

## THE EFFECTIVENESS OF INTERACTIVE LEARNING APPLICATIONS IN ENHANCING STUDENTS' ARABIC VOCABULARY MASTERY: A META-ANALYSIS

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### Abstract :

This study adopts a quantitative research approach using a meta-analytic method to examine the effectiveness of interactive learning applications in improving students' Arabic vocabulary mastery. The independent variable is the use of interactive learning applications, while the dependent variable is students' Arabic vocabulary acquisition. Educational level, class size, and application type were analyzed as moderator variables. The data set consisted of 25 experimental studies published between 2019 and 2025 that met the predetermined inclusion criteria. Data analysis was conducted using Comprehensive Meta-Analysis (CMA) software to calculate the pooled effect size and examine moderator effects. The results indicate a combined effect size of 0.86, categorized as large, with effect sizes ranging from 0.245 to 2.772, most of which fall within the large to very large categories. Moderator analysis revealed no statistically significant differences based on educational level, class size, or application type, although higher effectiveness was observed at the junior and senior high school levels and in gamification-based applications. These findings demonstrate that interactive learning applications have a strong and significant impact on Arabic vocabulary acquisition and provide empirical support for their integration into more effective Arabic language learning strategies.

**Keyword:** *Meta-analysis, interactive learning applications, Arabic vocabulary.*

### Abstrak :

Penelitian ini menggunakan pendekatan kuantitatif dengan metode meta-analisis untuk mengkaji efektivitas penggunaan aplikasi pembelajaran interaktif dalam meningkatkan penguasaan kosakata bahasa Arab siswa. Variabel independen dalam penelitian ini adalah penggunaan aplikasi pembelajaran interaktif, sedangkan variabel dependen adalah penguasaan kosakata bahasa Arab siswa. Tingkat pendidikan, ukuran kelas, dan jenis aplikasi dianalisis sebagai variabel moderator. Data penelitian terdiri atas 25 studi eksperimen yang dipublikasikan antara tahun 2019 hingga 2025 dan memenuhi kriteria inklusi yang telah ditetapkan. Analisis data dilakukan menggunakan perangkat lunak Comprehensive Meta-Analysis (CMA) untuk menghitung ukuran efek gabungan serta menganalisis pengaruh variabel moderator. Hasil penelitian menunjukkan ukuran efek gabungan sebesar 0,86 yang termasuk dalam kategori besar, dengan rentang ukuran efek antara 0,245 hingga 2,772, yang sebagian besar berada pada kategori besar hingga sangat besar. Analisis moderator menunjukkan tidak adanya perbedaan yang signifikan secara statistik berdasarkan tingkat pendidikan, ukuran kelas, maupun jenis aplikasi, meskipun efektivitas yang lebih tinggi ditemukan pada jenjang sekolah menengah pertama dan sekolah menengah atas serta pada aplikasi berbasis gamifikasi. Temuan ini menunjukkan bahwa aplikasi pembelajaran interaktif memiliki dampak yang kuat dan signifikan terhadap penguasaan kosakata bahasa Arab serta memberikan dukungan empiris bagi integrasinya dalam strategi pembelajaran bahasa Arab yang lebih efektif.

**Kata kunci:** *: meta-analisis, aplikasi pembelajaran interaktif, kosakata bahasa Arab.*

## مستخلص البحث :

تنمية إتقان مفردات اللغة العربية لدى الطلاب. ويتمثل المتغير المستقل في هذا البحث في استخدام تطبيقات التعليم التفاعلي، بينما يتمثل المتغير التابع في إتقان مفردات اللغة العربية لدى الطلاب. أما المتغيرات الوسيطة (المعديلة) فتشمل المستوى التعليمي، وسعة الصف، ونوع التطبيق المستخدم. وت تكون بيانات البحث من ٢٥ دراسة تجريبية نُشرت خلال الفترة من عام ٢٠١٩ إلى عام ٢٠٢٥، واستوفت معايير الاشتغال التي تم تحديدها مسبقاً. وقد تم تحليل البيانات باستخدام برنامج Comprehensive Meta-Analysis (CMA) لحساب حجم الأثر المجمع، إضافةً إلى تحليل تأثير المتغيرات الوسيطة. وأظهرت نتائج البحث أن قيمة حجم الأثر المجمع بلغت ٠,٢٤٥، و ٢,٧٧٢، وكانت غالبية هذه القيم ضمن الفئة الكبيرة، حيث تراوحت قيم أحجام الأثر بين ٠,٠٨٦، وهي قيمة تصنف ضمن الفئة الكبيرة، كما بين تحليل المتغيرات الوسيطة عدم وجود فروق ذات دلالة إحصائية تُعزى إلى المستوى التعليمي، أو سعة الصف، أو نوع التطبيق، على الرغم من ملاحظة فاعلية أعلى في مرحلتي التعليم المتوسط والتعليم الثانوي، وكذلك في تطبيقات التعليم التفاعلي القائمة على التعلم. وتشير هذه النتائج إلى أن استخدام تطبيقات التعليم التفاعلي يُحدث أثراً قوياً ودالاً إحصائياً في تحسين إتقان مفردات اللغة العربية لدى الطلاب، ويؤفر دعماً تجريبياً لدمجها في استراتيجيات تعليم اللغة العربية بصورة أكثر فاعلية.

