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A Meta-Analysis of the Existing Studies on Effects of Mobile Learning on Vocabulary Acquisition

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This meta-analysis examines the effect of mobile learning (m-learning) on students' vocabulary acquisition and explores the moderating effects of education level and intervention duration. By systematically synthesizing and evaluating data from 17 studies across four databases (IEEE Xplore, ScienceDirect, SAGE, and Emerald Insight), this study calculates effect sizes and conducts moderator analyses. The findings reveal that m-learning has a significant positive impact on vocabulary acquisition. While education level does not moderate this effect, intervention duration does ($p = 0.036$). Among the three subgroups analyzed, interventions lasting 4 to 12 weeks exhibit the strongest moderating effect, followed by those exceeding 12 weeks and those lasting less than 4 weeks. Based on these findings, this study recommends integrating m-learning into language education, particularly for vocabulary instruction, optimizing intervention duration, and selecting user-friendly, age-appropriate applications. However, limitations include the exclusive use of journal articles, restriction to four databases, and the absence of device type as a moderator, highlighting the need for broader data sources and further research on technological variations in m-learning.

Keywords: vocabulary acquisition, language learning, meta-analysis, mobile learning, m-learning

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INTRODUCTION

Vocabulary learning is well-established that it is pivotal in language acquisition (Keikhaie & Khoshkhoonejad, 2015), language learning and language proficiency (Schmitt & Schmitt,2020), in which vocabulary knowledge is fundamental in learning languages skills (speaking, listening, reading, and writing) (Putra, 2023). Pascual et al., (2022) agreed with such statement, they stated learning language skills encompassed speaking, listening, reading, and writing are heavily rely on vocabulary knowledge. A broad vocabulary is a prerequisite to language mastery, which in turn ensures a more efficient way of understanding and conveying information, particularly in the academic and professional settings that required a deep understanding of concepts through the use of advanced vocabulary. Insufficient vocabulary can impede learners in successfully understanding and articulating their ideas (Nurharjanti & Ghozali, 2018). Studies have shown that vocabulary acquisition plays a crucial role in mastering language (Hong, 2025). Effective vocabulary acquisition strategies may greatly facilitate the vocabulary acquisition (Feng, 2025), resulting in improving learners' proficiency in various language skills (Waluyo, 2018). Vocabulary acquisition not only involves memorization, but also fully absorbs the true meaning of each vocabulary, with the ability to categorize concepts, understand contexts, and adapt them to different contexts.

Vocabulary Acquisition

Vocabulary acquisition refers to the process of learning new words and phrases, facilitating language comprehension and communication (Nagy & Townsend, 2012). As a fundamental component of language mastery, vocabulary learning establishes the foundation for effective communication across different linguistic contexts (Pascual et al., 2022). Studies have consistently emphasized the pivotal role of vocabulary in achieving language proficiency, highlighting its impact on reading, writing, listening, and speaking skills (Lee, 2022; Waluyo, 2018; Chen, 2014). This has led researchers to explore strategies to enhance vocabulary acquisition and streamline the language learning process.

One widely recognized factor influencing vocabulary acquisition is learners' intentional attention to word prominence (Lee, 2022). Additionally, self-regulated learning strategies have been linked to improvements in both vocabulary knowledge and overall language proficiency (Waluyo, 2018). Research suggests that vocabulary learning necessitates cognitive engagement, which fosters deep learning and accelerates the acquisition process. This is particularly relevant for English language learners, where vocabulary acquisition plays a critical role in language comprehension and fluency development (Gu & Johnson, 1996; Wilang & Duy, 2021).

Several vocabulary learning strategies have been identified as beneficial to language acquisition. For example, the keyword strategy, which strengthens cognitive connections between word forms and meanings, has been found to be effective for vocabulary retention (Sagarra & Alba, 2006). Other intentional strategies, such as word analysis, dictionary use, and mnemonic techniques, have been shown to positively impact vocabulary acquisition (Yu & Trainin, 2021). Additionally, metacognitive strategies—including self-planning, self-monitoring, and self-evaluation—enhance vocabulary learning by promoting autonomous language development (Ghasemi et al., 2019). Recent research has emphasized the importance of integrating diverse strategies to optimize vocabulary acquisition and improve learners' comprehension of new words (Rodríguez-Arce, 2023).

Moreover, research findings on the role of education level in vocabulary acquisition remain inconsistent. Some studies suggest that adult learners benefit more from mobile-assisted vocabulary learning than younger learners (Mahdi, 2017), while others argue that m-learning is equally effective across all education levels (Guo et al., 2021; Garzón et al., 2023). The conflicting perspectives highlight the need for further meta-analytical investigations to clarify whether education level significantly moderates vocabulary learning outcomes.

The Role of Technology in Vocabulary Acquisition

The integration of advanced technologies has significantly reshaped vocabulary acquisition strategies. Digital learning tools, such as multimedia texts, interactive videos, and image-to-text recognition technologies, have been demonstrated to enhance learners' vocabulary retention (Shadiev et al., 2020). Furthermore, mobile-assisted learning platforms like Quizlet and language-learning applications (e.g., Duolingo, Babbel, and YouDao) provide structured vocabulary learning experiences, which have been particularly beneficial for English as a Second Language (ESL) and English as a Foreign Language (EFL) learners (Ji & Aziz, 2021).

Emerging Extended Reality (XR) technologies, including Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), have also demonstrated potential in improving vocabulary acquisition at various educational levels (Tegoan et al., 2021). Studies have found that interactive digital environments promote deeper cognitive engagement, allowing learners to visualize and contextualize new vocabulary in immersive settings (Xiao et al., 2023; Hung & Yeh, 2023). Additionally, gamification techniques and spaced repetition algorithms embedded in mobile learning applications have been found to optimize long-term vocabulary retention (Hadijah et al., 2020).

