Effects of Mobile App on Memory Retention of Vocabulary Knowledge among Low Proficiency EFL Learners

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Abstracts

A significant challenge in EFL vocabulary learning is ensuring long-term retention and effective use of newly acquired words, often hindered by limited exposure and meaningful practice. Considerable research has been conducted on mobile technologies for vocabulary learning in a second language (L2), but the comprehensive mastery of EFL vocabulary form, meaning, and use via mobile platforms in short-term and long-term memory has rarely been addressed. This quasi-experimental study investigated the effects of a mobile vocabulary app versus a paper-based wordlist on high-frequency core vocabulary from CET 4 among Chinese university students. Data were collected from 82 EFL freshmen at a private university in China from two intact groups. The experimental group used the Bai Cizhan app for out-of-classroom learning, while the control group used traditional paper-based methods. Vocabulary knowledge was tested through pretests, immediate recall tests, and delayed recall post-tests. Findings indicated that Bai Cizhan group significantly enhanced L2 vocabulary learning in improving high-frequency core words vocabulary in terms of form and meaning (Form: $F (1, 80) = 23.957$, $p < .05$, $\eta^2 = .230$; Meaning: $F (1, 80) = 16.342$, $p < .05$, $\eta^2 = .170$) in short-term memory, but no significant difference (Wilks' Lambda$=.187$, $F(3, 78)=1.641$; $P>.05$) in long-term memory. This study provides empirical evidence for the effectiveness of mobile-assisted vocabulary learning and offers insights into meeting the vocabulary needs of EFL learners.

Keywords: mobile application, high frequency core vocabulary, vocabulary knowledge, form, meaning and use

1. Introduction

Vocabulary acquisition is a cornerstone of EFL (English as a Foreign Language) learning, with significant implications for overall proficiency and communication skills. University students in non-English speaking environments, particularly in China, often face challenges in systematic vocabulary learning due to limited exposure and demanding schedules (Guan, 2024). In this context, the test-oriented education system emphasizes rote memorization, which can undermine both long-term retention and practical application of vocabulary. While short-term retention is necessary for immediate language use, long-term retention is crucial for effective communication in real-life situations.

The rapid pace of instruction and limited opportunities for authentic language practice further complicate vocabulary learning for Chinese EFL students. Dual Coding Theory suggests that information is better retained when presented both visually and verbally, and mobile applications have embraced this approach to revolutionize language learning. These apps provide engaging, personalized experiences that enhance short-term memory and support the transition to long-term memory. Features such as spaced repetition, multimedia, immediate feedback, and gamification help students move from mere recognition of vocabulary to practical use. The portability of mobile devices allows learners to practice anytime, anywhere, enriching their learning experience and increasing engagement (Kong & Song, 2015).

Over the past several years, research has increasingly focused on the various modalities of mobile devices, including email, short message service (SMS), multimedia message service (MMS), and mobile applications, for

vocabulary learning. These methods often involve delivering word lists, mini-lectures, or related text notifications to learners through SMS, MMS, or email (Li & Hafner, 2022; Mathee, 2017). Numerous mobile applications have adopted these strategies, demonstrating greater effectiveness compared to traditional methods. Klimova (2021, p. 863) noted in a review article that all mobile apps studied had a positive and significant impact on students' EFL vocabulary retention.

However, most research has focused on the overall effects of mobile-based methods (Guo, 2022; Cui, 2022; Liu, 2022; Cao, 2021), as well as on receptive and productive knowledge (Ying & Ismail, 2022; Wang & Suwanthep, 2017), with fewer studies examining the form, meaning, and comprehensive use of words (Liu, 2021; Chen, 2019; Bohinski, 2012; Ferguson, 2009). Therefore, this study will investigate the short-term and long-term recall effects of mobile-based versus paper-based word cards on EFL vocabulary knowledge, focusing on spelling, form-meaning connections, and word use.

This study is guided by the following research questions:

RQ1: Do mobile vocabulary application (Bai Cizhan) and traditional vocabulary learning approach have any effect on the Immediate Recall Test in terms of form, meaning and use for low proficiency EFL learners in Chinese private university?

H_01: There is no significant difference between the mobile vocabulary application (Bai Cizhan) and the traditional vocabulary learning approach on the Immediate Recall Test in terms of form, meaning and use for low proficiency EFL learners in Chinese private university.

RQ2: Do the mobile vocabulary application (Bai Cizhan) and traditional vocabulary learning approach have any effect on the Delayed Recall Post Test in terms of form, meaning and use for low proficiency EFL learners in Chinese private university?

H_02: There is no significant difference between the mobile vocabulary application (Bai Cizhan) and the traditional vocabulary learning approach on the Delayed Recall Post Test in terms of form, meaning and use for low proficiency EFL learners in Chinese private university.

2. Literature Review

2.1 Vocabulary Acquisition in EFL

Although vocabulary acquisition is a cornerstone of success in English as a Foreign Language (EFL) education, it presents substantial challenges. EFL learners face limitations in exposure to authentic English environments and the sheer volume of words to learn, requiring tailored instruction to address their preferences for memorization versus contextual learning (Zhou, 2023). In response, educators are exploring innovative approaches like multimedia resources and gamification to improve vocabulary acquisition (Kingsley & Grabner-Hagen, 2015). Effective vocabulary learning strategies are crucial for enhancing EFL learners' proficiency in English. This literature review explores various strategies, emphasizing contextual learning, mnemonic devices, and digital tools.

2.2 Previous Studies on Mobile Apps in EFL

Mobile applications have become increasingly integrated into English as a Foreign Language (EFL) learning environments, offering both opportunities and challenges. Research indicates that mobile apps significantly enhance vocabulary acquisition through interactive exercises, multimedia features, and spaced repetition algorithms, providing contextualized learning experiences and immediate feedback (Nikitina, 2024; Zhang, Zou & Xie, 2022). For instance, studies by Agarwal, Nunes & Blunt (2021) and Latimier, Peyre & Ramus (2021) highlight these benefits, demonstrating improved systematic vocabulary retention and retrieval. Furthermore, integrating mobile apps into classroom instruction, as explored by Yu, et al., (2022) and Firipis (2021), promotes student engagement and active participation, complementing traditional teaching methods and catering to diverse learning styles.

