Core Collection, Scopus, and ERIC. These databases have been searched by many researchers in meta-analysis studies (Mohsen et al., 2024; Tsai & Tsai, 2018). The reason we chose these databases is that they have high-quality academic literature (Zhu et al., 2024) and host a large repository (Chang et al., 2022). In this study, we confined the search process to the last 10 years (2015-2025). Augmented reality (AR) applications have been used more widely in recent years, and today they are accessible to everyone through dozens of open-access applications.

In addition, applications include increasingly advanced and interactive features. For this reason, it was thought that situations such as differentiation of AR content, an increase in image quality, or the use of more interactive features could affect the results of the studies. For this reason, studies over 10 years were included in the current meta-analysis. In this research, we first determined keywords for the search. While identifying keywords, we included not only general terms such as "language learning" but also more specific terms such as "writing education" in order to reach more research.

Thus, we conducted a detailed search using the keywords "AR and augmented reality" together with the keywords "language learning, second language, foreign language, language acquisition, English as a foreign language (EFL), writing education, listening education, reading education, speaking education, and vocabulary learning." In addition to this search, we also examined the reference lists of the studies we identified. Each researcher carried out the search process separately. After the search process, we compared the data obtained and moved on to the inclusion and exclusion criteria stage.

2.2 Study Eligibility: Inclusion and Exclusion Criteria

In line with the purpose of the present study, the criteria for inclusion of studies in the meta-analysis were as follows:

1. The focus of the current meta-analysis was on studies conducted to improve students' language skills through AR technology.
2. Studies must have been published between 2015 and 2025.
3. Only experimental studies and quasi-experimental studies were included. Research reviews, case studies, qualitative research, and survey research were excluded. AR-supported language learning should have been done in the experimental group, not the control group.
4. The participants of the studies should be studying at kindergarten, primary school, secondary school, high school, or university level.
5. To increase the compatibility of the experimental results, studies focusing on children with non-normal development were excluded.
6. All relevant articles written in different languages were included to evaluate the results of studies on language teaching in different languages.
7. Studies should report sufficient data to calculate the effect sizes.
8. Only published studies were included.

Based on the criteria listed above, we evaluated the articles after the search procedure. As a result of the evaluation, 47 articles remained that fulfilled the criteria for the meta-analysis. Details of this process are given in Figure 1. As a result of the search, we identified 184 studies. We listed the identified studies and found that some were duplicated in more than one database. We also noticed that some studies adopted qualitative data interpretation. After these were removed, 123 studies remained. Then we screened the titles and abstracts of the remaining studies. At this stage, we found that the control/experimental aspects of some studies were not suitable for our research. In addition, some studies focused on different effects other than AR-supported language learning.

These studies were not included in the analysis. We subjected the full text of the remaining 63 studies to further eligibility screening. We excluded 19 of these studies from the analysis because they did not provide the necessary data to compute effect sizes and did not employ an experimental design. As a result, we included a total of 47 studies in the analysis, including three studies that we added by screening their references. We (two researchers) conducted the investigations together and agreed on all the studies included in the analysis through discussion. The processes of the studies obtained as a result of the literature review procedure are shown in the flow chart in Figure 1.