**الكلمات المفتاحية:** التحليل التلوبي، وتطبيقات التعليم التفاعلي، والمفردات العربية.

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## INTRODUCTION

The Arabic language plays an important role in shaping language skills, especially for Muslims, as it is the language of the Qur'an and is widely used in religious and educational contexts. In addition, international recognition of the status of the Arabic language has grown stronger since UNESCO designated December 18 as World Arabic Language Day, affirming that this language not only serves as a means of communication, but also as an important tool for deepening religious knowledge.<sup>1</sup> Arabic language learning emphasizes not only understanding grammatical structures such as nahwu and sharaf, but also mastery of vocabulary, which is the main foundation for understanding texts, constructing sentences, and communicating effectively.<sup>2</sup>

Arabic vocabulary learning has tended to be dominated by conventional teacher-centered approaches, such as lectures and textbooks, which often fail to stimulate students' interest in learning.<sup>3</sup> Additionally, a number of Islamic educational establishments teach Arabic, and effective learning requires good communication and interaction through the application of appropriate

<sup>1</sup> B Arifah et al., "Bahasa, Pendidikan, Dan Agama Dalam Pembelajaran Bahasa Arab," *Lahjah Arabiyah: Jurnal Bahasa Arab Dan Pendidikan Bahasa Arab* 6, no. 1 (2025): 38–54.

<sup>2</sup> R M Naser, "Meningkatkan Pembelajaran Bahasa Arab Siswa Melalui Aplikasi Audio Visual Dalam Manajemen Pendidikan Islam Tinjauan (Studi Di Madrasah Aliyah Negeri 2 Kota Palu)," 2022.

<sup>3</sup> Nur Laili Hidayat, "Analisis Pembuatan Media Visual Untuk Pembelajaran Mufradat Oleh Mahasiswa Magister Pendidikan Bahasa Arab UIN Sunan Kalijaga Yogyakarta," *Jurnal* ... 2, no. 2 (2021): 90–102.

methods, media, and teaching materials.<sup>4</sup> This situation has resulted in low motivation and involvement among students in developing their language skills comprehensively. With the development of technology, interactive learning applications have begun to be implemented as a more participatory alternative, with features such as quizzes, educational games, audio-visuals, and direct feedback. Popular applications that have been used include Tobo Arabic, Duolingo, Quizizz, Quizlet, and Educandy, which offer a game-based and adaptive repetition approach to improve student vocabulary retention.

Several experimental studies have evaluated the effectiveness of interactive learning applications. Hakim et al. found a significant increase in vocabulary mastery through interactive multi-applications compared to the control class (post-test: 51.83 vs. 41.25;  $p = 0.004$ ).<sup>5</sup> Similar findings were also reported by Irfan, who demonstrated that the use of the *Fun Easy Learn* application was effective in improving students' vocabulary mastery. However, other studies have reported contradictory findings.<sup>6</sup> Miftahul Jannah revealed that the use of audiovisual applications, such as YouTube, resulted in lower post-test scores compared to conventional instructional methods.<sup>7</sup> These contrasting results indicate that the effectiveness of interactive learning applications remains inconclusive, particularly when findings are derived from individual experimental studies.<sup>8</sup>

The inconsistency of previous findings highlights a clear research gap, as most existing studies rely on single-sample experimental designs that are limited in explaining variations in effect size across different contexts. Non-meta-analytic studies are constrained by differences in sample characteristics, educational levels, class capacity, and application types, making it difficult to draw generalized conclusions or identify factors that influence learning outcomes. As a result, prior research provides fragmented evidence and lacks a comprehensive explanation of why interactive learning applications produce varying results.<sup>9</sup>

Meta-analysis offers a systematic way to resolve these variations by combining findings from multiple studies. Through this technique, the effect size can be estimated with greater precision, stability, and broader applicability.<sup>10</sup> The effectiveness of this approach has been demonstrated in educational technology research, where meta-analyses consistently report positive effects of technology-based applications on learning outcomes.<sup>11</sup> The success of this method can be seen in the research by Azkia et al. in the field of mathematics, which found a positive effect of the use of technology applications on learning outcomes (effect size = 1.115).<sup>12</sup> A similar approach has great potential for evaluating Arabic vocabulary mastery.

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<sup>4</sup> Hurriyatus Sa'adiyah, "Strategi Penerapan Al-Lu'bah Al-Lugawiyah Dalam Pembelajaran Mufradat," *Lahjah Arabiyah: Jurnal Bahasa Arab Dan Pendidikan Bahasa Arab* 5, no. 1 (2024): 107–19.

<sup>5</sup> M L Hakim, M Akhyar, and A Asrowi, "Efektivitas Multiaplikasi Interaktif Untuk Meningkatkan Penguasaan Kosakata Mata Pelajaran Bahasa Arab Siswa Kelas VIII SMP IT Al-Huda Wonogiri," in *Prosiding Seminar Nasional*, 2019.

<sup>6</sup> F H Irfan, "Efektivitas Penggunaan Aplikasi Fun Easy Learn Bahasa Arab Berbasis Mobile Learning Untuk Penguasaan Kosakata (Mufradat) Di UKM EASA IAIN Purwokerto" (2021).

<sup>7</sup> M Jannah, "Efektivitas Aplikasi Audiovisual Terhadap Kemampuan Penguasaan Mufradat Siswa Di SMA Muhammadiyah 5 Yogyakarta" (Universitas Islam Negeri Sunan Kalijaga Yogyakarta, 2022).

<sup>8</sup> Rod Ellis, *Understanding Second Language Acquisition 2nd Edition* (Oxford university press, 2015).

<sup>9</sup> David Gough, James Thomas, and Sandy Oliver, "An Introduction to Systematic Reviews," 2017.

<sup>10</sup> H Retnawati et al., *Pengantar Analisis Meta* (Yogyakarta: Parama Publishing, 2018).

<sup>11</sup> Laura A Schindler et al., "Computer-Based Technology and Student Engagement: A Critical Review of the Literature," *International Journal of Educational Technology in Higher Education* 14, no. 1 (2017): 25.

<sup>12</sup> N F Azkia, A Muin, and A Dimyati, "Pengaruh Aplikasi Pembelajaran Digital Terhadap Hasil Belajar Matematika: Meta Analisis," *JPMI (Jurnal Pembelajaran Matematika Inovatif)* 6, no. 5 (2023): 1873–86.