Mobile Learning (M-Learning) and Vocabulary Acquisition

Mobile learning (m-learning) leverages portable digital devices such as smartphones, tablets, and laptops to facilitate knowledge acquisition and interactive learning experiences (Zakaria et al., 2025; Cho et al., 2018). The flexibility of m-learning allows students to access educational content anytime and anywhere, enabling self-paced and personalized learning (Baloghné Nagy & Svraka, 2025). Research has shown that m-learning improves vocabulary retention and comprehension by integrating interactive multimedia resources and adaptive learning algorithms tailored to individual learning needs (Xiao et al., 2023).

Several studies have highlighted the effectiveness of m-learning in vocabulary acquisition. For instance, Kurt and Bensen (2017) found that smartphone-assisted learning expanded students' vocabulary knowledge without requiring physical classroom attendance. Similarly, Kennedy et al. (2013) reported that multimedia vocabulary instruction significantly benefited learners with language difficulties.

Additionally, Hariffin and Said (2019) found that captioned videos enhanced vocabulary learning outcomes, particularly for second-language learners. More recently, Nguyen and Le (2023) and Gavranović (2019) confirmed that computer-assisted language learning (CALL) and mobile-assisted language learning (MALL) improve vocabulary acquisition by fostering interactive and engaging learning experiences.

However, recent studies have also raised concerns about potential drawbacks of m-learning. One of the main issues is superficial learning, where students rely heavily on quick information retrieval rather than deep cognitive processing (Silva et al., 2021). This over-reliance on immediate feedback can impede long-term retention and hinder active engagement in vocabulary acquisition. Additionally, mobile learning environments often expose students to various digital distractions, such as social media notifications and messaging apps, which can reduce concentration and negatively impact vocabulary learning outcomes (Al-Sofi, 2020).

Moreover, the influence of education level on mobile-assisted vocabulary learning remains contested. While some studies suggest that younger learners benefit less from m-learning compared to adults (Mahdi, 2017), others indicate that education level does not significantly moderate m-learning effectiveness (Garzón et al., 2023). The conflicting findings underscore the need for further empirical studies to clarify how demographic factors, including education level, influence m-learning outcomes.

Given the mixed findings on the effects of m-learning on vocabulary acquisition, there is a growing need for comprehensive meta-analytical studies to synthesize existing research. Although meta-analyses have examined m-learning and vocabulary learning (e.g., Chen et al., 2020), many of these studies rely on outdated data. Recent research (Garzón et al., 2023) has emphasized the importance of including moderator analyses, particularly focusing on education level and intervention duration, to provide a more nuanced understanding of m-learning's impact on vocabulary acquisition.

To address these gaps, this study aims to conduct a meta-analysis to systematically evaluate the effect of m-learning on vocabulary acquisition. Additionally, this study will perform moderator analyses to determine how education level and intervention duration influence the effectiveness of m-learning. This approach will offer a more comprehensive and up-to-date perspective on the role of mobile learning in vocabulary acquisition, providing valuable insights for educators, policymakers, and researchers in the field of language education.

Aim of the Study

This meta-analysis aimed to examine the effect of m-learning on students' vocabulary acquisition and investigate the moderator effect of the education level and intervention duration. This study would conduct a meta-analysis study to systematically synthesize, integrate, and sequentially evaluate the effect of the mobile learning on vocabulary acquisition and carry out the moderator analysis of education level and intervention duration. With this, this study aimed to answer the following research questions:

(1) What is the effect of mobile learning on students' vocabulary acquisition?

(2) Does level of education moderate the effect of mobile learning on students' vocabulary acquisition?

(3) Does intervention duration moderate the effects of mobile learning on students' vocabulary acquisition?

METHOD

Literature Search and Inclusion of the Studies

This meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) standards to ensure the accuracy of this study. This study utilized four databases, namely IEEE Xplore, Science Direct, SAGE, and Emerald Insight for searching the potential inclusion publication. The selection of these databases was based on their inclusion of reputable publications. The search terms included "English", "Vocabulary", "Acquisition", "Mobile learning". This study limited the search within five years, which only include the studies that published from 2019 to 2024 to ensure the studies are all up-to-date. Moreover, this study included the published studies fulfilled the following criteria: (a) it was empirical research, (b) it was conducted in experimental or quasi-experimental, (c) its dependent variable focuses on vocabulary instead of language proficiency at whole, (d) sufficient information was presented to perform the effect size analysis and moderator analysis, such as sample size, mean, standard deviation, level of education, and intervention duration, and (e) it was written in English. The last search of this meta-analysis was conducted on end of January 2024, and the researcher identified 232 studies from the databases of IEEE Xplore, Science Direct, SAGE and Emerald Insight in the initial stage. Then, the researcher was removed the duplicates which remains 231 studies in the screening stage. The screening stage was removed 214 studies, which they are either not empirical research; and/or not conducted in experimental or quasi-experimental, such as correlational studies; and/or dependent variable focuses on language proficiency instead of mainly focusing on vocabulary acquisition; and/or provide insufficient information (size sample size, mean, and standard deviation) to calculate effect size and/or provide insufficient information on the statements of level of education, and intervention duration. After screening and removing the studies based on the inclusion and exclusion criteria in the screening and eligibility stages, 17 studies are included in this meta-analysis (see Figure 1).