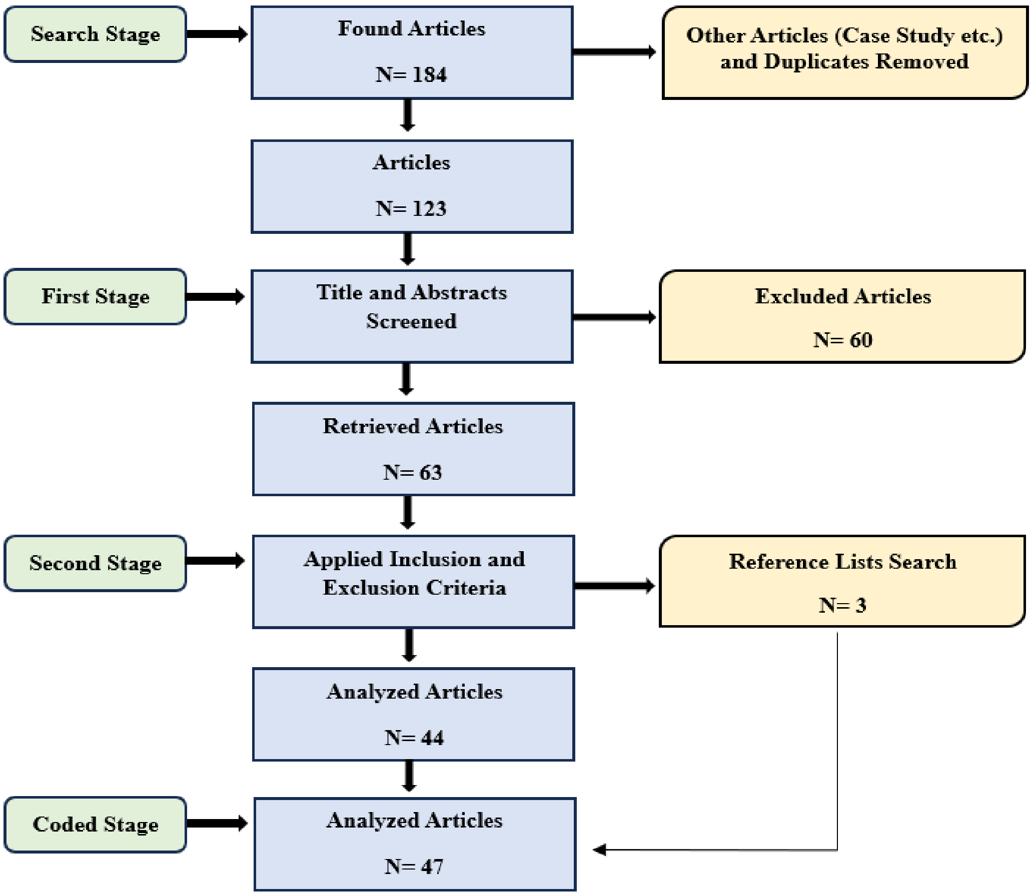

Figure 1: Diagram depicting the literature search and screening procedure

2.3 General Coding Procedure

We coded each study under the following headings:
1. Bibliographic information (title of the study, authors, year of publication)
2. Basic study information (keywords, research method)
3. Characteristics related to the potential moderators (language type, target language, learner educational level, device, invention duration, invention setting)
4. Quantitative information for calculating effect sizes (group sample sizes, means, standard deviations, t-value, Cohen's d value).

We coded each article separately. We met regularly to compare the coding results; the differences that emerged were discussed, and a code was agreed upon. The articles were re-examined to ensure the reliability of the coding when necessary. At the end of the process, all codes were reviewed by us, modified as needed, and 100% agreement was achieved among observers in the final coding.

In the current study, moderators such as language type, target language, target language skills, learner educational level, device, and intervention duration were considered. These moderators were determined by us. Language type was categorized into mother tongue (L1) and second language (L2). There were numerous studies in the meta-analysis that focused on English. In addition, we found that there were studies in languages such as Chinese, Tamil, Japanese, Filipino, and Turkish. Since the number of these studies was relatively small, we combined studies conducted in these languages and classified the target language titles as English and Non-English. We also evaluated the language skills specifically discussed in the studies as a separate moderator.

Studies that employed a joint assessment targeting more than one language skill were grouped under the category "integrated language" (e.g., Chang et al., 2022). We grouped the education levels of the students as preschool, elementary school, secondary school, and college. In addition, in the current study, we determined the intervention duration and device as moderators. Intervention time is a moderator used in many meta-analyses. When meta-analyses are examined, different intervention durations are determined (Lin & Lin, 2019; Thompson & von Gillern, 2020). We classified the articles we examined in the current study according to the data.

2.4 Conducting the Meta-Analysis

This meta-analytic review used Hedges' *g* to analyze the impact of AR applications on students' language learning achievements (Hedges & Olkin, 1985). Hedges' *g* refers to the difference between the two group means in terms of overall standard deviation and is more suitable for samples less than 20 (Cooper, 2010, pp. 163-168), because Cohen's d value may give biased results in studies conducted with small samples. Effect sizes are interpreted in different ways in calculations. According to Cohen (1988), effect sizes of ≥ 0.80 and ≤ 0.20 are considered large and small, respectively, with intermediate values considered moderate.