To address this gap, a systematic synthesis of prior findings is needed to support policy formulation and evidence-based decision making.<sup>13</sup> Accordingly, a meta-analysis approach is essential, as it integrates major studies within the same domain and facilitates quantitative interpretation of empirical results, leading to more robust and consistent conclusions.<sup>14</sup> Based on these considerations, this study aims to conduct a quantitative meta-analysis of experimental research examining the effectiveness of interactive learning applications on students' Arabic vocabulary mastery. Specifically, it seeks to estimate the overall effect size and examine the influence of moderator variables, including educational level, class size, and application type. The findings are expected to provide robust empirical evidence to support evidence-based instructional decision making in Arabic vocabulary learning.

## RESEARCH METHODS

The present study employed a meta-analytic approach to investigate the effectiveness of interactive learning applications in supporting Arabic vocabulary acquisition. Meta-analysis enables a comprehensive evaluation by statistically synthesizing quantitative data from independent studies addressing similar research questions.<sup>15</sup>

The inclusion criteria for this meta-analysis were as follows: (1) empirical studies published between 2019 and 2025, including journal articles, master's theses, and doctoral dissertations; (2) studies employing experimental or quasi-experimental research designs with clearly defined experimental and control groups; (3) research examining the effectiveness of interactive learning applications on students' Arabic vocabulary acquisition across different educational levels; and (4) studies reporting sufficient statistical information for effect size calculation, such as mean scores, standard deviations, and sample sizes for each group.

Data were extracted using a data coding sheet to ensure consistency and reliability in recording study characteristics and statistical information, as recommended in meta-analytic procedures.<sup>16</sup> The coded variables included application type, educational level, class size, and relevant quantitative data. Literature searches were conducted using Google Scholar and Google Search because of their wide coverage of academic publications. The search employed combinations of the keywords "*interactive learning application*" OR "*aplikasi pembelajaran interaktif*" AND "*experiment*" OR "*experimental*." The study selection process followed the PRISMA framework, including identification, screening, eligibility, and inclusion stages<sup>17</sup>, the number of articles at each stage was recorded as follows:

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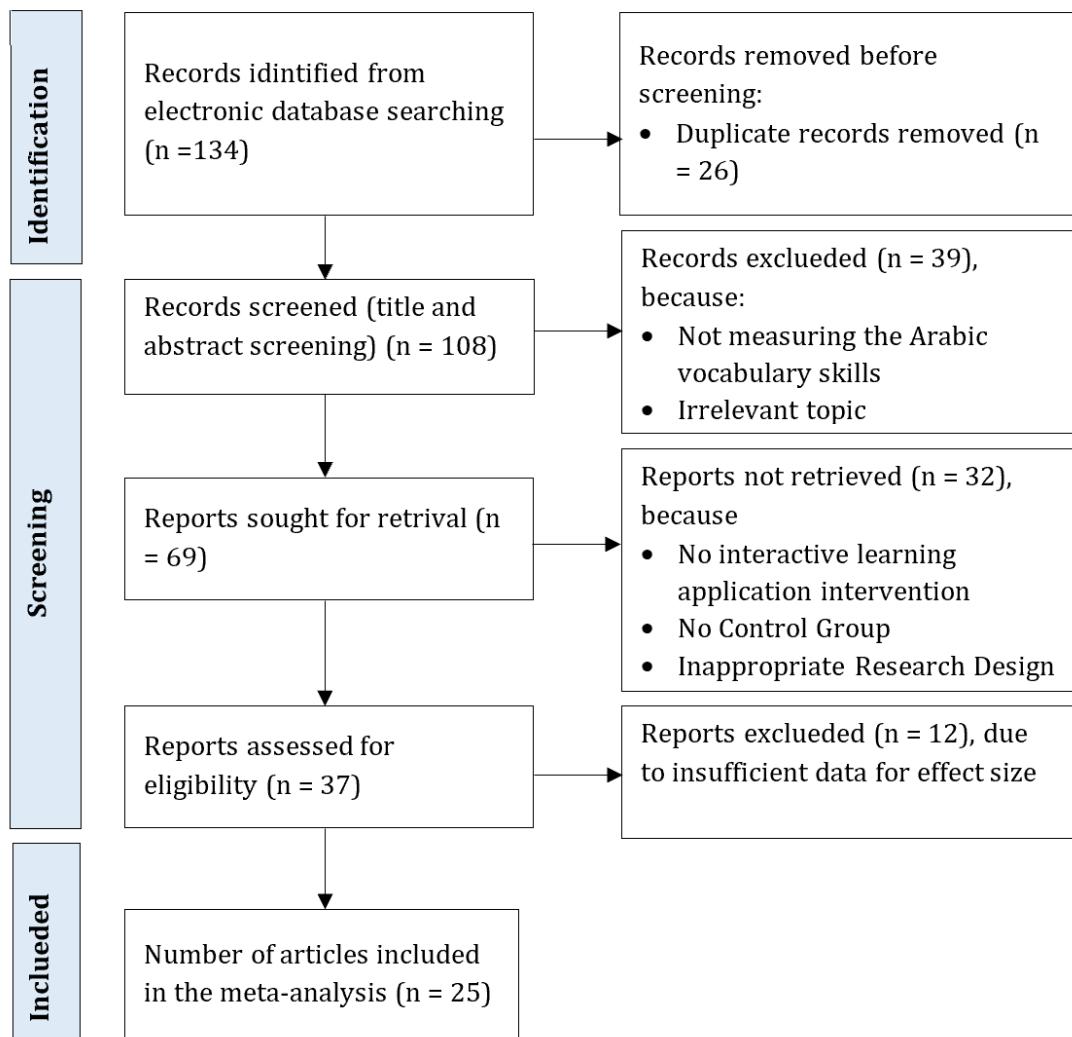
<sup>13</sup> Andy P Siddaway, Alex M Wood, and Larry V Hedges, "How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses," *Annual Review of Psychology* 70, no. 1 (2019): 747–70.