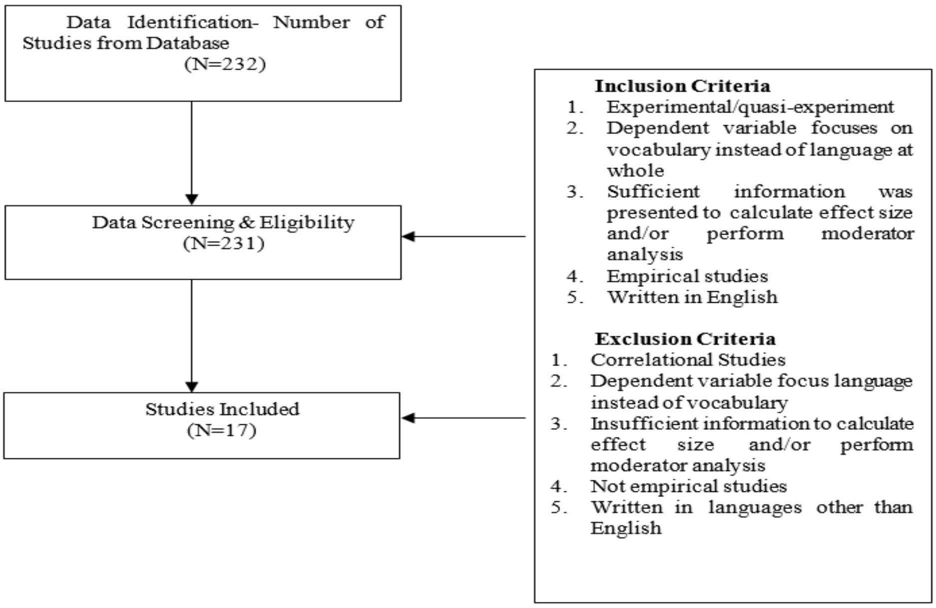


Figure 1
Process of selection of studies

Data Coding

The researcher extracted the data from 17 studies with the following information: name of the publication, publication year, type of research design, education level, mobile device that used in the m-learning, intervention duration, sample size, mean, and standard deviations. Then, the researcher used the Comprehensive Meta Analysis (CMA) 4.0 software with $p < 0.05$ set as the threshold for significance.to conduct the meta-analysis by carried out the effect size analysis and moderator analysis. CMA 4.0 is a robust software application specifically developed for performing meta-analyses, which involve the integration of data from several studies to generate more reliable findings. It is extensively utilized to integrate research findings, evaluate the overall effect of a treatment or intervention, and investigate potential factors that may influence the effects.

Effect Size Analysis

This study calculated the effect size using Hedges' *g* instead of Cohen's *d* value as Hedges' *g* is considered more precise than Cohen's *d* value. The primary objective of a meta-analysis is to determine the extent of the effect of an experimental treatment, which is subsequently transformed into standardized mean differences. Cohen's d or Hedges' g are frequently employed to estimate effect sizes. The ratio of the difference between the sample means of a continuous response to the pooled standard deviation is determined by both estimates. The Cohen's d estimate is frequently employed; however, it is susceptible to bias when applied to small sample sizes. However, Hedges' g addresses this tendency by incorporating a correction factor, which has recently become prominent in educational research (Borenstein et al., 2021). Hence, this study used Hedges' g as the effect size analysis.

Random-effects models are used in meta-analysis instead of fixed-effects models when there is heterogeneity among the studies being analyzed. Heterogeneity is used to indicate the existence of differences in the true effect size of studies. These differences can be attributed to factors such as differences in study design, population characteristics, or interventions. The random-effects model assumes that the true effect size is not constant across all studies, but rather follows a distribution, thereby accounting for the variation between studies. This approach incorporates the variation in effect sizes across studies and provides a more conservative estimate by assigning appropriate weights to each study. The effects were examined using the random-effects model due to the fact that the study samples were obtained from populations with different effect sizes. The studies included in the analysis are presumed to be a random sample from a population with potential studies. This analysis will be utilized to draw conclusions about that population (Borenstein et al., 2021; Hedges & Vevea, 1998). The guidelines to infer the effect sizes were as follows: negligible ($-0.15<g<0.15$); small ($0.15\leq g<0.40$); medium ($0.40\leq g<0.75$); large ($0.75\leq g<1.10$); very large ($1.10\leq g<1.45$); and huge ($1.45\leq g$) (Garzón, 2023).

Moderator Analysis

Statistical heterogeneity was assessed using Cochran's Q test, the I^2 statistic, and p-values, with I^2 values of 0–25% (low), 25–50% (moderate), 50–75% (substantial), and >75% (high). Based on the examination of the three values, researcher will figure out whether the null hypothesis of heterogeneity should be rejected. This indicated that is it necessary to conduct tests for moderators. The analysis of heterogeneity in a moderator (subgroup) analysis is a statistical method that is used to determine the level of heterogeneity of calculated effect sizes in different studies. The objective is to determine whether the size of effect is radically different among subgroups or moderators of the studies, such as the particular conditions or characteristics of the study and participants. The analysis is statistical in nature by utilizing methods such as Cochran's Q test or $I2$ statistic to determine the level of heterogeneity. However, if the heterogeneity exists in this study, a further step of subgroup analyses and sensitivity analysis should be performed to identify the potential causes of the variation among the studies and be able to better understand the sources of heterogeneity. In summary, homogeneity analysis in moderator analysis helps determine if the effect sizes in a meta-analysis vary significantly across different subgroups or moderators, providing insights into the sources of heterogeneity and potentially guiding further analyses or interpretations of the meta-analysis results.