In the present meta-analysis, the overall effect size was calculated to measure the size of the difference between the groups. In addition, moderator analysis was conducted to compare the average effects of study groups with different characteristics. Furthermore, heterogeneity testing was used to determine the presence and magnitude of heterogeneity among studies. Heterogeneity tests examine whether the observed variance in effect sizes differs from the expected variance due to sampling error (Cooper, 2010, p. 185). This test was run based on Q and I2 results. If Q is significant and I2 exceeds 75, homogeneous effect sizes tend to be violated, necessitating a random effect model and moderator analyses (Borenstein et al., 2009).

Some studies in this study used more than one outcome measure. An effect size of 83 was obtained for the 47 articles included in the meta-analysis. In addition, moderator analysis was conducted to determine whether the common effect size of AR-supported instruction on language teaching differed significantly between language type, target language, language skills, learner educational level, intervention duration, and intervention setting.

3. Results

A summary of the overall effect size information is presented in Table 1. The pooled effect size estimate for AR intervention in language teaching is 1,227 (95%CI [1.065, 1.388], $p < 0.05$). This effect size is considered **large** according to Cohen's (1998) criteria. Therefore, it can be said that the use of AR has a significant impact on language learning. The heterogeneity index for language acquisition is I2 = 88.431%. This result suggests that the effect sizes are more heterogeneous than the expected sampling variability alone. Furthermore, it is shown that the observed effects are likely the main moderators. This supports the need for moderator analysis to test whether the study descriptor explains some of the variability we detected in estimates of effect sizes. The overall effect size and heterogeneity test are given in Table 1, and the forest plot of the effect sizes according to learning achievement is given in Figure 1.

Table 1: Overall effect sizes and the heterogeneity test results

Model	Effect size					Test of heterogeneity			
	N	*k*	*g*	SE	*95% CI*	*Q*	*df*	*p*	I^2
Random	2450	83	1.227	0.082	[1.065, 1.388]	708.776	82	0.000	88.431

*Note. N: number of participants; k: number of independent comparisons; SE: standard error; CI: confidence interval; df: degrees of freedom. *p<.05.*