<sup>14</sup> Steve Higgins et al., "The Sutton Trust-Education Endowment Foundation Teaching and Learning Toolkit," 2013.

<sup>15</sup> Gene V Glass, "Primary, Secondary, and Meta-Analysis of Research," *Educational Researcher* 5, no. 10 (1976): 3–8.

<sup>16</sup> Harris Cooper, *Research Synthesis and Meta-Analysis: A Step-by-Step Approach*, vol. 2 (Sage publications, 2015).

<sup>17</sup> Matthew J Page et al., "The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews," *Bmj* 372 (2021).



**Figure 1: Literature screening followed the PRISMA guidelines**

Data analysis was performed using Comprehensive Meta-Analysis (CMA) software version 3, a widely used tool for meta-analytic research.<sup>18</sup> Effect sizes were calculated using Hedges'  $g$ , which provides unbiased estimates and is particularly appropriate for meta-analyses involving small sample sizes.<sup>19</sup> The interpretation of effect size magnitude followed Cohen's classification.<sup>20</sup>

The choice of statistical model was determined based on heterogeneity testing. A random-effects model was applied when heterogeneity was present, whereas a fixed-effect model was used when effect sizes were homogeneous. To enhance the robustness of the findings, publication bias was assessed using multiple methods, including the Fail-Safe N (FSN) method<sup>21</sup> and funnel plot analysis, which is commonly recommended in meta-analytic research to visually detect potential publication bias.<sup>22</sup>

<sup>18</sup> Michael Borenstein et al., *Introduction to Meta-Analysis* (John Wiley & Sons, 2021).

<sup>19</sup> Larry V Hedges and Ingram Olkin, *Statistical Methods for Meta-Analysis* (Academic Press, 2014).

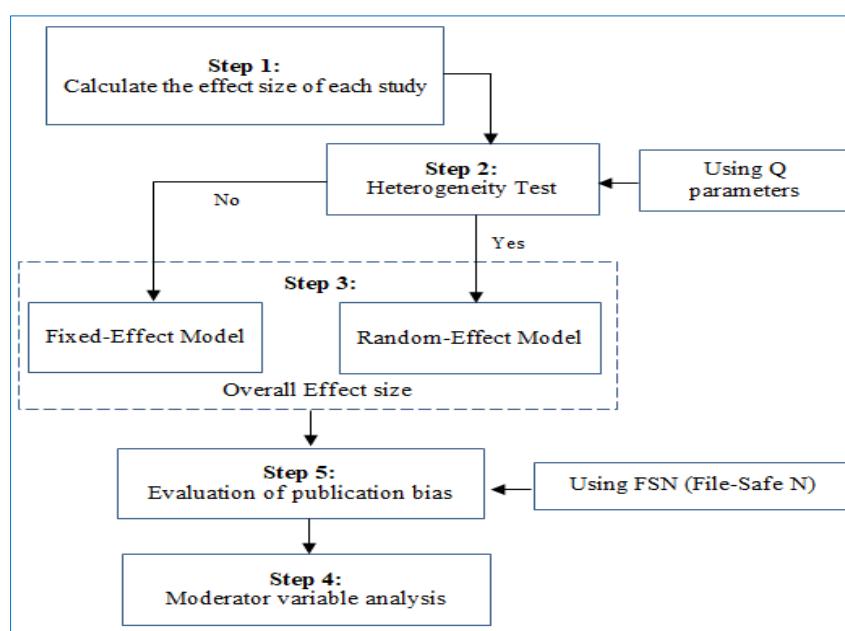
<sup>20</sup> L Cohen, L Manion, and K Morrison, *Research Methods in Education*, ed. 8th (Routledge, 2018).

<sup>21</sup> Hannah R Rothstein, Alexander J Sutton, and Michael Borenstein, "Publication Bias in Meta-analysis," *Publication Bias in Meta-analysis: Prevention, Assessment and Adjustments*, 2005, 1–7.

<sup>22</sup> Matthias Egger et al., "Bias in Meta-Analysis Detected by a Simple, Graphical Test," *BmJ* 315, no. 7109 (1997): 629–34.

**Table 1. Effect size classification**

Description	Effect size
Ignored	$0.00 < \text{Effect size} \leq 0.19$
Small	$0.19 < \text{Effect size} \leq 0.49$
Medium	$0.49 < \text{Effect size} \leq 0.79$
Large	$0.79 < \text{Effect size} \leq 1.29$
Very large	$\text{Effect size} > 1.29$



**Figure 2: Data analysis with CMA software**

## RESULTS AND DISCUSSION

### Research Overview

Based on the established inclusion criteria, a total of 25 studies were identified for analysis. Table 2 provides a synthesized summary of the studies included in the meta-analysis, presenting the study titles and publication years, along with statistical information from both the experimental and control groups, including mean values, standard deviations (SD), and sample sizes (N). Table 3 outlines descriptive information related to the moderator variables examined in this study.