Motivation and engagement are also positively influenced by mobile app usage in EFL learning. Studies by Kukulska-Hulme and Shield (2008) and Traxler (2007) show that the interactive nature and gamification elements of mobile apps foster intrinsic motivation (Luarn, Chen & Chiu, 2023; Mohammed & Ozdamli, 2021), encouraging sustained interest and effort in language learning activities. Despite these advantages, challenges such as technical issues, privacy concerns, and equitable access to technology, as noted by Burston (2014) and Crompton (2013), need to be addressed for seamless implementation. In conclusion, while mobile apps hold significant potential to enhance EFL learning, future research should focus on innovative app designs, effective pedagogical strategies, and sustainable implementation models to optimize their educational benefits.

2.3 Bai Cizhan App

2.3.1 Features and Functionality

Bai Cizhan is a popular Chinese language learning app focused on improving vocabulary through interactive and engaging methods. It introduces new words using flashcards that display Chinese characters, Pinyin, English translations, example sentences, and related images to aid memory.

The app utilizes spaced repetition and interactive activities to reinforce learning. The spaced repetition algorithm schedules reviews at optimal intervals for long-term retention, while interactive activities like matching words with images, filling in blanks, and choosing correct translations keep learners engaged.

Bai Cizhan also offers a robust testing and feedback system. Learners start with an initial test to assess their level, followed by daily quizzes and periodic review tests to ensure retention. The app adapts to the user's progress, offering personalized word lists and detailed progress reports that highlight strengths and areas needing more review.

Additionally, Bai Cizhan promotes community and social learning. Users can join study groups to collaborate on vocabulary learning and compare their performance with friends and other learners, fostering a sense of competition and community. The app's combination of visual aids, gamification, and personalized study plans makes vocabulary learning both effective and enjoyable.

Bai Cizhan is a popular Chinese language learning app designed to help learners improve their vocabulary and focused on memorizing new words through various interactive and engaging methods. The app introduces new words using flashcards, which include the word in both Chinese characters and Pinyin, its English translation, example sentences, and an image related to the word to aid memory.

2.3.2 Previous Research on Effectiveness of Bai Cizhan App on EFL Vocabulary Acquisition

The Bai Cizhan app has gained popularity among English learners for its innovative approach to vocabulary acquisition. Studies in China have demonstrated its effectiveness in improving overall vocabulary knowledge and both receptive and productive vocabulary skills across different proficiency levels. For instance, Cao (2021) found that middle school students using Bai Cizhan showed significantly greater vocabulary gains than those in a control group after one semester.

Chen (2021) supported these findings with a study on senior high school students, showing a significant improvement in word dictation performance for those using Bai Cizhan. Guo (2022) also highlighted the app's benefits, particularly for low-proficiency learners. Meanwhile, Cui (2022) combined Mobile-Assisted Language Learning (MALL) with traditional classroom instruction and found notable improvements in vocabulary acquisition after four months of using Bai Cizhan, though results were not significantly different after just two months compared to traditional methods.

Zhang (2022) compared Bai Cizhan with the Bubei Danci app in a study involving 16 participants, revealing that both apps significantly enhanced vocabulary retention immediately and one week after learning. However, no significant difference was found between the two apps. Interviews suggested that individual learning preferences and strategies, such as the use of pictures and context sentences, played a role in the outcomes. Some students noted that while the apps helped them remember images, they struggled with spelling and word usage.

The primary strength of Bai Cizhan lies in its visual aids, review functions, and motivational features, which enhance word recall. Its query function also allows users to review vocabulary in their preferred order. However, most research has focused on overall vocabulary size, with limited studies addressing the form, meaning, and usage of vocabulary knowledge.

2.4 Theoretical Framework

The theoretical framework of this study is based on Dual Coding Theory, which offers insights into the cognitive processes involved in language learning and memory retention. Introduced by Allan Paivio, Dual Coding Theory suggests that information is processed and stored in two interconnected systems: verbal (language-based) and non-verbal (visual or sensory-based) (Paivio, 2014). In language learning, presenting vocabulary through both verbal (written/spoken) and non-verbal (images/gestures) modalities enhances learning outcomes by creating richer mental representations, supporting better memory storage and retrieval.

Dual Coding Theory highlights the effectiveness of multimedia approaches in language education, advocating for the use of visual aids, audio materials, and interactive exercises to reinforce vocabulary learning and comprehension. This framework provides a solid foundation for understanding the cognitive mechanisms behind vocabulary acquisition among EFL learners and guides the design of educational interventions. It is particularly

relevant for digital tools and instructional strategies aimed at improving both short-term and long-term memory retention in language learning. This theory provides a valuable framework for understanding how multimedia resources might improve the durability and depth of vocabulary acquisition.

3. Methodology

3.1 Research Design

The study employed a quasi-experimental design (Creswell, 2014). involving two groups: an experimental group using the Bai Cizhan app and a control group receiving traditional vocabulary instruction. The design is shown in below Table 1.

Table 1. Non-randomized (Pre-test, Immediate Recall Test and Delayed Post-test) with Control Group Design

Group	Pre-test	IV	Immediate Test	No Intervention	Delayed Post-test
EG	Y1	X	Y2	-	Y3
CG	Y1	-	Y2	-	Y3
Total	82				82

(Adapted from Creswell, 2014)

3.2 Participants

Participants were drawn from a population of EFL (English as a Foreign Language) learners at A private university in China. A total of 82 non-English majors were recruited, ensuring a representative sample of learners at similar proficiency levels. Participants were randomly assigned to either the experimental group or the control group. Random assignment was conducted to minimize selection bias and ensure that both groups were comparable at the outset. Experimental class consists of 38 learners and traditional class is made up of 44 learners, matching the requirements for statistical power and ensuring sufficient sample size for meaningful analysis. Prior to the intervention, all participants completed a pretest assessing their baseline knowledge of vocabulary form, meaning, and use. This pretest established a control for initial differences between groups.

