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The Effectiveness Study on the Application of Bai CiZhan to High School English Vocabulary Memory Strategy

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ABSTRACT

With the advancement of network technology and the increasing prevalence of smartphones, mobile-assisted vocabulary learning has gained flexibility and popularity among language learners. This study investigates the effectiveness of the Bai CiZhan learning application on English vocabulary acquisition and memory strategies among senior high school students. Using a quasi-experimental design with 100 participants (50 in the experimental group and 50 in the control group) over one semester, this research employed pre- and post-vocabulary tests and strategy questionnaires to evaluate the application's impact. Results demonstrated that students using Bai CiZhan achieved significantly higher vocabulary scores ($M = 36.20$, $SD = 5.76$) than the control group ($M = 32.31$, $SD = 6.20$; $p < 0.001$). Specifically, significant improvements were observed in English interpretation, synonym group analysis, and word spelling (all $p < 0.01$), whereas no significant difference was found in the selection of appropriate word forms. Strategy assessment revealed significant enhancements in spelling strategy, association strategy, and word formation strategy (all $p < 0.05$), with no significant improvements in repetition, contextual, flexible application, and metacognitive strategies. This study contributes to mobile-assisted language learning research by providing empirical evidence for the selective effectiveness of vocabulary learning applications in enhancing specific memory strategies. The findings suggest that while mobile applications offer innovative pathways for vocabulary acquisition, they should complement rather than replace traditional instruction in comprehensive vocabulary development for high school English learners.

Keywords: Bai CiZhan Learning App; English Vocabulary Memory Strategies; High-School Students

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1. Introduction

English remains an important language in the world due to its widespread use and universality. It is widely used by people abroad to have better communication. Besides, it is a main course in schools and one of the assessment criteria for the college entrance examination. However, English vocabulary is a key and challenging point for many students. English vocabulary, like the foundation of a building, is the essential component in English learning[1]. According to Webb and Nation[2], a robust vocabulary inventory is the fundamental prerequisite for English learners to use a foreign language flexibly and effectively. Otherwise, the meaning and function of language cannot be fully expressed and utilized. Therefore, students need to have a command of English words. Many high school students rely on rote memorization for vocabulary learning, which can lead to low efficiency and difficulty in retention. Therefore, under the enormous pressure of the college entrance examination, high school students need to master relevant skills in word memory, expand their vocabulary, and use the words they have learned flexibly. Recent research has highlighted how educational technology can support these vocabulary learning needs across various educational contexts[3]. It can improve learning efficiency, inspire learning interest, and improve their English grades.

With the development of internet technology and the rapid advancement of electronic technology, smartphones are becoming increasingly popular. Smartphones have become popular among English learners as portable intelligent devices. Specifically, vocabulary learning applications on these devices offer rich resources that address common challenges in vocabulary acquisition, such as limited access to authentic materials and insufficient practice opportunities. Compared with traditional paper materials, mobile vocabulary applications create simulated, authentic learning contexts through multimedia technology, enhancing learning effectiveness. Learners can learn English at their own pace, in their own time, and according to their needs in their spare time. This approach facilitates a more autonomous and exploratory learning process, while potentially transforming traditional teaching concepts and methodologies. Studies examining mobile data-driven language learning have confirmed that such applications offer unique affordances for vocabulary acquisition not available in traditional learning environments[4].

In the rapidly developing information society of science and technology, the core issue is how English teachers can change the traditional training mode of English vocabulary memory strategies and transform the dull and monotonous standard vocabulary teaching mode into a new, exciting, and efficient vocabulary teaching mode using flexible modern and multimedia technologies. That means that students also need to change their learning styles. This paper will focus on that. As an emerging mobile learning terminal, the *"Baicizhan"* app can integrate its design concept with English vocabulary memory strategies to guide learners in mastering scientific vocabulary memory methods. This study aims to test the effectiveness of this teaching model in helping high school students acquire English vocabulary memory strategies, guiding them to expand their vocabulary by flexibly using mobile learning apps. The software application can provide better educational and teaching services, as well as specific reference suggestions for vocabulary teaching methods. Moreover, it promotes in-depth reform in vocabulary development. Therefore, applying computer-assisted mobile phone vocabulary learning software in English vocabulary teaching poses essential research value.

Despite the growing interest in mobile-assisted language learning, a significant research gap remains in connecting mobile learning applications to specific vocabulary memory strategies in the senior high school context. While studies have examined the general efficacy of vocabulary apps[5], few have systematically investigated how these applications impact the development of distinct memory strategies among adolescent learners facing the unique challenges of high-stakes examinations, such as the college entrance examination. Furthermore, research has not adequately addressed which specific aspects of vocabulary acquisition (semantic, phonological, or morphological) are most effectively enhanced through mobile applications in comparison to traditional instruction methods.