The Q-value on moderating analysis (subgroup analysis) in meta-analysis is a statistical measure used to assess the heterogeneity (variation) among the studies included in a meta-analysis. It quantifies the extent of effect size variability that exceeds the level that would be anticipated from chance alone. The Q-value is determined by summing the squared variances between the effect size of each study and the pooled effect size, weighted by the inverse of the estimated variance of each study's effect size. Higher values of the Q-value indicate a larger degree of heterogeneity among the studies. Q-value is commonly used along with the p-value from the chi-square test to determine whether the observed heterogeneity is statistically significant. The p-value provides an indication of the likelihood that the observed heterogeneity is due to chance alone. If the p-value is less than a predetermined significance level, which set at 0.05 in this meta-analysis, it suggests that the observed heterogeneity is unlikely to be due to chance and may be attributable to genuine differences or moderators among the studies.

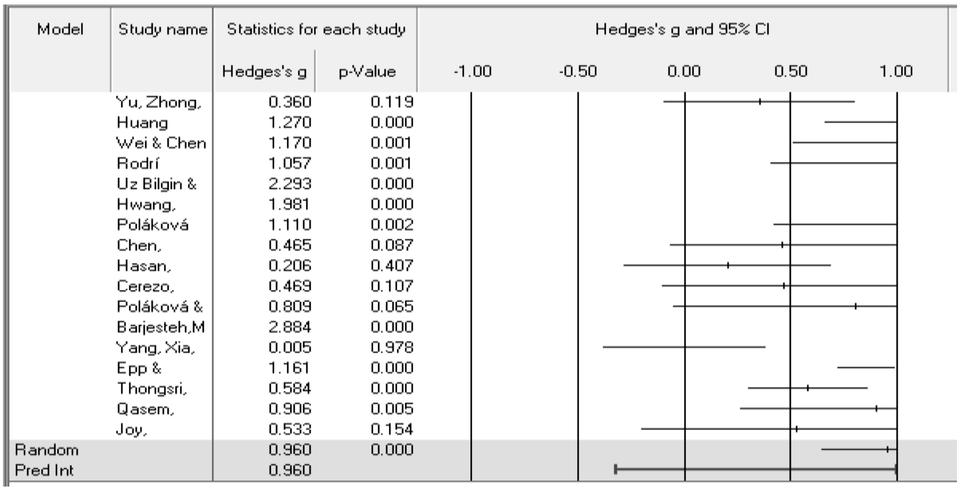
This study has identified the specific educational levels that derive the greatest advantages from m-learning. Consequently, it has been able to determine the circumstances in which the utilization of mobile devices in English education is beneficial or not. The researcher coded the education level in by preschool education, primary education, secondary education, college education, undergraduate, master, doctorate and adult learning. While for the intervention duration, the researcher coded into below 4 weeks, 4 to12 weeks, 12 weeks above.

FINDINGS

Effect Size Calculation

This meta-analysis was conducted based on data that extracted from the seventeen included studies in the four databases of IEEE Xplore, Science Direct, SAGE and Emerald Insight. The effect size index is the standardized difference in means (Hedges' g) and the random-effects model was employed for the analysis. Based on the effect size calculation, it shown that the mean effect size (Hedges' g) is 0.960 with a 95% confidence interval of 0.648 to 1.272, $g=0.96$, *95% CI [0.65–1.27]*. Following the rule of thumb of Hedges' g (Garzón, 2023), this means that there is a large effect size. Z-value tested the null-hypotheses and indicated mean effect size is zero, along with the Z-value of 6.033, and p-value smaller then 0.001, $p<0.001$. Using a criterion alpha of 0.050 that ensure a less than 5% that the data being examined may have occurred by chance under the null hypothesis, this study rejected the null hypothesis. This could be concluded that m-learning positively impacts vocabulary acquisition. Figure 2 shows the value of each study that included in this study.

The Q-statistic is used to test the null hypothesis that all studies included in the analysis have the same effect size. If all studies had an exact true effect size, the anticipated value of Q would be equivalent to the degrees of freedom (the total number of studies minus one). The Q-value is 86.280 with 16 degrees of freedom and a p-value less than 0.001. With a significance level (alpha) of 0.100, the researcher in this study is able to reject the null hypothesis that the true impact size is equal across all of these trials. The I-squared statistic is 81%, indicating that approximately 81% of the variation in observed effects may be attributed to true effects rather than sampling error. The variance for true effect sizes, often known as Tau-squared, is equal to 0.333 when measured in g units. The standard deviation of genuine effect sizes, denoted as Tau, is equal to 0.577 in units of g. Assuming that the genuine effects follow a normal distribution in units of g, the researcher can estimate that the prediction interval ranges from -0.316 to 2.237. The true effect size in 95% of all comparable populations falls in this interval. These values support the assumption of the random effects model and imply the possibility of moderating variables.



Model	Study name	Hedges's g	p-Value
	Yu, Zhong,	0.360	0.119
	Huang	1.270	0.000
	Wei & Chen	1.170	0.001
	Rodrí	1.057	0.001
	Uz Bilgin &	2.293	0.000
	Hwang,	1.981	0.000
	Poláková	1.110	0.002
	Chen,	0.465	0.087
	Hasan,	0.206	0.407
	Cerezo,	0.469	0.107
	Poláková &	0.809	0.065
	Barjesteh,M	2.884	0.000
	Yang, Xia,	0.005	0.978
	Epp &	1.161	0.000
	Thongsri,	0.584	0.000
	Qasem,	0.906	0.005
	Joy,	0.533	0.154
Random		0.960	0.000
Pred Int		0.960	