3.3 Instruments

3.3.1 Bai Cizhan Mobile Application

The study utilized Bai Cizhan, a free and popular English vocabulary learning app developed by Chengdu Chaoyouai Technology Co., Ltd., which caters to Chinese students preparing for various English exams, including CET-4, CET-6, IELTS, TOEFL, and GRE. The app is designed for students aged 12 to 24 and employs interactive methods like flashcards, visual aids, gamification, personalized learning, audio pronunciation, a review system, and community features to help learners memorize new words.

Conducted outside regular English classes, the study used different vocabulary learning tools for two groups: the experimental group used the Bai Cizhan app, while the control group used a physical word list. Bai Cizhan was chosen for its features such as spaced repetition, audio pronunciation, L1 support, and the unique "Zhan" vocabulary test. The app introduces a vocabulary item with audio pronunciation and four images. If the user fails to select the correct image, the app provides context and the word's meaning in the user's native language (L1). If the word remains unrecognized, the English definition is shown. Upon correct identification, the app offers more details, including part of speech, L1 meaning, images, sample sentences, and related collocations, helping users gain a deeper understanding of the word.

For reviews, the app provides exercises like multiple choice and fill-in-the-blank, where users must type the correct word into a sentence. The app uses spacing algorithms to monitor and record user performance, adjusting the retrieval sequence based on familiarity with each word. As users complete a set of vocabulary items, the app introduces new ones, with the sequence determined by its algorithm.
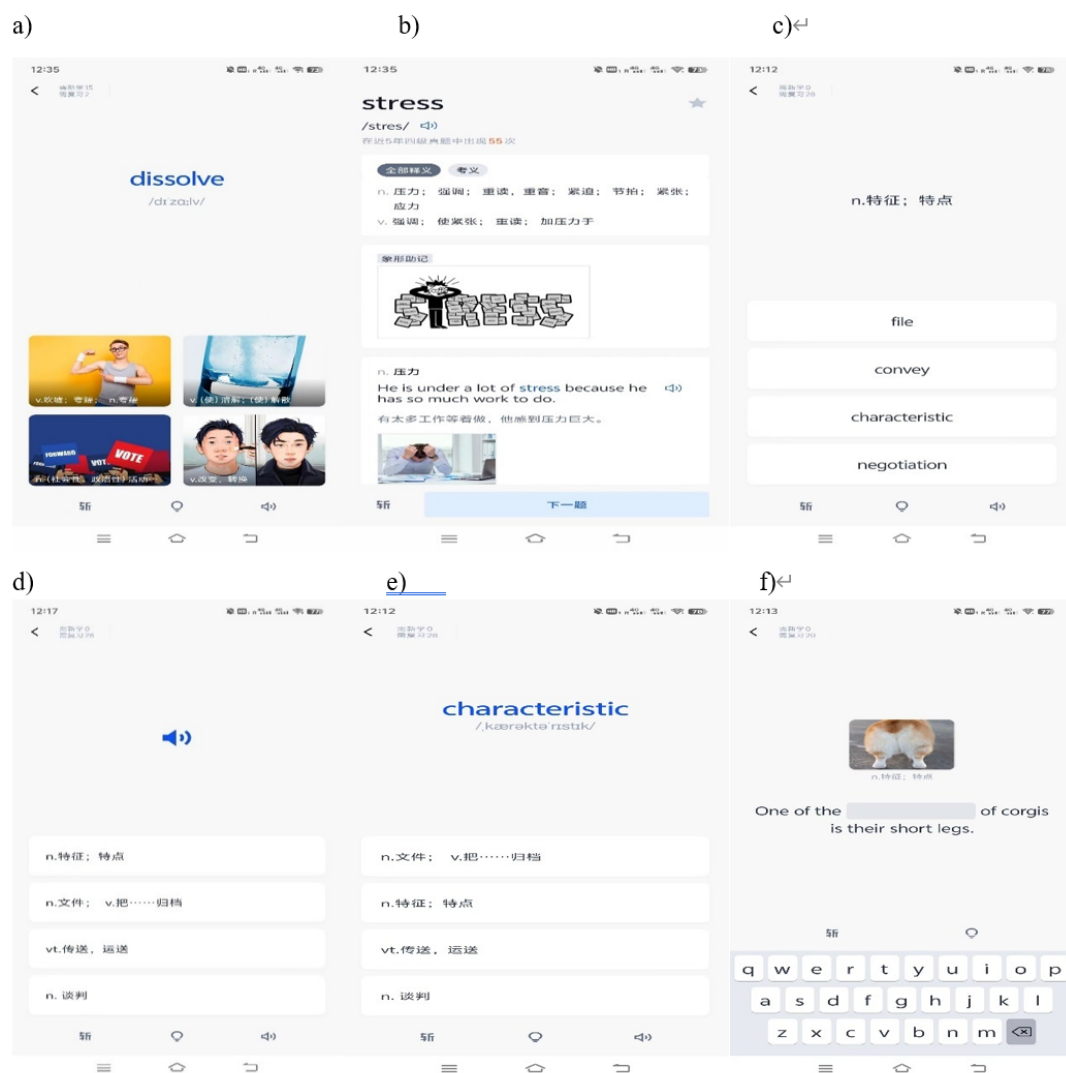
Figure 1. Screenshots of the Bai Cizhan App Used by the Experimental Group

For this study, the wordlist used by the control group had to align with the content of the mobile app. To maintain consistency across both the wordlists and the app, identical vocabulary items, L1 definitions, phonetic symbols, parts of speech, and sample collocations were replicated from the app onto the wordlist. The primary distinctions between the two learning tools were as follows: in the app, English vocabulary items were automatically presented, followed by form-meaning connection exercises to test users; the app's retrieval sequence was adjusted based on the user's performance and skill level; it provided standard audio pronunciations of the words; and it notified users when they had completed a set of assigned learning tasks. In contrast, the control group's wordlist could not reflect an individual's learning progress in the same manner.