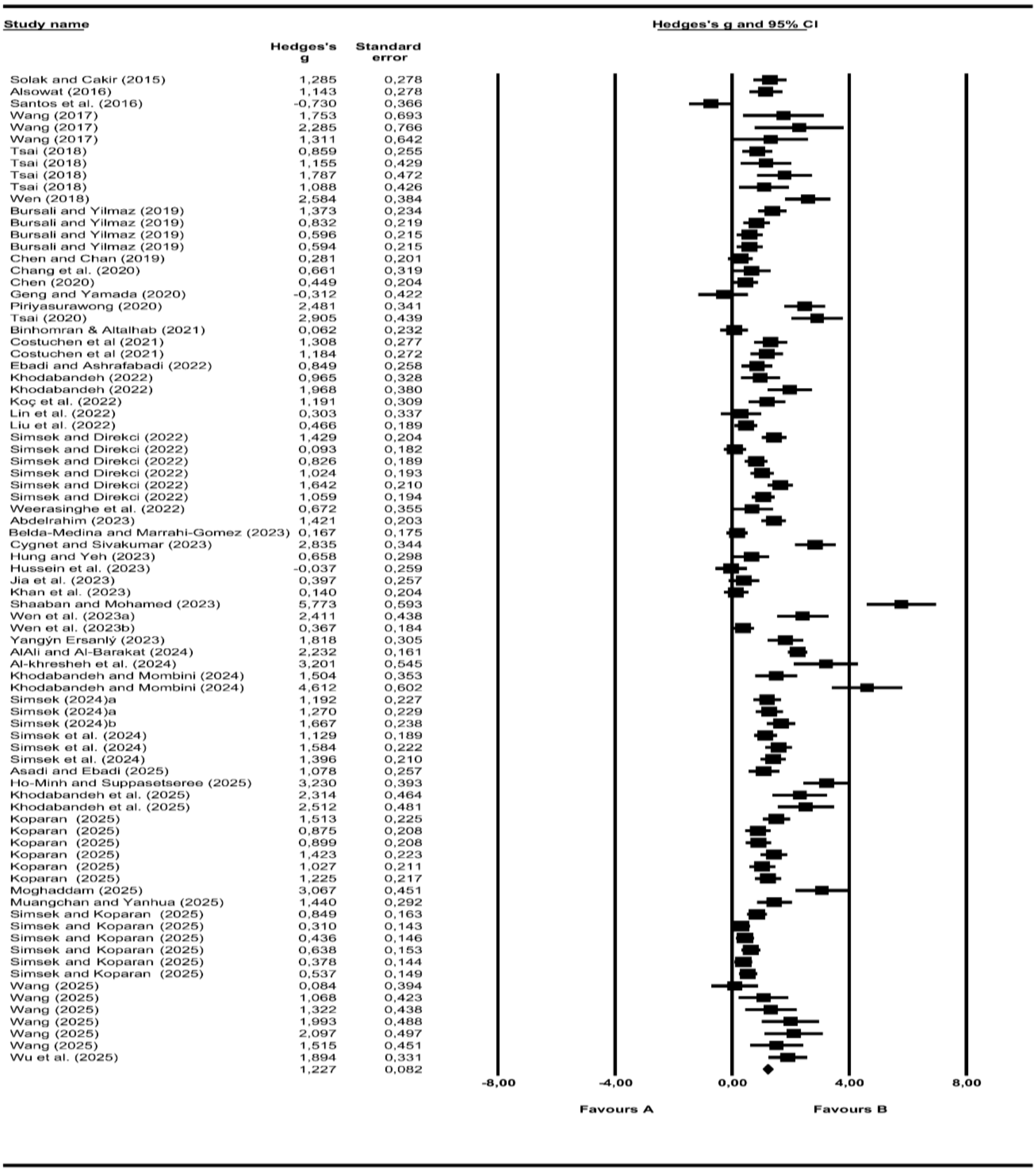

Figure 2: Forest plot of meta-analysis results

3.1 Moderator Analysis

Since homogeneity estimates showed a significant amount of heterogeneity, moderator analyses were performed to determine whether moderator variables could explain the variance detected in the estimates. Levels with k ≤ 1 were excluded from the analysis.

Table 2: Moderator analysis

Moderator variable level	*k*	*g*	SE	95% CI Lower	95% CI Upper	Q	*df*	*P*
Language type						4.212	1	0.040
1. L1	33	1.042*	0.088	0.870	1.124			
2. L2	50	1.379*	0.139	1.107	1.651			

Moderator variable level	*k*	*g*	SE	95% CI Lower	95% CI Upper	Q	*df*	*P*
Target language						5.680	1	0.017
1. English	46	1.429*	0.141	1,152	1.706			
2. Non-English	37	1.026*	0.092	0,845	1,207			
Target language skills						3.740	5	0.587
1. Integrated language	4	1.413*	0.505	0.424	2.402			
2. Listening	3	1.369*	0.145	1.085	1.654			
3. Reading	31	1.120*	0.11	0.903	1.337			
4. Speaking	10	1.695*	0.377	0.955	2.435			
5. Writing	8	1.280*	0.203	0.881	1.679			
6. Vocabulary	27	1.166*	0.181	0.811	1.521			
Learner educational level						5.722	3	0.126
1. Preschool	4	1.094*	0.307	0.493	1.695			
2. Elementary school	18	1.682*	0.268	1.156	2.208			
3. Secondary school	34	1.029*	0.092	0.849	1.210			
4. College	27	1.222*	0.170	0.888	1.555			
Device						0.016	1	0.900
1. Computer-based AR	3	1.295*	0.544	0.228	2.362			
2. Mobile-based AR	80	1.226*	0.084	1.061	1.391			
Intervention duration						9.991	2	0.007
1. Up to 1 day	33	0.981*	0.088	0.808	1.154			
2. Up to 1 month	17	1.129*	0.208	0.721	1.537			
3. Up to half a year	33	1.599*	0.074	1.257	1.941			

*Six moderator variables were used to examine the potential effects of AR intervention on language learning. The findings for these moderators are as follows. *p <.05*

3.2 Language Type

There are two subgroups in the language type variable, L1 (k = 33) and L2 (k = 50). According to the results of the analysis, the impact of AR-enabled applications was higher in the L2 group (g = 1.379, 95% CI [1.107, 1.651]). On the other hand, the effect size was relatively smaller in the L1 group (g = 1.042, 95% CI [0.870, 1.124]). A significant difference was found between language types: Q(1) = 4.212, p = 0.040. This result shows that AR is more effective in teaching foreign languages (L2) compared to a native language.