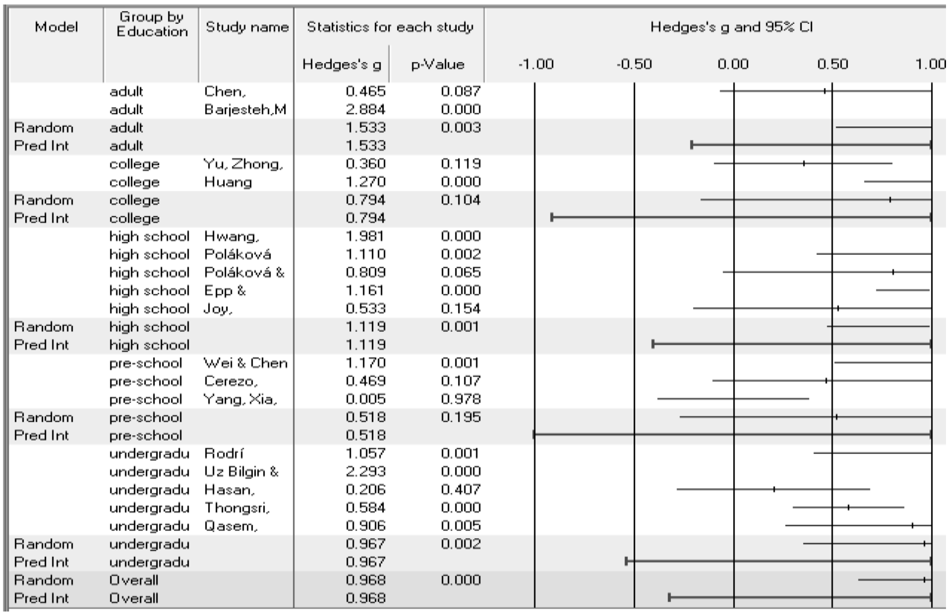
Figure 2
Statistic of each study

Moderator Analysis

This study carried out the moderator analysis. Firstly, this study classified the moderator of education level into preschool education, primary education, secondary education, college education, undergraduate, master, doctorate and adult learning and conducted the moderator analysis. Figure 3 shows that the Q-value using the mixed method approach to identify group differences and it is 2.826 with p-value of 0.587, *p=0.587*, which indicated education level did not moderate the effect of m-learning on vocabulary acquisition. With this, Figure 4 shows the effect was large at the adult learning level (*g*=1.53, *p*=0.003) and large at the college education (*g*=0.80, *p*=0.104) and high school level (*g*=1.12, *p*=0.001) and undergraduate study (*g*=0.97, *p*=0.002). The effect was found to be medium on preschool education (*g*=0.52, *p*=0.195).

Groups	Effect size and 95% confidence interval						Test of null[2-tail]		Prediction Interval		Between-study		other heterogeneity statistics			
Group	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Lower limit	Upper limit	Tau	TauSq	Q-value	df (Q)	P-value	I-squared
Fixed effect analysis																
adult-learning	2	1.134	0.236	0.056	0.671	1.596	4.801	0.000					21.456	1	0.000	95.339
college	2	0.692	0.187	0.035	0.325	1.058	3.695	0.000					5.61	1	0.018	82.175
high school	5.000	1.149	0.149	0.022	0.858	1.440	7.735	0.000						4	0.113	46.454
pre-school	3	0.344	0.148	0.022	0.054	0.635	2.327	0.000						2	0.010	78.451
undergraduate	5	0.747	0.106	0.011	0.539	0.955	7.049	0.000						4	0.000	84.459
Total within														12	0.000	
Total between														4	0.002	
Overall	17.000	0.770	0.106	0.004	0.640	0.9	11.588	0.000						16	0.000	81.594
Mixed effects analysis																
adult learning	2	1.562	0.526	0.276	0.531	2.592	2.971	0.003	-0.215	3.339	0.647	0.418				
college	2	0.806	0.497	0.247	-0.168	1.780	1.622	0.105	-0.933	2.545	0.647	0.418				
high school	5	1.145	0.333	0.111	0.493	1.798	3.441	0.001	-0.405	2.696	0.647	0.418				
preschool	3	0.528	0.407	0.166	-0.271	1.326	1.295	0.195	-1.102	2.157	0.647	0.418				
undergraduate	5	0.982	0.317	0.101	0.360	1.604	3.095	0.002	-0.554	2.518	0.647	0.418				
Total between													2.826	4	0.587	
Overall	17	0.986	0.175	0.031	0.643	1.329	5.632	0	-0.322	2.293	0.588	0.346				

Figure 3
Q-value using the mixed method approach (Education Level)



Model	Group by Education	Study name	Statistics for each study: Hedges's g	p-Value
	adult	Chen,	0.465	0.087
	adult	Barjesteh,M	2.884	0.000
Random	adult		1.533	0.003
Pred Int	adult		1.533	
	college	Yu, Zhong,	0.360	0.119
	college	Huang	1.270	0.000
Random	college		0.794	0.104
Pred Int	college		0.794	
	high school	Hwang,	1.981	0.000
	high school	Poláková	1.110	0.002
	high school	Poláková &	0.809	0.065
	high school	Epp &	1.161	0.000
	high school	Joy,	0.533	0.154
Random	high school		1.119	0.001
Pred Int	high school		1.119	
	pre-school	Wei & Chen	1.170	0.001
	pre-school	Cerezo,	0.469	0.107
	pre-school	Yang, Xia,	0.005	0.978
Random	pre-school		0.518	0.195
Pred Int	pre-school		0.518	
	undergradu	Rodrí	1.057	0.001
	undergradu	Uz Bilgin &	2.293	0.000
	undergradu	Hasan,	0.206	0.407
	undergradu	Thongsri,	0.584	0.000
	undergradu	Qasem,	0.906	0.005
Random	undergradu		0.967	0.002
Pred Int	undergradu		0.967	
Random	Overall		0.968	0.000
Pred Int	Overall		0.968	