3.3.2 Vocabulary Testing Instruments

To evaluate learners' short-term and long-term memory of vocabulary knowledge, focusing on form, meaning, and use, a series of assessments were administered: a pre-test during orientation, an immediate recall test in the third week, and a delayed post-test at the end of the semester. All three tests contained identical content. The assessment employed three types of questions—dictation, multiple choice, and fill-in-the-blanks—to measure vocabulary knowledge development, with questions organized into three sections to assess form, meaning, and use (see Appendix in the supplementary material for the complete test battery).

The first section, which assessed the spelling of words in written form (Nation, 2001, p. 603; Brown, 1998; Kreiner & Gough, 1990), was designed to evaluate productive knowledge of word form. An example of a vocabulary item set used in this section is illustrated in Extract 1.

Extract 1. Sample of the section testing productive knowledge in word form

Word Dictation (1 point*10=10 points)

1._____

2._____

3._____

The second section, designed to assess receptive knowledge, utilized multiple-choice questions to evaluate the connection between form and meaning. This section aimed to measure the learners' understanding of vocabulary in terms of its form-meaning connection. An example of a vocabulary item set used in this section is illustrated in Extract 2.

Extract 2. Sample of the section testing receptive knowledge in form -meaning connection

Table 2. Matching (1 point*10=10 points)

Answers	Target Words	Definitions
( )	1. underneath	A. to cause (it to explore);(v.)
( )	2. trigger;	B. a person or a book that provides information for a news story or for a piece of research(n.)
( )	3. replace;	C. unusual; unexpected;

Productive knowledge was assessed to evaluate the extent to which students acquired the ability to use words appropriately in grammatical contexts (Nation, 2001, p. 538). An example of this assessment is presented in Extract 3.

Extract 3. Sample of section testing productive knowledge in grammatical functions

Fill in the blanks with given words in the box. Please change the form if necessary. (1 point *10=10 points)

1. Each statement _____information given in one of the paragraphs. (contain)

2. A capsule containing vitamin B_____ by her under doctor's guide yesterday. (swallow)

3. Keep your office space looking good,_____ your desk. (particular)

Immediate Recall Tests were used to immediately evaluate the benefits of vocabulary learning. A reliable vocabulary test should have at least 30 items, according to Beglar and Hunt (1999, as referenced in Nation, 2001, p. 536). Word form was tested using the dictation format as the first Section (10 items), word meaning was tested using the form-meaning link as the second Section (10 items), and word use was tested as the third Section (10 items), measuring students' knowledge of grammar in the inflectional change of content words. Students were required to write down appropriate responses for Sections 1, 2 and 3. Each test, administered by the English teacher in each class, lasted 20 minutes. The pre-test, immediate test, and post-test of vocabulary knowledge exhibited a high level of reliability, with Cronbach's alpha values of .87 and .91 for the two groups of learners. To assess the internal consistency of the quantitative data—specifically, the dichotomously scored vocabulary knowledge tests—Kuder-Richardson Formula 20 (KR-20) was employed (Ary, Razavieh, & Jacobs, 2003).

3.4 Procedure

Data collection for the study involved a comprehensive approach, combining assessments and usage metrics to evaluate vocabulary acquisition and the impact of the Bai Cizhan app.

Initially, participants' vocabulary knowledge was assessed through three types of tests: a Form Test, which measured their ability to recognize and reproduce vocabulary forms; a Meaning Test, which evaluated their understanding of vocabulary meanings through L1 definitions; and a Use Test, which examined their ability to use vocabulary words in grammar correctly in sentences or practical contexts. These pretests established a baseline for evaluating the effectiveness of the intervention.

For the experimental group using the Bai Cizhan app, additional data on app usage was collected, including the frequency of use, types of exercises completed, and session durations. This data helped in understanding the relationship between app engagement and learning outcomes.

Following the initial assessments, participants in the experimental group installed the Bai Cizhan app on their smartphones and received one hour of classroom training on its use for vocabulary learning outside of class. The

app's features, including the creation of small virtual classes, facilitated convenient tracking of individual learning progress by the teacher or researcher.

The treatment period lasted four months, during which participants were enrolled in a college English course at a private institution designed to develop comprehensive language skills. The control group continued their studies using a paper-based word list, while the experimental group utilized the Bai Cizhan app to enhance their vocabulary outside of the classroom. Despite being taught by different instructors, both groups followed the same institutional syllabus and used identical materials and methods.

At the end of the treatment, participants' vocabulary knowledge was reassessed. A delayed post-test was administered one month after the completion of the intervention to measure the long-term effects of the vocabulary learning strategies employed.

To analyze the impact of the Bai Cizhan app on vocabulary learning, Descriptive Statistics and Inferential Statistics (MANOVA) were employed. Effect Size was calculated to quantify the magnitude of differences between groups and the practical significance of the findings.

4. Data Analysis and Results

Vocabulary test scores were analyzed using IBM SPSS (version 25) to perform both descriptive and inferential statistical analyses. Table 3 presents the descriptive statistics, which detail the mean scores for the various learning groups.

Table 3. Descriptive Statistics of Pretest, Immediate Recall Tests and Delayed Posttest of Control and Experimental Groups

Group N	Form		Meaning		Use	
	M	SD	M	SD	M	SD
PreEG	8.16	3.50	5.58	2.20	3.03	2.27
PreCG	8.23	3.89	6.23	3.54	2.36	2.78
ImmeEG	15.05	3.77	10.18	4.62	7.55	3.13
ImmeCG	10.98	4.39	13.09	3.81	6.93	3.19
DelayedEG	12.84	3.61	6.71	3.62	8.3947	3.54
DelayedCG	11.64	3.95	7.68	3.23	8.3864	2.64

As seen in Table 3. the mean scores of pretests in Form, Meaning and Use for the experimental group (M_{form}=8.16, $M_{meaning}$=5.58, M_{use}= 3.03) is near the same the control group (M_{form}=8.23, $M_{meaning}$=6.23, M_{use}=2.36). By comparing mean scores of independent T-test, there is no significant difference in EG and CG in form, meaning and use (P_{form}=.933; $P_{meaning}$=.434; P_{use}=.200).