1.1. Research Objectives and Hypotheses

This study aims to systematically evaluate the effectiveness of the Bai CiZhan mobile application in enhancing English vocabulary acquisition among senior high school students. The following research objectives and hypotheses guide the investigation:

Research Objective 1:

To quantitatively assess the impact of the Bai CiZhan Learning App on multiple dimensions of students' vocabulary proficiency.

Research Question 1: To what extent does regular use of the Bai CiZhan Learning App improve students' vocabulary proficiency as measured by comprehensive vocabulary assessments?

H1. *Students who use the Bai CiZhan Learning App will demonstrate statistically significant improvement in overall vocabulary proficiency compared to students using traditional vocabulary learning methods, with particular enhancement in:*

a) English interpretation comprehension (semantic dimension)
b) Synonym group discrimination (semantic network dimension)
c) Word spelling accuracy (orthographic dimension)

Research Objective 2:

To identify and analyze how specific design features of the Bai CiZhan Learning App influence the acquisition and application of vocabulary memory strategies.

Research Question 2: How does the multimodal design of the Bai CiZhan Learning App affect students' development and utilization of specific English vocabulary memory strategies?

H2. *The integrated design of Bai CiZhan will significantly enhance students' utilization of:*

a) Spelling strategies through enhanced orthographic awareness and visual-motor practice
b) Association strategies through pictorial-verbal connections and multimedia representations
c) Word formation strategies through systematic presentation of morphological structures

In this study, "effectiveness" is operationally defined through multiple metrics:

1. Quantitative improvement in vocabulary test scores between pre-test and post-test measurements
2. Statistically significant differences between experimental and control groups using independent sample t-tests ($p < 0.05$)
3. Measurable increases in frequency and sophistication of strategy use as assessed through a validated strategy questionnaire

By examining these specific aspects of vocabulary acquisition and memory strategy development, this research seeks to provide empirical evidence for the selective efficacy of mobile learning applications in vocabulary instruction and to identify practical implications for integrating such technology into senior high school English curricula.

2. Literature Review

A vocabulary Learning App is an innovative method to be employed and developed. This section of the paper examines relevant research on English vocabulary memory strategies, as well as the Vocabulary Learning App and Bai CiZhan Learning App, to support the study.

2.1. Language Learning Strategies

Language learning strategies refer to the methods and means foreign language learners adopt in vocabulary acquisition. Effective vocabulary learning strategies are conducive to improving learners' vocabulary acquisition rates and expanding their vocabulary inventory[6]. According to Wilbert, 'learning strategies' as' learners employ the various operations, steps, plans, and behavioral habits to enable themselves to acquire, memorize, store, process, and utilize foreign language information.

Professor Wen Qiufang, a famous linguist in China, proposed in 2003 that "foreign language learning strategies are the behavior that learners adopt to improve learning efficiency. This behavior can be both an observable foreign language speech act and an unobservable psychological activity of learners." This definition briefly points out that English vocabulary memory strategies, as an essential part of vocabulary learning strategies, refer to the process in which learners use specific vocabulary memory methods and follow certain vocabulary memory rules to store, memorize, process, and extract the words they have learned. English vocabulary memory strategies play an irreplaceable role in helping language learners acquire basic vocabulary. Vocabulary learning strategies encompass both general approaches and specific actions or techniques to make vocabulary learning easier,

faster and more effective.

English vocabulary memory strategies are employed in analyzing, summarizing, or transforming learning materials during language learning activities, directly impacting language acquisition. Specifically, they refer to reasoning, deduction, organization, summary, and rehearsal. Recent research by Nikolova and Vieira[7] has further expanded our understanding of vocabulary learning strategies in the digital age, highlighting the increasing importance of contextual learning approaches facilitated by mobile technologies. The classification methods are complex and diverse, with specific details.

Domestic and foreign scholars have summarized different vocabulary memory methods with precise classification. In summary, the commonly used vocabulary memory methods in the academic community mainly include ten categories: spelling strategies, repetition strategies, word list strategies, part-of-speech analysis strategies, chunking strategies, word formation strategies, contextual strategies, association strategies, classification strategies, and Metacognitive strategy (as an essential way for learners to process vocabulary deeply, the metacognitive approach emphasizes learners' self-awareness and monitoring of the use of English vocabulary memory strategies). These traditional categories are now being reconceptualized in light of digital technologies, with recent investigations examining how contextual learning approaches are facilitated explicitly by mobile applications[7].