**Table 2. Findings derived from the data extraction process**

No	Author	Nc	Ne	t.count/ sig
1	Al-Gifari et al., (2025)	20	20	0.001
2	Yazid et al.,(2023)	26	26	0.000
3	Zakiyah et al., (2024)	30	31	0.001
4	Kadir (2025)	39	39	0.000
5	Fauziah et al., (2024)	31	31	0.010
6	Noor (2025)	29	29	0.000
7	Yuspa & Bahsin (2025)	17	17	0.001
8	Siregar (2023)	22	22	0.000
9	Utami (2023)	31	31	0.000
10	Adira et al., 2024	26	23	0.050
11	Nurisman et al., (2024)	36	36	0.000
12	Amaliya (2024)	17	17	0.050
13	Asura et al., (2024)	19	14	0.000
14	Ela (2024)	18	18	0.367
15	Tilawati (2023)	31	32	0.001
16	Muthoharoh & Abidin (2023)	22	22	0.000
17	Indriyana et al., (2024)	18	19	0.001
18	Rahayu et al. (2024)	27	28	0.018
19	Mustamin et al., (2019)	28	28	0.357
20	Nabilla (2021)	21	19	2.011
21	Rabbani (2023)	32	32	2.079
22	Zulkifli et al., (2019)	25	25	5.490
23	Khan & Muchtar( 2025)	14	14	7.554
24	Zidni (2022)	30	30	4.273
25	Qadri (2023)	21	19	2.837

**Table 3. Descriptive statistics of included studies**

Moderator Variable	Identified Categories	Counts
Application Type	Gamification Application	9 (12.00%)
	Mobile Application	9 (12.00%)
	Web-based Application	7 (9.33%)
Education Level	SD/MIN	6 (8.00%)
	SMP/MTs	11 (14.67%)
	SMA/SMK	8 (10.67%)
Class Capacity	Large (> 30)	18 (24.00%)
	Small (≤ 30)	7 (9.33%)

## Main Analysis

The effect sizes of the included studies were computed using Comprehensive Meta-Analysis (CMA) software version 3, and the results are visually summarized through a forest plot presented in (Figure 3). Within the forest plot, the central vertical line denotes the combined (pooled) effect size, while the horizontal lines associated with each study illustrate the 95% confidence intervals, indicating the degree of estimation uncertainty. Each plotted marker represents the effect size estimate derived from an individual study.

A study is considered statistically non-significant when its confidence interval overlaps the vertical reference line. In contrast, studies whose confidence intervals do not intersect the vertical line demonstrate statistically significant effects. The length of the horizontal line corresponds to the sample size, with longer lines reflecting larger study samples. Furthermore, the size of each marker indicates the relative weight assigned to the study in the meta-analytic calculation, meaning that studies with higher weights exert a stronger influence on the overall pooled effect.