This section outlines the statistical procedures used to address the research questions, employing a one-way MANOVA to assess the dependent variables: form, meaning, and use. MANOVA requires continuous dependent variables and at least one independent variable with two or more categorical groups. Observations were independent, and the sample size was adequate for MANOVA. The dependent variables were both conceptually and statistically correlated, with basic vocabulary knowledge in low proficiency EFL learners assessed through performance in form, meaning, and use. Details of the correlation test are in the next section. Before running the MANOVA, assumptions were verified, and results from testing these assumptions in SPSS are presented below.

4.1 Test for Outliers and Linear Relationship

The data from the Form, Meaning and Use test were checked for outliers and linearity as MANOVA requires a linear relationship to be present between each pair of the dependent variables across each level of the independent variable.

Table 4. Descriptive Statistics for Outliers in Immediate Recall Tests

Items	Types	Mahalanobis Distance	Types	Items	
Form in Immetest	Min	0.853	Min	Form	in
	Max	1.144	Max	Delayedtest	
Meaning in Immetest	Min	0.853	Min	Meaning	in
	Max	1.144	Max	Delayedtest	
Use in Immetest	Min	0.853	Min	Use	in
	Max	1.144	Max	Delayedtest	

For a degree of freedom (df=1) and a significance level (p=0.001), the critical value in the chi-square distribution table is 10.828. This means that observations with a Mahalanobis distance exceeding 10.828 can be considered outliers. According to the table 4 above, the maximum value (1.144) and the minimum value (0.853) are both smaller than the critical value, so there are no outliers.

Meanwhile, a Matrix Scatterplot diagram was built to test whether a linear relationship existed in Immediate tests and Delayed post Tests separately. The test found a linear relationship which could be explained from the Matrix Scatter Plot below (Figure 2).
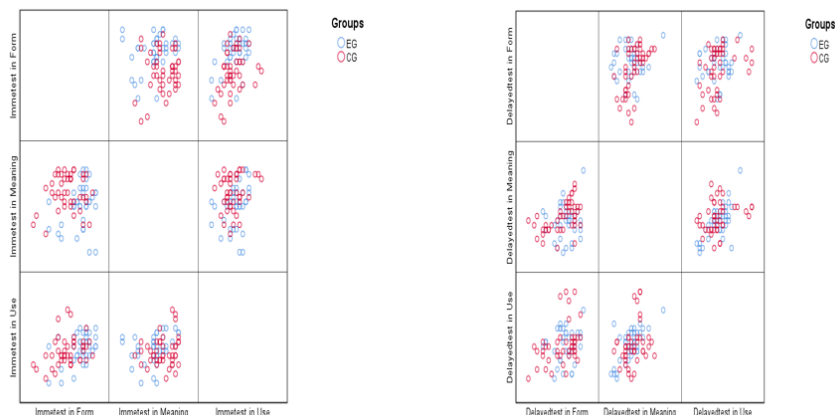

Figure 2. Linear Relationship among Form, Meaning and Use across Learning Approaches in Immediate Recall Tests (Left) and Delayed Recall Tests (Right)

From the above Figure 2, it can be seen that shows that there was an elliptical pattern moving from the bottom left to the top right of the boxes in Immediate Recall tests and Delayed Recall tests in both groups. Thus, it can be said that the general pattern of linear relationship existed, so the assumption of linear relationship was not violated.

4.2 Multivariate Normality

Table 5. Tests of Normality

	Groups	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest in Form	EG	.140	38	.059	.972	38	.440
	CG	.094	44	.200*	.961	44	.146
Pretest in Meaning	EG	.133	38	.087	.970	38	.401
	CG	.148	44	.017	.961	44	.137
Pretest in Use	EG	.130	38	.108	.925	38	.014
	CG	.156	44	.009	.940	44	.023
Immetest in Form	EG	.130	38	.105	.953	38	.114
	CG	.078	44	.200*	.974	44	.407
Immetest in Meaning	EG	.164	38	.012	.950	38	.092
	CG	.132	44	.051	.961	44	.138
Immetest in Use	EG	.136	38	.075	.932	38	.023
	CG	.135	44	.043	.959	44	.116
Delayed test in Form	EG	.095	38	.200*	.961	38	.204
	CG	.111	44	.200*	.961	44	.142
Delayed test in Meaning	EG	.111	38	.200*	.950	38	.092
	CG	.108	44	.200*	.981	44	.677
Delayed test in Use	EG	.121	38	.178	.960	38	.197
	CG	.109	44	.200*	.976	44	.467

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Multivariate normality was also assumed after being tested. The above Table 5 presented the results of the normality test. It can be seen that the significance values of two immediate recall test in terms of form, meaning and use were almost above .05 in two groups, indicating that the data met the assumption of multivariate normality.

4.3 Multivariate Homogeneity of Variances

Table 6. Box's Test of Equality of Covariance Matrices[a]

	Pretests	Immediate Recall Tests	Delayed Recall Tests
Box's M	6.402	3.755	21.077
F	1.023	.600	3.369
df1	6	6	6
df2	43709.945	43709.945	43709.945
Sig.	.408	.731	.003

a. Design: Intercept + Groups

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups in Pretests, Immediate recall tests and Delayed recall tests.

The homogeneity of covariance matrices in pretests, Immediate Recall Tests and Delayed Recall tests were checked during the one-way MANOVA procedure. Box's M Test is to test equality of covariance between the groups, which is the equivalent of a multivariate homogeneity of variance. Usually, significance for this test is set at $\alpha = .001$ because it is considered highly sensitive. As shown in Table 6 above, the obtained significance value of .408/731/.003 which is larger than .001 concluded that the assumption of homogeneity of covariance matrices was met.