Figure 4
Effect size (g) of each level of education

This study also conducted the moderator analysis of intervention duration with the classification of below 4 weeks, 4 to12 weeks, 12 weeks above. Figure 5 shows that the Q-value using the mixed effect analysis to identify group differences and it is 6.650 with p-value of 0.036, which indicated intervention duration does moderate m-learning's effect on vocabulary acquisition. With this, Figure 6 shows the effect was large at the intervention duration between 4 to 12 weeks (g=1.79, p<0.001) and intervention duration above 12 weeks and (g=0.94, p=0.002) and medium on the intervention duration below 4 weeks (g=0.74, p=0<0.001). A large effect size in Hedges' g suggests a considerable and meaningful difference between the groups or conditions being compared. A large effect indicates a considerable and perceptible influence of the intervention or treatment being studied. In terms of that, the intervention duration between 4 to 12 weeks plays a largest moderator effect on the effect of mobile learning on students' vocabulary acquisition, followed by the intervention duration above 12 weeks and the intervention duration below 4 weeks.

Groups	Effect size and 95% confidence interval						Test of null (2-tail)		Prediction Interval		Between-study		other heterogeneity statistics			
Group	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Lower limit	Upper limit	Tau	TauSq	Q-value	df (Q)	P-value	I-squared
Fixed effect analysis																
4 to 12 weeks	3	1.770	0.213	0.045	1.352	2.188	8.300	0.000					5.900	2	0.052	66.100
above 12	4	0.668	0.142	0.020	0.389	0.947	4.699	0.000					30.344	3	0.000	90.113
below 4 weeks	10	0.653	0.079	0.006	0.499	0.808	8.284	0.000					25.356	9	0.003	64.506
Total within													61.601	14	0.000	
Total between													24.680	2	0.000	
Overall	17	0.762	0.066	0.004	0.633	0.891	11.616	0.000					86.280	16	0.000	81.456
Mixed effects analysis																
4 to 12 weeks	3	1.786	0.363	0.132	1.075	2.497	4.920	0.000	0.456	3.116	0.508	0.258				
above 12	4	0.939	0.298	0.089	0.355	1.522	3.153	0.002	-0.316	2.193	0.508	0.258				
below 4 weeks	10	0.735	0.185	0.034	0.372	1.098	3.969	0.000	-0.417	1.887	0.508	0.258				
Total between													6.650	2	0.036	
Overall	17	0.949	0.144	0.021	0.666	1.232	6.577	0.000	-0.319	2.218	0.577	0.333				

Figure 5
Q-value using the mixed method approach (Intervention Duration)

Model	Group by Intervention	Study name	Hedges's g	p-Value
	4 to 12	Uz Bilgin &	2.293	0.000
	4 to 12	Hwang,	1.981	0.000
	4 to 12	Poláková	1.110	0.002
Random	4 to 12		1.786	0.000
Pred Int	4 to 12		1.786	
	above 12	Yu, Zhong,	0.360	0.119
	above 12	Hasan,	0.206	0.407
	above 12	Barjesteh,M	2.884	0.000
	above 12	Qasem,	0.906	0.005
Random	above 12		0.939	0.002
Pred Int	above 12		0.939	
	below 4	Huang	1.270	0.000
	below 4	Wei & Chen	1.170	0.001
	below 4	Rodrí	1.057	0.001
	below 4	Chen,	0.465	0.087
	below 4	Cerezo,	0.469	0.107
	below 4	Poláková &	0.809	0.065
	below 4	Yang, Xia,	0.005	0.978
	below 4	Epp &	1.161	0.000
	below 4	Thongsri,	0.584	0.000
	below 4	Joy,	0.533	0.154
Random	below 4		0.735	0.000
Pred Int	below 4		0.735	
Random	Overall		0.949	0.000
Pred Int	Overall		0.949	

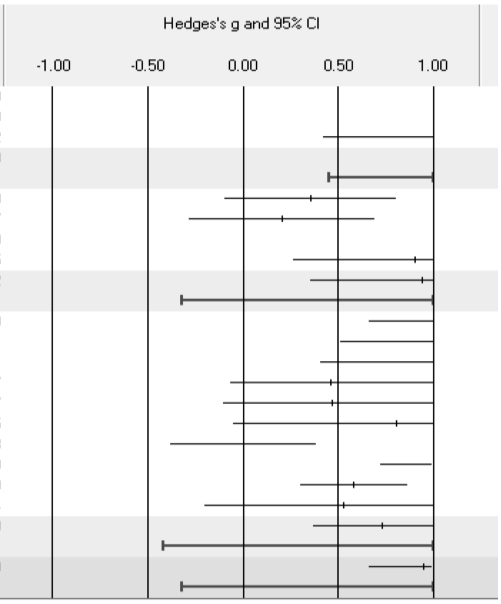


Figure 6
Effect size (g) of level of intervention duration

DISCUSSIONS

This study included 17 studies and conducted the meta-analysis to investigate the effect of m-learning on students' vocabulary acquisition and identified the moderator effect of the education level and intervention duration. With this, the study revealed that there was a large positive effect of mobile learning on students' vocabulary acquisition, *g=0.96, 95% CI [0.65–1.27], p<0.001.* This study revealed education level does not moderates the effect of mobile learning on students' vocabulary acquisition, *p= 0.587;* while intervention duration moderates the effect of mobile learning on students' vocabulary acquisition, *p=0.036.* With this, there are three subgroup of the intervention duration was run in the moderator, which the intervention duration between 4 to 12 weeks *(g=1.79, p<0.001)* plays a largest moderator effect on the effect of mobile learning on students' vocabulary acquisition, followed by the intervention duration above 12 weeks *(g=0.94, p=0.002)* and the intervention duration below 4 weeks *(g=0.74, p=0<0.001).*