3.3 Target Language

The target language variable was examined in two subgroups: English (k = 46) and non-English languages (k = 37). According to the results of the analysis, the effect size was found to be higher in studies conducted in the target language of English (g = 1.429, 95% CI [1.152, 1.706]) and lower in studies conducted in non-English languages (g = 1.026, 95% CI [0.845, 1.207]). A significant difference was observed in terms of target language type: Q(1) = 5.680, p = 0.017. This finding reveals that AR technology yields stronger results, especially in the context of English language teaching.

3.4 Target Language Skills

There are six subgroups in the target language skill variable: integrated language (k = 4), listening (k = 3), reading (k = 31), speaking (k = 10), writing (k = 8), and vocabulary (k = 27). The highest effect size was seen in speaking skill (g = 1.695, 95% CI [0.955, 2.435]), followed by integrated language (g = 1.413, 95% CI [0.424, 2.402]) and listening (g = 1.369, 95% CI [1.085, 1.654]). On the other hand, the effect sizes in reading, writing, and vocabulary skills were relatively small. However, the difference between the subgroups is not statistically significant, Q(5) = 3.740, p = 0.587. This suggests that AR applications are similarly effective across all language skills.

3.5 Learner Educational Level

The learner education level variable was examined as four subgroups: preschool (k = 4), elementary school (k = 18), secondary school (k = 34), and college (k = 27). The highest effect was achieved at the elementary school level (g = 1.682, 95% CI [1.156, 2.208]). This was followed by college (g = 1.222, 95% CI [0.888, 1.555]) and preschool (g = 1.094, 95% CI [0.493, 1.695]) groups, respectively. In the secondary school group, the effect size was relatively small (g = 1.029, 95% CI [0.849, 1.210]). However, this difference is not statistically significant, Q(3) = 5.722, p = 0.126. These results show that AR is similarly effective at all levels of education, but its effect is slightly more evident in early age groups.

3.6 Device

The device type moderator was examined in two subgroups: computer-based AR (k = 3) and mobile-based AR (k = 80). Both types of devices showed high effect sizes; *g* = 1.295, 95% CI [0.228, 2.362] for computer-based AR and *g* = 1.226, 95% CI [1.061, 1.391] for mobile-based AR. However, the difference by device type is not significant, Q(1) = 0.016, p = 0.900. This suggests that the type of device used (computer or mobile) does not significantly change the impact of AR on learning.

3.7 Intervention Duration

The intervention duration variable was examined in three subgroups: up to one day (k = 33), up to one month (k = 17), and up to half a year (k = 33). The effect size increased with duration; *g* = 0.981 (95% CI [0.808, 1.154]) for interventions lasting up to one day, *g* = 1.129 (95% CI [0.721, 1.537]) for interventions lasting up to one month, and *g* = 1.599 (95% CI [1.257, 1.941]) for interventions lasting up to six months. The difference between the three groups was statistically significant, Q (2) = 9.991, p = 0.007. This result shows that the effect of AR applications on learning strengthens as the duration of the activity increases.

3.8 Publication Bias

Publication bias indicates the probability that a group of studies selected from published studies on a particular topic are not representative of all studies (Rothstein et al., 2006). If a meta-analysis mostly includes studies with statistically significant results, there is likely publication bias in the analysis (Borenstein et al., 2009). A funnel plot (Figure 3) and Classic Fail-safe N were used to determine the publication bias of the studies and its impact on the results obtained.