4.4 Test of no Multicollinearity

Table 7. Coefficients[abc]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Groups	1.000	1.000

a. Dependent Variable: Pretests in Form/meaning/use

b. Dependent Variable: Immediate tests in Form/meaning/use

c. Dependent Variable: Delayed Posttests in Form/meaning/use

It is generally understood that a VIF value greater than 10 indicates the presence of multicollinearity and tolerance value less than 0.1 also indicates the presence of multicollinearity. By examining the VIF and Tolerance values in the Coefficients table 7 above, both values equal to 1, which confirmed that the assumption of no multicollinearity between the dependent variables was also met.

The one-way MANOVA was conducted to determine the effects of vocabulary learning app and conventional leaning approach on three dependent variables (form, meaning and use) of EFL low proficiency learners in the present study. MANOVA was considered to be an appropriate analysis technique as no violation of MANOVA assumptions was detected prior to the procedure.

4.5 Comparison of Effects Between Groups in Immediate Tests

The first objective of the study was to determine the short-term retention of mobile vocabulary app on the vocabulary knowledge achievement of EFL learners compared with traditional group. Vocabulary knowledge achievement in the present study was determined by form, meaning and use. The one-way MANOVA procedure was performed to test RH0l: There is no significant mean difference in the achievement of words retained in terms of form, meaning and use in the short-term recall among low proficiency EFL learners between control group and experimental group in Chinese private university.

Table 7. Multivariate Testsa

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.956	569.707[b]	3.000	78.000	.000	.956
	Wilks' Lambda	.044	569.707[b]	3.000	78.000	.000	.956
	Hotelling's Trace	21.912	569.707[b]	3.000	78.000	.000	.956
	Roy's Largest Root	21.912	569.707[b]	3.000	78.000	.000	.956
Groups	Pillai's Trace	.415	18.443[b]	3.000	78.000	.000	.415
	Wilks' Lambda	.585	18.443[b]	3.000	78.000	.000	.415
	Hotelling's Trace	.709	18.443[b]	3.000	78.000	.000	.415
	Roy's Largest Root	.709	18.443[b]	3.000	78.000	.000	.415

a. Design: Intercept + Groups

b. Exact statistic

Computed using alpha= .001

Result: RH_01 was rejected (Wilks' Lambda=.585, F (3, 78) =18.443; P<.001)

The first research question was done to compare differences in form, meaning and use in short-term memory by levels of learning approach. The results of Multivariate Analysis of Variance presented in Table 7 above shows that a significant difference was found between experimental group and conventional group on the dependent variables. Wilks' Lambda =.585, F (3, 78) = 18.443, p < .001, partial η^2 = .415. This indicates that different groups have a substantial and significant effect on the combined variance of the dependent variables. In other words, there was a significant difference in the vocabulary knowledge when different learning approaches were used. The effect size for the groups (.415) showed that the groups explain 41.5% of the changes in vocabulary knowledge, which means a substantial effect can be explained by the treatment.

Table 8. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Imme test in Form	338.652[a]	1	338.652	23.957	.000	.230
	Imme test in Meaning	172.275[b]	1	172.275	16.342	.000	.170
	Imme test in Use	7.859[c]	1	7.859	1.065	.305	.013
Intercept	Imme test in Form	13815.530	1	13815.530	977.336	.000	.924
	Imme test in Meaning	11046.031	1	11046.031	1047.828	.000	.929
	Imme test in Use	4277.859	1	4277.859	579.862	.000	.879
Groups	Imme test in Form	338.652	1	338.652	23.957	.000	.230
	Imme test in Meaning	172.275	1	172.275	16.342	.000	.170
	Imme test in Use	7.859	1	7.859	1.065	.305	.013
Error	Imme test in Form	1130.872	80	14.136			
	Imme test in Meaning	843.347	80	10.542			
	Imme test in Use	590.190	80	7.377			
Total	Imm etest in Form	15043.000	82				
	Imme test in Meaning	12325.000	82				
	Imme test in Use	4872.000	82				
Corrected Total	Imme test in Form	1469.524	81				
	Imme test in Meaning	1015.622	81				
	Imme test in Use	598.049	81				

a. R Squared = .230 (Adjusted R Squared = .221)

b. R Squared = .170 (Adjusted R Squared = .159)

c. R Squared = .013 (Adjusted R Squared = .001)

Analyses on the three dependent variables revealed significant difference for form, F (1, 80) = 23.957, p < .05, partial η^2 = .230, significant difference for meaning, F (1, 80) = 16.342, p < .05, partial η^2 = .170 and significant difference for use, F (1, 80) = 1.065, p> .05, partial η^2 = .013. According to Cohen's widely accepted interpretation of the effect size of η^2: (.14 is large; .06 is medium, .01 is small, <.01 is trivial), it means there is a large effect size in form and meaning, while there is a small effect size on use. In other words, 23% and 17% variances in form and meaning are accounted for and only 1.3% variances in use are accounted for by levels of learning approach in Immediate Recall Tests, indicating that there was a significant difference in form and meaning but no difference in use when different learning approaches were used in two Immediate Recall Tests.

In brief the first research objective (RO1) was partially achieved. This is because the vocabulary learning app demonstrated a significant advantage in enhancing short-term memory for word form and meaning, which aligns with the core principles of Dual Coding Theory. Dual Coding Theory emphasizes that memory can be enhanced by presenting information both visually and verbally. Bai Cizhan utilizes multimedia presentations that combine visual and textual elements, allowing learners to effectively remember word forms and meanings in the short term. However, the app's impact on short-term memory for word use was less pronounced. This may be because learning word usage often requires more complex cognitive processing and application in real contexts, which cannot be fully supported by dual coding alone. Therefore, while dual coding theory provides effective support for short-term memory of word forms and meanings, additional instructional strategies or learning tools may be necessary to improve memory retention for word usage.