## Meta Analysis

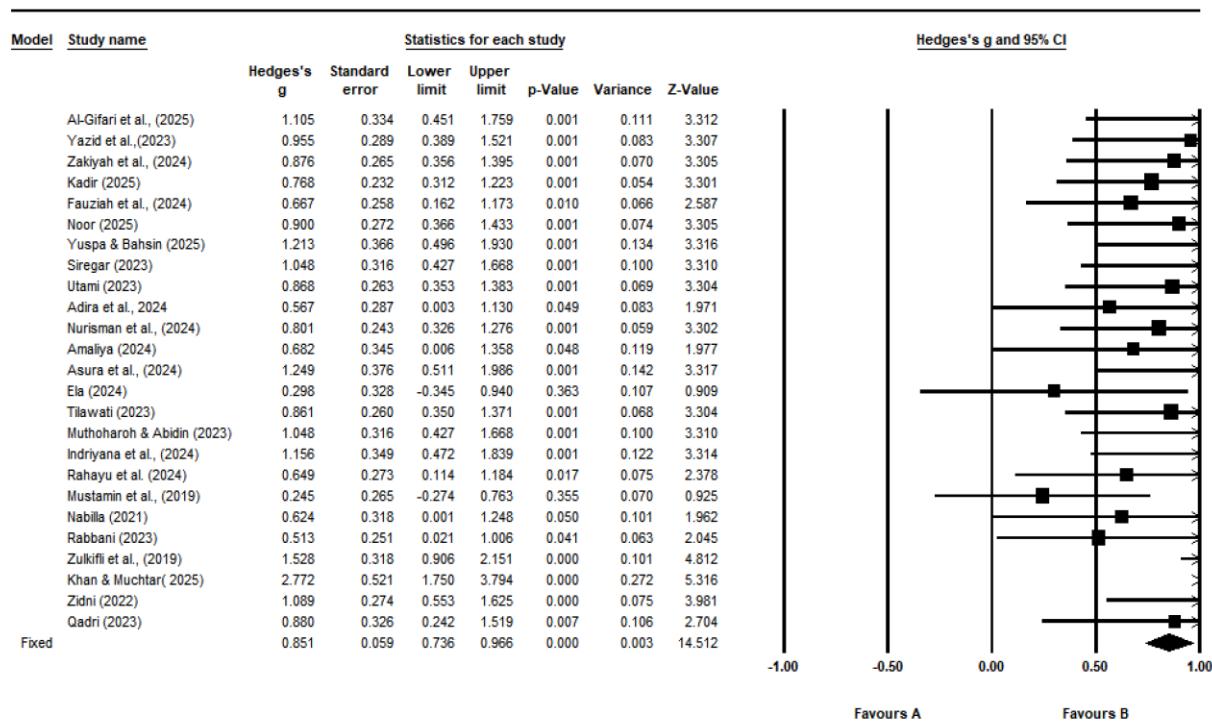


Figure 3: Forest Plot

## Overall Effectiveness of Interactive Learning Applications

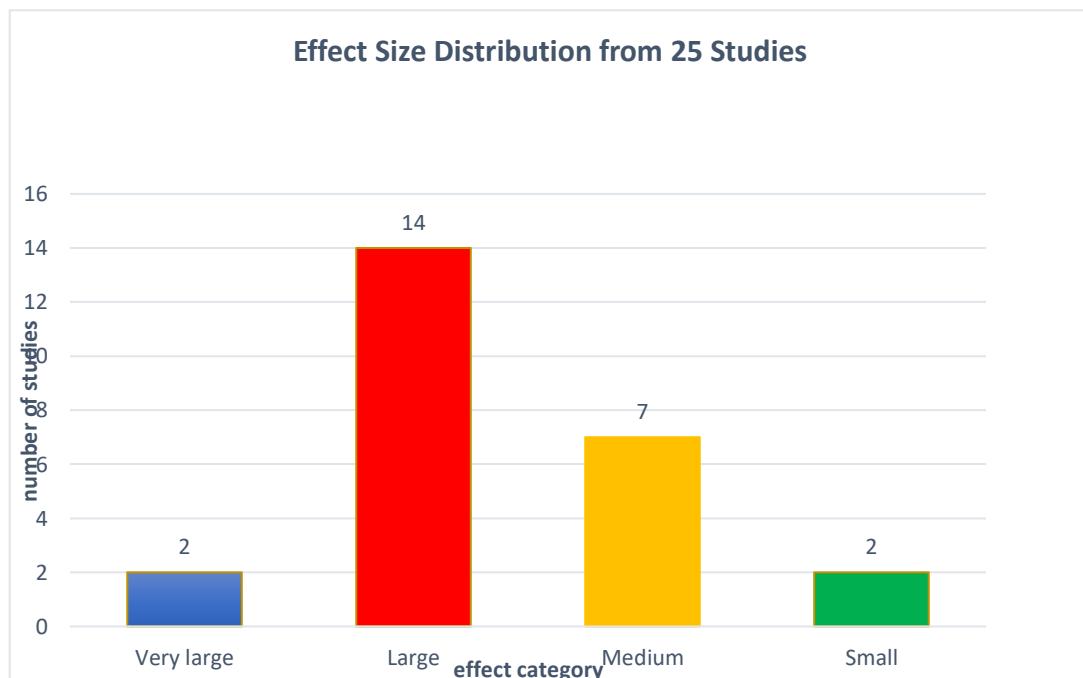
This study aimed to compare the effectiveness of interactive learning applications and conventional instructional media in enhancing Arabic vocabulary acquisition. A synthesis of 25 empirical studies indicated that the effect sizes ranged from 0.245 to 2.772 within a 95% confidence interval. Based on Cohen et al.'s effect size classification framework, two ( $n = 2$ ) were classified as having very large effects, twelve ( $n = 12$ ) fell into the large-effect group, six ( $n = 6$ ) demonstrated moderate effects, and three ( $n = 3$ ) were categorized as having small effects.<sup>23</sup> Although all included

<sup>23</sup> Cohen, Manion, and Morrison, *Research Methods in Education*.

studies reported positive directions of effect, two studies namely study 24 by Mustamin et al. using the Arabic Words Quiz application and study 18 by Ela (2024) employing Educandy exhibited small and statistically insignificant results ( $p > 0.05$ ). These findings indicate that the effectiveness of technology-based learning tools varies depending on their pedagogical and interactive design characteristics. Applications that offer limited learner interaction and feedback tend to yield weaker learning outcomes.<sup>24</sup>

This pattern aligns with the Cognitive Theory of Multimedia Learning, which explains that meaningful learning occurs when learners actively integrate verbal and visual information.<sup>25</sup> Furthermore, recent studies in technology-enhanced language learning emphasize that interactive and gamified environments facilitate higher cognitive engagement, sustained motivation, and improved vocabulary retention.<sup>26</sup> The predominance of large and very large effect sizes in this meta-analysis therefore supports active and constructivist learning perspectives, which stress learner interaction, immediate feedback, and active knowledge construction as essential components of effective instruction.<sup>27</sup>

Figure 3 presents a forest plot illustrating the distribution of effect sizes across the analyzed studies, while Figure 4 summarizes the effect size distribution of all studies. Overall, despite the presence of several studies reporting small effects, the results demonstrate that interactive Arabic learning applications generally produce a substantial and statistically significant impact on vocabulary development when designed according to sound pedagogical and interactive principles.



**Figure 4. Effect Size Classification for Interactive Learning Applications**

<sup>24</sup> Zhenzhen Chen et al., "The Effects of Using Mobile Devices on Language Learning: A Meta-Analysis," *Educational Technology Research and Development* 68, no. 4 (2020): 1769–89.

<sup>25</sup> R Mayer, "Multimedia Learning (Chapter 7)" (Cambridge University Press, 2020).

<sup>26</sup> Qi Zhang and Zhonggen Yu, "Meta-Analysis on Investigating and Comparing the Effects on Learning Achievement and Motivation for Gamification and Game-Based Learning," *Education Research International* 2022, no. 1 (2022): 1519880.

<sup>27</sup> Ruofei Zhang, Di Zou, and Gary Cheng, "Technology-Enhanced Language Learning with Null and Negative Results since 2000: A Systematic Review Based on the Activity Theory," *Education and Information Technologies* 29, no. 4 (2024): 5017–77.