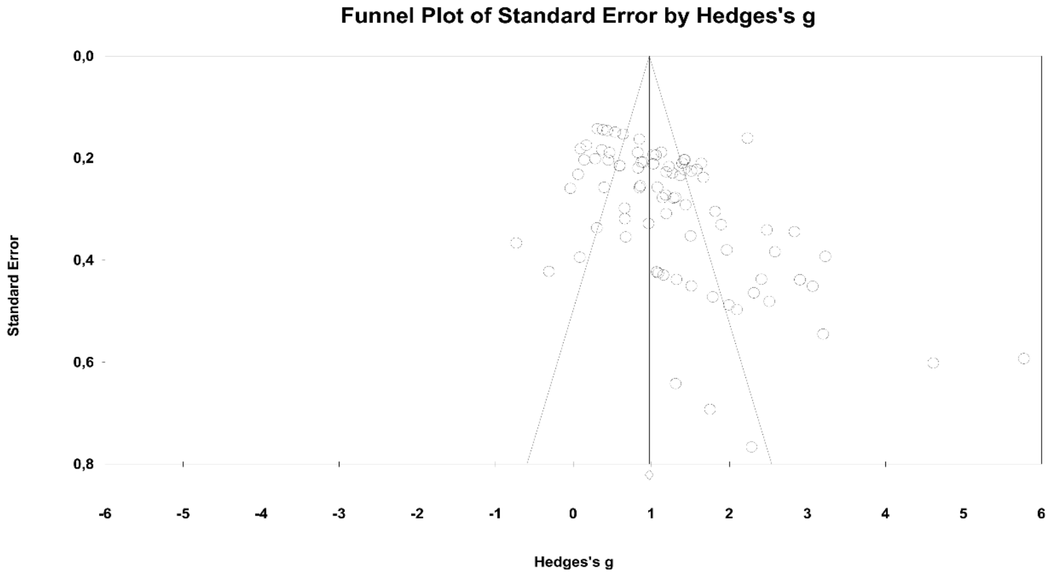

Figure 3: Funnel plot

The potential existence of publication bias was examined via computing with CMA software. The Classic Fail-safe N test was conducted to assess the number of missing studies required to make the effect nonsignificant in the analysis. This test indicated that 2,009 studies would need to be found before the cumulative effect would become trivial.

4. Discussion

The results of this meta-analysis study clearly revealed that AR technology is an effective tool in language teaching. The overall effect size (g = 1.227) was high, indicating that AR had a strong positive impact on language learning outcomes. This finding is consistent with previous research showing that AR supports learners' cognitive and affective processes by offering multisensory, contextual, and interactive learning environments, thereby enhancing learning performance (Alhebaishi & Stone, 2024; Balcha & Ramadhana, 2025; Billinghurst & Duenser, 2012; Chang et al., 2022; Koç& Kanadlı, 2025; Şimşek & Koparan, 2025; Yuen et al., 2011; Wen et al., 2023). In fact, the meta-analysis conducted by Cai et al. (2022)

reported that AR applications had a large effect (g = 0.93) on linguistic acquisition and a small-to-moderate effect (g = 0.42) on learner motivation. The researchers attribute these positive effects to the fact that AR increases learners' cognitive engagement through multimodal presentation and interactive representation. However, the high level of heterogeneity reported in the study (I^2 = 87.05) suggests that effect sizes differ significantly based on variables such as context, participant characteristics, and duration of administration.

This situation reveals that AR applications may not be equally effective across all learning environments and that their effectiveness may vary depending on application conditions. In fact, some studies in the literature show that AR can increase cognitive load, especially in complex tasks (Alessa et al., 2023; Altmeyer et al., 2024; Buchner et al., 2022; Şimşek et al., 2025), or support learning retention in short-term applications to a limited extent (Alkhabra et al., 2023; Alhebaishi & Stone, 2025; Lai & Chang, 2021). These findings point to the necessity of considering variables such as the type of technology used in teaching processes, the level of interaction, pedagogical design, and learner characteristics. Therefore, it is important to systematically consider a range of moderator variables to comprehensively evaluate the effects of AR on learning.

The meta-analysis findings reveal that the type of target language significantly affects learning outcomes in language teaching interventions supported by AR technology. It was determined that the effect size obtained in second language (L2) teaching (g = 1.379) was significantly higher than in first language (L1) teaching (p =.040). This result shows that AR applications make a more substantial contribution to learning a new language. This finding is consistent with theoretical approaches in which L2 learning needs a higher level of conceptual, lexical, and contextual support, and the audiovisual and interactive environments offered by AR facilitate meaning making (Kaplan-Rakowski & Kevin, 2024; Khodabandeh et al., 2025; Weerasinghe et al., 2022; Schorr et al., 2024).

There are several meta-analysis studies in literature examining the effect of technologically assisted learning tools on language acquisition in teaching EFL. For example, Yang and Zhang (2025), in a study on AR applications, reported that AR-supported teaching has significant and positive effects in general education. These findings support our interpretation that AR in L2 teaching offers a systematic pedagogical advantage. Similarly, Cai et al. (2022) suggested that AR-assisted applications significantly improved linguistic performance, and this improvement was positively correlated with motivational gains. Accordingly, AR plays a supportive role not only in cognitive learning outcomes but also in affective processes.