The heterogeneity assessment of the included studies was conducted using Cochran's Q test, the I^2 statistic, and the tau (τ^2) statistic, as shown in the tables (Figure 5 & 6). The fixed-effect model results indicate substantial heterogeneity across subgroups, with the overall Q statistic = 26.280 (p = 0.006) and I^2 = 81.456%, suggesting a high level of heterogeneity. Specifically, subgroup analyses show that the "below 4 weeks" group exhibited the highest heterogeneity (Q = 21.600, I^2 = 64.506%), followed by the "above 12 weeks" group (Q = 30.344, I^2 = not explicitly listed). The "4 to 12 weeks" group displayed the lowest heterogeneity (Q = 5.900, I^2 = 66.100%).

In the mixed-effects model, the overall heterogeneity remains considerable, but slightly reduced, with Q = 6.650 (p = 0.036), indicating that the random-effects model accounts for some variation. The τ^2 values suggest variance among effect sizes, highlighting that substantial between-study differences exist. The forest plot further illustrates this heterogeneity, with individual studies showing varied effect sizes (Hedge's g ranging from approximately 0.564 to 2.293). Several studies, particularly within the "4 to 12 weeks" and "below 4 weeks" subgroups, demonstrate wide confidence intervals, further reflecting between-study variation. Given the significant heterogeneity detected, further sensitivity analyses or moderator analyses may be necessary to explore potential sources of variation, such as study characteristics, sample differences, or intervention implementation.

Effects of Mobile Learning (M-learning) on Vocabulary Acquisition in English Education

This meta-analysis revealed that mobile learning has a large effect on vocabulary acquisition. This result is similar to the past studies such as the meta-analysis of Cho et al., (2018), Chen et al., (2020) and Garzón (2023). These meta-analysis studies showed the results that m-learning effectively effect on language learning in terms of vocabulary learning.

Mobile learning is a method that offers flexibility to the learners, it allows the students to study at their own pace and convenience. It provides various tools and resources that are helpful for improving vocabulary learning. For example, there are language learning platforms that provides the digital contents of definition of vocabulary, following with its pronunciation, synonyms, and also the related flashcard applications and vocabulary games (Hongjin, 2021). The interactive nature of these applications guarantees that learners remain actively involved and are more inclined to recall newly acquired vocabulary. The ubiquity and mobility of mobile devices enable learners to employ these tools at any time and in any location, seamlessly incorporating language learning into their regular schedules (Martono & Nurhayati, 2014). Enhanced immersion in the target language is essential for the acquisition of new vocabulary. Mobile applications utilizing spaced repetition techniques facilitate the transfer of words from short-term to long-term memory, hence enhancing vocabulary retention. Mobile learning excels in the aspect of personalization, allowing learners to tailor their vocabulary lists to suit their individual requirements and interests. The inclusion of collaborative functionalities in numerous m-learning applications promotes user engagement with peers or native speakers, enhancing the learning experience and immersing them in authentic language usage. Mobile devices' multimedia functionalities assist the process by providing a variety of content types, such as video contents (vodcasts) and audio lessons (podcasts) (Goundar & Kumar, 2022). M-learning facilitates many learning preferences, such as visual learners utilizing infographics or videos, auditory learners utilizing podcasts or audio flashcards, kinesthetic learners utilizing touchscreen interfaces, and read/write learners having access to abundant reading resources and note-taking applications. Mobile learning has the significant advantage of providing prompt feedback to improve vocabulary acquisition. Students can promptly ascertain whether they have employed a term accurately or enunciated it correctly, reinforcing the accurate application of the language and averting the entrenchment of faults that may prove challenging to rectify in the future (Fageeh, 2013). Mobile learning is a noteworthy advancement in language education technology. It enhances vocabulary acquisition by being efficient, engaging, adaptable, collaborative, multimodal, and suitable for different learning styles. Hence, it could be said that mobile learning (m-learning) positively influences vocabulary acquisition.

Moderator Analysis

Education Level

This study revealed that education level does not moderate the effect of mobile learning (m-learning) on students’ vocabulary acquisition. This finding aligns with Garzón et al. (2023), who also found that education level did not influence the effectiveness of m-learning on student learning outcomes. While some studies suggest that adult learners may benefit more from mobile-assisted vocabulary learning than younger learners (Mahdi, 2017), the overall impact of mobile learning on vocabulary acquisition has been found to be **moderate and consistent across different learner groups** (Guo et al., 2021).

The literature further supports the broad applicability of m-learning in vocabulary acquisition. For instance, Arumugam and Noor (2021) highlighted the benefits of mobile applications for vocabulary learning, while Ji and Aziz (2021) emphasized that vocabulary retention improves when learners are exposed to diverse digital resources. Additionally, studies have shown that Mobile-Assisted Language Learning (MALL) positively influences vocabulary acquisition, particularly among university freshmen (Van & Thanh, 2021). Similarly, Poláková and Klímová (2019) demonstrated that mobile applications enhance academic performance in vocabulary learning, and

Klímová (2019) found that such applications improve learning efficiency for students across various education levels.

One possible explanation for the lack of a moderating effect of education level is that mobile learning tools are generally designed for broad accessibility, catering to learners from diverse educational backgrounds. These applications are typically user-friendly and adaptable, allowing students to engage with content in ways that align with their individual learning preferences and needs, regardless of their education level. This widespread accessibility may contribute to the consistent effectiveness of m-learning across different learner groups, further reinforcing the idea that education level does not significantly influence the impact of m-learning on vocabulary acquisition.