4.6 Comparison of Effects Between Groups in Delayed Recall Posttests

This section addresses Research Objective 2 and Research Question 2. The second objective of the study was to determine the long-term effects of mobile vocabulary app on the vocabulary knowledge achievement among low proficiency EFL learners. Vocabulary knowledge achievement in the present study was also determined by form, meaning and use. RH02 There is no significant difference in the achievement of vocabulary knowledge in terms of form, meaning and use in the long-term recall among low proficiency EFL learners between control group and experimental group in Chinese private university. The one-way MANOVA was conducted to determine the effects of mobile app and conventional leaning approach on three dependent variables (form, meaning and use) of EFL low proficiency learners in delayed recall test. MANOVA was considered to be an appropriate analysis technique as no violation of MANOVA assumptions was detected prior to the procedure.

Table 9. Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.913	271.509[b]	3.000	78.000	.000	.913
	Wilks' Lambda	.087	271.509[b]	3.000	78.000	.000	.913
	Hotelling's Trace	10.443	271.509[b]	3.000	78.000	.000	.913
	Roy's Largest Root	10.443	271.509[b]	3.000	78.000	.000	.913
Groups	Pillai's Trace	.059	1.641[b]	3.000	78.000	.187	.059
	Wilks' Lambda	.941	1.641[b]	3.000	78.000	.187	.059
	Hotelling's Trace	.063	1.641[b]	3.000	78.000	.187	.059
	Roy's Largest Root	.063	1.641[b]	3.000	78.000	.187	.059

a. Design: Intercept + Groups

b. Exact statistic

Computed using alpha= .05

Result: Fail to reject RH_02 (Wilks' Lambda=.187, F (3, 78) =1.641; P>.05)

Table 9 above shows that no significant difference was found overall between mobile vocabulary learning approach and conventional leaning approach on the dependent variables (Wilks' Lambda =.187, F (3, 78) =1.641; P>.05.). In other words, there was no significant difference in the vocabulary knowledge when different learning approaches were used. Effect size at .059 showed a medium effect which meant that only 5.9% of the changes in vocabulary knowledge can be explained by the treatment as a whole.

Table 10. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Delayed test in Form	29.644[a]	1	29.644	1.584	.212	.019
	Delayed test in Meaning	19.236[b]	1	19.236	1.649	.203	.020
	Delayed test in Use	.001[c]	1	.001	.000	.993	.000
Intercept	Delayed test in Form	12217.741	1	12217.741	652.816	.000	.891
	Delayed test in Meaning	4223.627	1	4223.627	362.014	.000	.819
	Delayed test in Use	5742.001	1	5742.001	350.788	.000	.814
Groups	Delayed test in Form	29.644	1	29.644	1.584	.212	.019
	Delayed test in Meaning	19.236	1	19.236	1.649	.203	.020
	Delayed test in Use	.001	1	.001	.000	.993	.000
Error	Delayed test in Form	1497.234	80	18.715			
	Delayed test in Meaning	933.361	80	11.667			
	Delayed test in Use	1309.511	80	16.369			
Total	Delayed test in Form	13722.000	82				
	Delayed test in Meaning	5241.000	82				
	Delayed test in Use	7082.000	82				
Corrected Total	Delayed test in Form	1526.878	81				
	Delayed test in Meaning	952.598	81				
	Delayed test in Use	1309.512	81				

a. R Squared = .019 (Adjusted R Squared = .007)

b. R Squared = .020 (Adjusted R Squared = .008)

c. R Squared = .000 (Adjusted R Squared = -.012)

As is indicated on the effect as a whole in table 10, Analyses on the three dependent variables also revealed no significant difference for form, $F (1, 80) = 1.584$, $p > .05$, partial $\eta^2 = .019$, for meaning, $F (1, 80) = 1.649$, $p > .05$, partial $\eta^2 = .020$, and for use, $F (1, 86) = .728$, $p > .05$, partial $\eta^2 = .008$. According to effect size conventions: (.01 is small, <.01 is trivial), it means there is a small effect size in form and meaning, and trivial effect size in use in long-term memory. In another word, only 1.9% and 2.0% variances in form and meaning and no variances in use are accounted for by levels of learning approach.

In brief, the second research objective (RO2) was not achieved. This is because no significant effect on form, meaning and use was found between experimental group and control group in long-term recall. This observation can be interpreted through the lens of Dual Coding Theory, which posits that presenting information both visually and verbally enhances memory. While the app effectively utilizes multimedia elements to support short-term retention, the limited long-term retention observed suggests that dual coding alone may not be sufficient for sustained vocabulary acquisition. Dual Coding Theory emphasizes the role of visual and verbal encoding in enhancing memory; however, long-term retention often requires deeper cognitive engagement and repeated exposure to the vocabulary in various contexts. The Bai Cizhan app's approach, while beneficial for initial learning, might need to be complemented with additional strategies such as spaced repetition, contextual practice, or more immersive learning experiences to strengthen long-term retention. These methods can help reinforce the encoding of vocabulary over extended periods and ensure that the learned vocabulary transitions from short-term to long-term memory.

5. Discussion

5.1 The Effects of Mobile Vocabulary App on Short-term Vocabulary Memory in Terms of Form, Meaning and Use

Dual Coding Theory posits that information is processed and stored through two interconnected systems: the verbal system and the visual system. According to the theory, memory and learning are enhanced when information is encoded both verbally—through text or speech—and visually—through images or diagrams. Engaging both cognitive channels allows learners to form more comprehensive and accessible mental representations, which leads to improved retention and recall.

In this study, the observed improvement in total scores for both groups support previous research showing that both paper-based word lists and mobile apps are effective tools for vocabulary learning (Yüksel, Mercanoğlu & Yilmaz, 2022; Li & Hafner, 2021; Klimova, 2021; Lin & Lin, 2019; Lin, Zhou & Yang, 2018; Ludwig, 2018). These gains can be largely attributed to the retrieval process, which involves recalling vocabulary-related information. This strategy has been proven to significantly enhance foreign language vocabulary acquisition (Nakata et al., 2021; Nakata, 2017; Chen & Chung, 2008; Barcroft, 2007).