### Heterogeneity Test and Pooled Effect Size

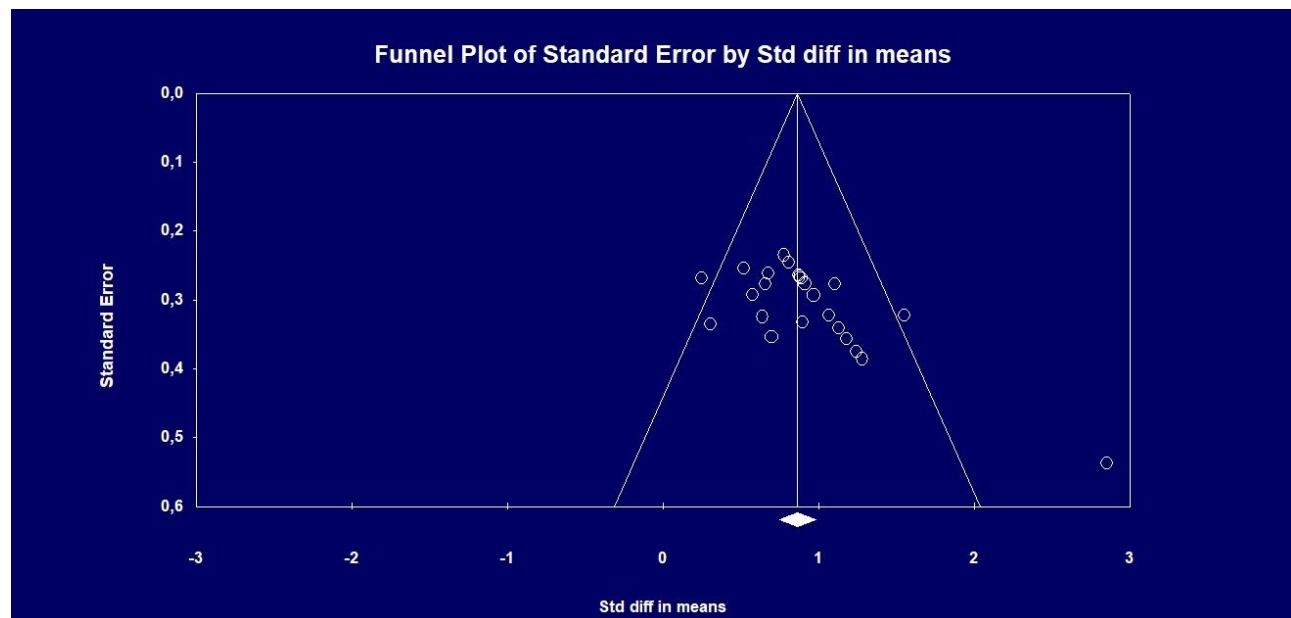
The purpose of the heterogeneity test is to determine the most appropriate model for estimating the combined effect size. Table 4 presents the computed overall effect size. The obtained value of  $Q = 279.15$ , which is greater than the critical  $\chi^2$  value of 86.36 ( $df = 95$ ;  $p < 0.001$ ), indicates that the effect sizes across the included studies are heterogeneous. Therefore, a random-effects model was employed to estimate the overall effect size. The overall effect size using the random-effects estimation method is  $g = 0.85$  (large category according to Cohen), with a  $p$ -value  $< 0.01$ .<sup>28</sup> Thus, based on the analysis of the 25 included studies, it can be concluded that interactive learning applications have a strong and statistically significant effect on students' Arabic vocabulary acquisition compared to traditional instructional media.

**Table 4. Summary of the overall effect size results**

Estimation Method	k	g	P	df	Heterogeneity		
					Q	p	$i^2$
Random-Effect	25	0.86	0.00	24	36.13	0.05	33.57
Fixed-Effect	25	0.85	0.00	24			

### Publication Bias

Additionally, the 25 studies under analysis will be used to assess the problem of publication bias. We may analyze the funnel plot and determine the Rosenthal fail-safe N (FSN) value to determine the likelihood of publishing bias issues.<sup>29</sup> Figure 1 displays the funnel plot's diagnostic results.



**Figure 5: Random Effect Funnel Plot Model**

<sup>28</sup> Cohen, Manion, and Morrison, *Research Methods in Education*.

<sup>29</sup> Dadang Juandi Suparman and Maximus Tamur, "Problem-Based Learning for Mathematical Critical Thinking Skills: A Meta-Analysis," *Journal of Hunan University Natural Sciences* 48, no. 2 (2021).

In spite of variations in sample size or the strength of the reported effects, the study of publication bias seeks to guarantee that the effect size distribution follows a normal pattern and stays constant.<sup>30</sup> The results of the funnel plot in Figure 1 indicate whether the funnel plot is simetris or not, so the next step is to calculate Rosenthal's fail-safe N (FSN). The diagnostic results for fail-safe N Rosenthal are shown in Table 5 below.

**Table 5. Summary of the publication bias findings**

Classic FSN	
Z	14.91
P	0.00
FSN	1423

The publication bias of the meta-analysis was evaluated using the Classic Fail-Safe N (FSN) method, with the results presented in Table 5. The analysis yielded a Z value of 14.91, a p-value of 0.00, and an FSN of 1423. Because the FSN value greatly exceeds the threshold of  $5K + 10$  (where K is the number of included studies), it can be concluded that the meta-analysis does not present significant publication bias. These results indicate that the findings are robust and can be considered scientifically reliable.

### **Interactive Learning Applications and Arabic Vocabulary: Moderator Effects**

In meta-analysis research, moderator variable analysis is crucial for identifying variables that may impact the efficacy of interactive learning applications on Arabic vocabulary knowledge. Moderator variables in this study consist of the type of interactive learning application, education level, and class capacity. A summary of the moderator variable analysis can be seen in Table 6 below.

**Table 6. Results of Moderator variable analysis**

Variabel Moderator	k	g	p	Heterogeneity	
				Qb	P
<b>Application Type</b>					
Gamification Application	9	1,03	0.00	1,60	0,44
Mobile Application	9	0,85	0.00		
<b>Education Level</b>	7	0,75	0.00		
SD	6	0,62	0.00	4,95	0,08
SMP/MTs	11	0,91	0.00		
<b>Class Capacity</b>	8	1,05	0.00		
Large (> 30)	18	0,95	0.00	1,63	0,20
Small ( $\leq 30$ )	7	0,77	0.00		

<sup>30</sup> R M Bernard et al., "Meta-Analysis: A Methodological Primer," *TechTrends* 58, no. 5 (2014): 5–14.

## Types of Interactive Learning Applications

The moderator of application type included three categories: gamified apps, mobile learning apps, and web-based learning apps. Analysis (Table 6) revealed no statistically significant differences in mean effect sizes across these groups ( $Q_b = 1.60$ ;  $p = 0.44$ ). However, gamified applications ( $g = 0.94$ ;  $p < 0.05$ ) showed a slightly greater impact than mobile ( $g = 0.94$ ;  $p < 0.05$ ) and web-based apps ( $g = 0.74$ ;  $p < 0.05$ ).