Intervention Duration

This study revealed that intervention duration moderates the effect of mobile learning on vocabulary acquisition. This result was not consistent to the past studies, such as the meta-analysis of (Chen et al., 2020). In term of that, intervention duration within 4 to 12 weeks and above 12 weeks were with large effect while intervention duration with below 4 weeks only has medium effect. With this, this indicated that intervention duration between 4 to 12 weeks plays a largest moderator effect on the effect of mobile learning on students' vocabulary acquisition, followed by the intervention duration above 12 weeks and the intervention duration below 4 weeks. This could be said that a moderate intervention duration is the best moderator in the effect of mobile learning on vocabulary acquisition. Coyne et al., (2022) stated the intervention duration was highly related to the outcomes of the vocabulary learning. A consistent and intensive approach in vocabulary learning could lead to an improvement in the vocabulary acquisition. A longer intervention period might be increasing the exposure and consistent the practices, resulting in a better vocabulary acquisition. With a sufficient intervention period, it also allows to use the effective vocabulary learning strategies, such as the spaced repetition. The consistent practices with a sufficient intervention period are beneficial to the vocabulary acquisition with a long-term retention. The progressive nature of language development necessitates a significant amount of time and exposure to diverse situations. On the other hand, a very short intervention period, such as 4 weeks and below, may not allow sufficient time for students to go through the various phases of vocabulary acquisition. Despite a longer session would be benefitting, the novelty effect tends to diminish in a very long intervention duration (Liakin ei al., 2017) such as 12 weeks and above, which may reduce the impact on learning. Hence, the the intervention duration between 4 to 12 weeks that falls on the medium just right and sufficient as the intervention duration, and so it plays a largest moderator effect on the effect of mobile learning on students' vocabulary acquisition.

CONCLUSION AND RECOMMENDATIONS

This study revealed that m-learning has a large positive effect on vocabulary acquisition, which m-learning positively affects vocabulary acquisition. This study revealed education level does not moderates the effect of mobile learning on students' vocabulary acquisition; while intervention duration moderates the effect of mobile learning on students' vocabulary acquisition. With this, there are three subgroup of the intervention duration was run in the moderator, which the intervention duration between 4 to 12 weeks plays a largest moderator effect on the effect of mobile learning on students' vocabulary acquisition, followed by the intervention duration above 12 weeks and the intervention duration below 4 weeks.

Based on the findings of this meta-analysis, this study provides several recommendations for the education field. The results revealed that m-learning has a significant positive effect on vocabulary acquisition, making it a valuable tool for language instruction. Educators, particularly those teaching English as a second or foreign language, are encouraged to integrate mobile learning into their teaching strategies to enhance students' vocabulary development, as vocabulary serves as the foundation for reading, writing, speaking, and listening skills. M-learning can improve both classroom and non-classroom learning environments by making vocabulary instruction more engaging and accessible (Irudayasamy et al., 2021).

To maximize the benefits of m-learning, course design and implementation should be carefully planned. While education level does not moderate the effect of mobile learning, intervention duration plays a crucial role. This study found that interventions lasting 4 to 12 weeks have the strongest impact on vocabulary acquisition, followed by durations exceeding 12 weeks, while interventions shorter than 4 weeks show the least effectiveness. Therefore, educators intending to implement mobile learning should design vocabulary programs within a 4-to-12-week timeframe to maximize learning outcomes.

Additionally, educators must select age-appropriate, user-friendly mobile applications to ensure accessibility and engagement for learners across different age groups. Since m-learning is effective regardless of education level, it can be widely applied, but educators should still be cautious in choosing applications that align with students' needs. To sustain motivation and counteract the novelty effect (Liakin et al., 2017), educators are advised to periodically rotate mobile applications or update learning materials within the m-learning environment.

Lastly, effective implementation requires structured lesson plans that integrate mobile learning with traditional instruction, ensuring a balanced approach. Ongoing assessments should be conducted to track students' vocabulary progress, refine teaching strategies, and provide targeted support. By following these guidelines, educators can strategically implement m-learning to optimize its impact on vocabulary acquisition and overall language proficiency.

LIMITATIONS

The first limitation of this study is that this meta-analysis included only journal articles instead of all types of papers, such as dissertations, conference papers and books due to their strong relevance to the research domain, rigorous peer-review standards, and comprehensive coverage of high-impact journals. While limiting the search to these sources may exclude some grey literature, such as dissertations and conference papers, this approach ensures the inclusion of high-quality, peer-reviewed studies that contribute to the reliability of the findings. Nonetheless, potential publication bias is acknowledged, and future research could expand to additional sources to capture a broader spectrum of perspectives, such as dissertations might provide useful information in such field. In addition to that, this meta-analysis was conducted based on data that extracted from the seventeen included studies in the four databases of IEEE Xplore, Science Direct, SAGE and Emerald Insight. This study was limited to the studies from the four databases. To provide a more comprehensive view of the effect of m-learning on students' vocabulary acquisition, future studies are recommended to expand the number of the databases that include journals with good quality. Moreover, this meta-analysis was limited to include more potential moderators. Type of the devices that used in the mobile learning might be critical. There are different types of the devices could be used in m-learning, such as smartphones, tablets, smartboards, and so on, and each of them might act differently in the effect of m-learning on students' vocabulary acquisition. Future studies are recommended to include the device type in the moderator analysis.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material; further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethical approval was granted by University Putra Malaysia, Approval Number: [2024-341]." for the study on human participants in accordance with the local legislation and institutional requirements.

AUTHOR CONTRIBUTIONS

All authors contributed to the design and implementation of the research, to the analysis of the results, and to the writing of the manuscript.

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