In examining the between-subjects effects of the Bai Cizhan app on short-term vocabulary retention, the analysis revealed notable efficacy, particularly in terms of form (p=.000) and meaning (p=.000). Participants in the experimental group demonstrated a significant improvement in recalling and recognizing the form of newly learned words shortly after exposure, compared to those in the wordlist group (Xu, Ma & Huang, 2023; Hao, 2019). This finding aligns with previous research suggesting that the retrieval of material significantly enhances L2 vocabulary learning (Li & Hafner, 2021; Barcroft, 2007). The app's engaging interface, along with its repetitive practice exercises, reinforces both visual and auditory recognition of words. Additionally, the provision of immediate feedback on exercises and quizzes further supports the reinforcement of correct word forms and meanings, helping users identify areas for improvement. This timely feedback fosters self-regulated learning behaviors, encouraging learners to actively monitor their progress (Wei, 2023; Palalas & Wark, 2020). Moreover, the integration of multimedia elements, such as images and example sentences, likely contributed to the enhanced retention of word meanings by providing contextual understanding that aids memory consolidation (Wang, 2021).

While the Bai Cizhan app excels at facilitating short-term recall of vocabulary form and meaning, particularly through instant access to definitions and examples, it appears to be less effective in promoting long-term retention and practical vocabulary use. The app's primary focus on isolated word learning, rather than contextualized language acquisition, may lead to a superficial understanding where users quickly grasp the form and meaning of words but struggle to apply them accurately and fluently in real-life communication. Although the app includes features like "Words Practice," which emphasize form and meaning, there is limited emphasis on practical usage, despite the availability of the "Love Reading" feature. As a result, while users may recall and recognize words, their ability to use these words in context, such as inflected forms, remains limited in the short term (p=.305) compared to those in traditional learning groups.

In summary, the Bai Cizhan app is highly effective in helping users quickly memorize vocabulary items and understand their meanings. However, it falls short in encouraging the active use of these words in meaningful contexts. Future app designs should incorporate exercises that promote the use of vocabulary in sentences and conversations, thereby bridging the gap between recognition and practical application.

5.2 The Effects of Mobile Vocabulary App on Long-term Vocabulary Memory in Terms of Form, Meaning and Use

Although the Bai Cizhan app shows notable short-term benefits in vocabulary form and meaning, it does not significantly outperform traditional methods in supporting long-term retention across form, meaning, and use (Wilks' Lambda = .187, F (3, 78) = 1.641; P > .05). Over a 16-week period, while there was a slight improvement from pretests, the change was not substantial. This outcome suggests a partial alignment with Dual Coding Theory, as the app's dual modality of visual and verbal input appears to support short-term memory effectively, but falls short in fostering long-term retention.

Klimova (2021) similarly found that mobile apps need guided and controlled implementation to achieve effective long-term learning. Klimova noted that while apps might enhance short-term retention of isolated words or phrases, consistent practice is required to strengthen long-term memory, indicating that the benefits observed with the Bai Cizhan app might be constrained to short-term gains rather than lasting retention. This supports the view that while dual coding can enhance immediate recall, it may not suffice for deeper, enduring learning without additional reinforcement.

Bohinski (2012) also reported no significant improvement in long-term retention of Spanish nouns despite using visual support methods, suggesting that similar to Bai Cizhan, the reliance on passive techniques might not effectively support long-term memory. Conversely, Yuan (2019) found that students using a mobile app outperformed those receiving traditional instruction across multiple vocabulary dimensions, indicating that mobile apps can be effective for long-term learning when combined with appropriate instructional strategies.

The ease and immediacy with which Bai Cizhan provides vocabulary definitions may inadvertently limit long-term retention. Immediate access to word meanings could discourage deeper cognitive processing, leading to a superficial understanding of vocabulary. This reliance on quick reference might prevent learners from engaging in more meaningful and sustained learning activities, thus hindering long-term retention.

In conclusion, while the Bai Cizhan app effectively supports short-term vocabulary learning, particularly in terms of form and meaning, its impact on long-term retention is less pronounced. This suggests that while Dual Coding Theory is supported in terms of immediate memory enhancement, the app's passive learning techniques may not fully align with the theory's potential for deep, long-term retention. To improve long-term vocabulary memory, a more comprehensive approach is necessary, incorporating contextual learning, active use, varied practice, and personalized content alongside the app's existing features.

5.3 Implications for EFL Teaching

The study's findings have significant implications for educational technology in language learning. They highlight the potential of mobile apps to offer personalized, adaptive learning experiences tailored to the diverse needs of low-proficiency EFL learners. Developers can enhance app effectiveness by incorporating multimedia elements, immediate feedback, and gamification to boost engagement and retention. The research also emphasizes the importance of integrating features that support both short-term and long-term memory retention, such as spaced repetition, contextual learning, and interactive exercises. Additionally, the study advocates for continuous assessment and progress tracking within apps to help learners monitor their improvement and allow educators to tailor instruction. These insights can inform best practices in educational technology design, contributing to more effective and equitable language learning environments that support greater language proficiency and academic success.

6. Conclusion

This study contributes to mobile-assisted vocabulary learning research by comparing the effectiveness of mobile apps and paper-based wordlists across form, meaning, and use. While both methods were beneficial, the mobile app demonstrated superior gains in form and meaning knowledge, likely due to more frequent exposures and more effective short-term memory practice. The findings underscore the potential of smartphone-based vocabulary apps, especially when they integrate visual and auditory cues to enhance pronunciation recall and utilize multimedia to improve learning outcomes.

However, this study has several limitations. The out-of-classroom time was not controlled, which could have influenced the results. Additionally, the focus on Chinese learners limits the generalizability of the findings. Future research should include diverse learner groups and incorporate more longitudinal studies to assess the long-term effects of mobile-assisted vocabulary learning.

7. 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.

8. 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. The patients/participants provided their written informed consent to participate in this study.

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