In the current study, the target language variable showed a significant difference in language teaching interventions supported by AR technology. According to the meta-analysis, the effect size (g = 1.429) of the studies conducted in the target language of English was significantly higher than the effect size of the studies conducted in non-English languages (g = 1.026). This difference may be attributed to the fact that AR content for English is both more abundant, more pedagogically developed and can be integrated into classroom teaching processes in a more systematic manner (Christou et al., 2025). Similarly, another meta-analysis focusing on the EFL context reported that AR demonstrates significant and consistent effects in English language teaching (Yang & Zhang, 2025). In line with these, a comprehensive study by Christou et al. (2025) revealed promising examples of AR applications in under-taught languages such as Japanese, Thai, Quechua, and Persian. However, the scarcity of these studies significantly limits the generalizability of the findings. Therefore, the development of AR-based materials in languages other than English, reflecting local cultural context and unique linguistic elements, is considered a basic requirement in the field.

The results of this meta-analysis show that the impact of AR technology on language teaching varies significantly with the duration of the intervention. The increase in the effect size with longer intervention duration (1 day → g = 0.981; 1 month → g = 1.129; 6 months → g = 1.599) indicates that AR applications may be more effective in supporting long-term learning outcomes. Short-term interventions can provide a rapid increase in students' motivation levels, mostly through the "novelty effect" (Cai et al., 2022); however, there is growing evidence that lasting performance gains are amplified by continuous structured AR exposures (Cheung & Slavin, 2013; Chauhan, 2017). On the other hand, in the motivation dimension, although the effects are evident in short-term applications, they are partially reduced in long-term applications at the annual level (Cai et al., 2022). This suggests that the novelty effect may fade over time.

When the results of this meta-analysis were evaluated in terms of target language skills, high effect sizes were observed for speaking (g = 1.695) and listening (g = 1.369). On the other hand, the observed effects on reading, writing, and vocabulary skills were relatively low. Similarly, in a meta-analysis of 44 studies conducted by Sung et al. (2015), mobile-device-assisted language learning provided a significant improvement overall, but the level of effect varied according to the language skill learned. It was also reported that there were higher effects on mixed skills practices and vocabulary/pronunciation areas, and more limited effects on receptive skills such as reading and listening.

However, the current research shows that the effect of AR on language skills is more pronounced, especially in productive and interactional skills. AR presents language in context by activating gestures, facial expressions, spatial cues, and real-life scenarios; thus, it facilitates comprehensible input and meaningful output in speaking and listening processes (Chandel, 2025; Khodabandeh et al., 2025; Mansour et al., 2025). It has also been shown to enhance depth of comprehension and reinforce retention compared to traditional card-based practices through three-dimensional objects and multimedia elements in vocabulary teaching (Chen & Chan, 2019; Ibrahim et al., 2018; Santos et al., 2016). In reading skills, although AR can support comprehension by increasing attention to and interaction with the text, the effects in this area may be more limited depending on the application's pedagogical design (Çetinkaya Özdemir & Akyol, 2021; Ebadi & Ashrafabadi, 2022; Şimşek et al., 2025).

Although the effect of AR applications did not differ significantly by education level, the highest effect size was observed at the primary school level (g = 1.682). This may be because children's play-based and exploratory learning tendencies are compatible with the structure of AR applications (Aydoğdu, 2022; Albayrak & Yılmaz, 2022). In fact, the study conducted by Cai et al. (2022) similarly found that AR provided the highest level of achievement in language learning for primary school students; however, the effect size was reported to be relatively lower at the university level. Christou et al. (2025) pointed out that AR is used for a wide range of learners, from preschool to adult education. However, many studies do not report pedagogical orchestration details (study layout, device sharing, activity duration, etc.), which weakens the visibility of the relationship between design and learning outcomes.

When the effects of AR applications were compared by device type (computer-based and mobile-based), no significant difference was observed (p = 0.900). Both types of devices are highly effective. While mobile devices contribute to the execution of learning processes in a more flexible and location-independent manner thanks to their portability, computer-based applications, on the other hand, allow for the collective examination of three-dimensional AR content with the support of large screens or projections in the classroom environment (Çalışır et al., 2022; Demir & Akpınar, 2018; FitzGerald et al., 2013; Küçük Avcı et al., 2019; Solak & Çakır, 2016). This suggests that the effectiveness of AR depends on pedagogical design and interactivity, rather than on the device.