The relative advantage of gamification can be theoretically explained by the features of game-based learning. Gamified elements such as points, levels, challenges, and immediate feedback enhance intrinsic motivation, cognitive engagement, and memory consolidation, thereby supporting vocabulary learning.<sup>31</sup> These interactive features encourage active participation and repeated retrieval practice, consistent with principles of multimedia learning<sup>32</sup> and retrieval-based learning.<sup>33</sup> Recent meta-analytic studies further confirm that gamified and mobile applications improve vocabulary retention more effectively than conventional methods.<sup>34</sup>

## Level of Education

The education-level moderator comprised Elementary (SD), Junior High/Madrasah Tsanawiyah (SMP/MTs), and Senior High/Vocational High School (SMA/SMK). Although effect size differences were not statistically significant ( $Q_b = 4.95$ ;  $p = 0.08$ ), students in junior ( $g = 0.91$ ;  $p < 0.05$ ) and senior high levels ( $g = 1.05$ ;  $p < 0.05$ ) displayed higher gains than elementary students ( $g = 0.62$ ;  $p < 0.05$ ).

This trend aligns with Piaget's cognitive development theory. Learners in the formal operational stage (11 years and older) are capable of abstract reasoning, metacognitive strategies, and managing complex interactive features within learning applications. Older students' greater technological literacy also facilitates more effective navigation, practice, and reinforcement of vocabulary.<sup>35</sup> Recent studies indicate that age and cognitive readiness significantly moderate the impact of gamified and mobile applications on second-language vocabulary acquisition.<sup>36</sup>

## Class Capacity

Class size was categorized into small ( $\leq 30$  students) and large ( $> 30$  students). The analysis indicated no significant difference in effect size ( $Q_b = 1.63$ ;  $p = 0.20$ ), suggesting that interactive applications are effective regardless of class size. Effect sizes were  $g = 0.77$  ( $p < 0.05$ ) for small classes and  $g = 0.95$  ( $p < 0.05$ ) for large classes.

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<sup>31</sup> Karnlapin Rodjanagosol, "Gamification's Role in Enhancing Vocabulary Acquisition for Adult English Learners," *Journal of Asian Language Teaching and Learning (Online)* 5, no. 2 (2024): 58–68.; Juho Hamari, Jonna Koivisto, and Harri Sarsa, "Does Gamification Work?--A Literature Review of Empirical Studies on Gamification," in *2014 47th Hawaii International Conference on System Sciences* (Ieee, 2014), 3025–34.

<sup>32</sup> Mayer, "Multimedia Learning (Chapter 7)."

<sup>33</sup> Henry L Roediger and Andrew C Butler, "The Critical Role of Retrieval Practice in Long-Term Retention," *Trends in Cognitive Sciences* 15, no. 1 (2011): 20–27.

<sup>34</sup> Yonghong Zhou and Mingming Zhou, "A Meta-Analysis on Mobile-Assisted Vocabulary Learning: Do Mobile Applications Help?," *ReCALL*, 2025, 1–19.; Mostafa Janebi Enayat, Nazanin Asadi Ghadim, and Ali Arabmofrad, "Effects of Two Mobile-Assisted Language Learning Apps on L2 Receptive and Productive Vocabulary Knowledge: A Mixed-Methods Study," *System* 133 (2025): 103763.

<sup>35</sup> J Piaget, *The Psychology of the Child* (New York: Basic Books, 1972).

<sup>36</sup> Chen et al., "The Effects of Using Mobile Devices on Language Learning: A Meta-Analysis."; Reza Teymouri, "Recent Developments in Mobile-Assisted Vocabulary Learning: A Mini Review of Published Studies Focusing on Digital Flashcards," in *Frontiers in Education*, vol. 9 (Frontiers Media SA, 2024), 1496578.

The adaptability of interactive applications allows teachers to adjust activities according to class size. Gamified quizzes or mobile exercises can be delivered individually or in groups, whereas web-based collaborative tasks can engage larger cohorts without compromising learning quality. This supports the principle that digital learning environments can facilitate differentiated instruction and peer-assisted learning, maintaining consistent effectiveness across classroom contexts.<sup>37</sup>

### Integration with Previous Meta-Analyses

Overall, these results reinforce the international evidence that interactive learning applications positively influence vocabulary acquisition across platforms, education levels, and class sizes. The stronger effects observed for gamification and higher-level students are consistent with prior meta-analyses showing that game-based interventions and cognitively mature learners consistently achieve superior language learning outcomes.<sup>38</sup> This study extends existing knowledge by emphasizing the moderating roles of application design and learner characteristics in optimizing vocabulary acquisition outcomes.

## CONCLUSION

A meta-analysis of 25 studies revealed a combined effect size of 0.86, indicating a large and statistically significant impact ( $p < 0.05$ ) of interactive applications on Arabic vocabulary learning.<sup>39</sup> This demonstrates that such applications can substantially enhance students' vocabulary acquisition compared to conventional methods. The effect is consistent across educational levels (elementary, junior high, and senior/vocational high school) and class sizes, with gamification-based applications showing particularly stable results. Pedagogically, these findings suggest that integrating interactive applications allows educators to design more engaging, repetitive, and student-centered vocabulary learning activities.

However, this study is limited by the small number of included studies, the short publication period (2019–2025), and the narrow range of moderator variables examined (education level, class size, and application type). Future research should expand the number and range of studies, consider longer publication periods, and include additional moderators such as student motivation, learning strategies, or gender, to provide a more comprehensive foundation for developing effective Arabic vocabulary teaching strategies.

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<sup>37</sup> David W Johnson, Roger T Johnson, and Edythe Holubec, *Cooperation in the Classroom* (Boston, 1998).

<sup>38</sup> Zhou and Zhou, "A Meta-Analysis on Mobile-Assisted Vocabulary Learning: Do Mobile Applications Help?"

<sup>39</sup> Cohen, Manion, and Morrison, *Research Methods in Education*.

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