Overall, the meta-analysis reveals that AR is a pedagogically powerful, effective, and adaptive tool for language teaching. It is seen that the effect is especially pronounced in speaking and listening skills in the second language context, and meaningful learning gains are achieved thanks to 3D multimedia and contextual cues (Alshumaimeri & Mazher, 2023; Garzón & Acevedo, 2019; Ibrahim et al., 2021; Koparan, 2025; Santos et al., 2016; Yang & Zhang, 2025; Wu et al., 2024). Current studies show that task typologies (information visualization, translation and transformation tasks, location-based exploration, avatar communication, segmental generation, AR product design) and classroom orchestration strategies directly affect design success in AR applications. In this regard, the implementation of AR applications in language education should be based on a holistic pedagogical approach that emphasizes sustained, skill-based, and contextual learning (Garzón et al., 2020; Khodabandeh et al., 2025; Ngo, 2025; Özçelik et al., 2022; Ulutaş, 2025).

5. Conclusion

This meta-analysis systematically reviewed experimental and quasi-experimental studies conducted between 2015 and 2025 that examined the effects of AR technology on language learning. A total of 47 studies were included in the meta-analysis, yielding 83 effect sizes derived from data from 2,450 participants. The time span covered, the number of studies included, and the consideration of multiple moderators (e.g., language type, device) substantially distinguish the findings of this study from those in the previous literature. The meta-analysis revealed a general effect size of g = 1.227 (95% CI [1.065, 1.388]), concluding that

AR is a highly effective tool in language learning. The high level of heterogeneity indicates that this effect varies across different studies. To determine the source of this variation, a moderator analysis was conducted. The meta-analysis showed that AR is more effective in second language teaching. Therefore, AR offers significant advantages in learning a new language. Furthermore, the results of the analysis regarding the target language moderator show relatively higher effect sizes in studies focused on English. This result can be attributed to the more widespread use of digital tools developed for English language teaching and the global position of this language. The analysis results show no significant difference in the target language skill moderator.

However, AR applications have a higher impact on oral communication (listening and speaking) skills. In addition, the educational level of the group that received language instruction through AR did not show a significant difference. However, when the effect sizes were examined, it was found that the highest effect was at the primary school level, followed by the preschool period. Another factor included in the analysis as a moderator was the type of device used in the AR teaching process. The analysis results showed that the effect of AR was not dependent on the device type. This result indicates that AR has flexible usage. According to the results of the intervention duration variable, long-term use of AR in the teaching process has the greatest effect. Therefore, extending AR-based teaching applications over a longer period can increase teaching effectiveness. When the results are evaluated generally, it can be said that AR has a strong effect on language learning outcomes.

6. Limitations and Recommendations

The findings of this study may stimulate further research to gain a deeper understanding of the potential of leveraging AR technology to enhance learners' language skills. However, the current research is limited to studies published between 2015 and 2025. In addition, only studies in the specified indices were included in the meta-analysis. Therefore, it should be noted that the results may show differences in meta-analyses if different studies are included. When the studies included in the current meta-analysis were examined generally, we determined that they focused more on the impact of AR on L2. In addition, the number of studies on English is quite high.

Therefore, it can be recommended to conduct new studies on AR in different languages and in the context of L1. Studies on the effect of AR on the development of listening, writing, and speaking skills are very limited. In this respect, it may be recommended to conduct research that highlights these skills. In addition, when the sample groups of the studies were examined, it was noted that the studies conducted with preschool children were quite limited. Considering the results of the relevant studies, it would be useful to conduct current AR research on preschool children. Thus, clearer results can be obtained on the effect of AR at different learning levels. It should also be noted that broad moderator categories (such as "integrated language" or wide duration ranges) may conceal important variation. Finally, considering the impact of long-term interventions through AR, it can be recommended that instructors plan for long-term integration of this technology into their course content. Despite these limitations, the findings of the present study demonstrate the positive contribution of AR interventions to language teaching. In this regard, it is recommended that AR applications be incorporated into teacher education programs, that teacher-guided AR implementations be systematically examined, and pilot studies be conducted to explore the integration of AR into curricula.

Conflict of Interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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