2.2. Theoretical Framework for Vocabulary Acquisition and MALL

This study is grounded in three complementary theoretical perspectives that inform our investigation of mobile-assisted vocabulary learning.

First, Webb's[8] comprehensive framework of vocabulary knowledge conceptualizes acquisition along dimensions of form, meaning, and use. This framework provides specific criteria for evaluating Bai CiZhan's comprehensiveness in addressing vocabulary knowledge dimensions and learning strategies (noticing, retrieval, and generative use). We examine how the app's design features align with these dimensions, particularly whether its visual-verbal connections enhance form-meaning associations and whether its exercises adequately address morphological awareness.

Second, Mayer's[9] updated Cognitive Theory of Multimedia Learning posits that simultaneous verbal and visual presentation facilitates dual-channel processing in working memory, thereby enhancing learning efficiency. Bai CiZhan's integration of pictorial representations with vocabulary items aligns with this principle. This theoretical position is further supported by systematic reviews of visual-verbal synergy in multimedia learning, which confirm that integrated multimodal presentation significantly enhances vocabulary acquisition and retention. "Memorization efficiency" is thus operationally defined as vocabulary acquisition with reduced cognitive load through optimized information presentation, a variable measured explicitly in this study through performance outcomes relative to time invested. This principle is supported by recent systematic reviews of visual-verbal synergy in multimedia learning, which confirm that multimodal presentation significantly enhances vocabulary retention[10].

Third, Self-Determination Theory[11,12] offers a framework for understanding how mobile applications influence motivation by satisfying autonomy, competence, and relatedness needs. This perspective contextualizes "strategy use" as the deliberate application of specific cognitive approaches to vocabulary acquisition, sustained by motivational factors inherent in app design.

The integration of these frameworks enables a nuanced analysis of how Bai CiZhan influences vocabulary acquisition strategies in high-stakes examination contexts, addressing not only what knowledge is developed but also how cognitive processing is facilitated and what motivational factors sustain engagement with vocabulary learning strategies.

2.3. The Study on Vocabulary Learning App

As computer-based teaching technology develops and teaching philosophy evolves, many scholars have conducted extensive research on vocabulary learning Apps, applying vocabulary learning from various perspectives.

This research analyzes the effectiveness of vocabulary learning software from learners' perspectives across different periods. In addition, vocabulary software also improves middle school students' ability to use English vocabulary by providing multiple levels of learning. Li Xiang[5] pointed out that the application of mobile knowledge in high school students' English vocabulary acquisition not only breaks

away from traditional "cramming" teaching to a certain extent but also provides learners with a more authentic context and greatly helps "students" deep vocabulary acquisition and contextual awareness development. Mobile learning can effectively alleviate the rigid and mechanical situation of high school English vocabulary teaching and gradually increase learners' interest in learning English vocabulary. Moreover, it aims to improve learners' English subject performance by enhancing their motivation for English learning.

Zhu Dandan conducted a study on the effectiveness of mobile phone apps in college English vocabulary learning. By comparing the word scores of two groups of subjects in the post-test, he confirmed the effectiveness of using word memorizing software in learning English words. Gan Lingyan studied the effect of vocabulary learning software on college English vocabulary learning, pointing out that this model impacts the breadth and depth of students' vocabulary knowledge. Meanwhile, students' autonomy in vocabulary learning has also improved significantly, and they have developed a positive attitude toward using vocabulary learning software. Han Jiaxiao applied mobile learning to the study of English vocabulary learning among secondary vocational school students and summarized that applying mobile learning to the learning of English vocabulary among secondary vocational school students is conducive to their learning of English vocabulary, improving learning interest and memory effects, and developing a good habit of word review. Li and Chen[13] compared the effects of various vocabulary-learning applications on senior high school students' English vocabulary learning and found that using vocabulary-learning software is more effective than traditional vocabulary-learning methods[14]. Zhang Yanan and Yang Rui demonstrated that Mobile technology (MALL), especially smartphone applications (Apps), is effective in vocabulary acquisition through research. According to the language learning habits and characteristics of college students in the information age, vocabulary teaching models are being reshaped to help students transition from passive to active learning, thereby effectively alleviating the pressure of classroom vocabulary instruction. It is suggested that applying computer-assisted vocabulary learning software is a practical approach for vocabulary learning, based on the above studies. However, Liu and Jiang[15] caution that digital vocabulary learning environments present both unique affordances and limitations that must be considered for practical implementation in educational settings.

2.4. The Study on Bai CiZhan Learning App

Bai CiZhan Learning App is a "picture memorization word software" developed by Chengdu Chaoyouai Technology Co., Ltd. for English learning. The software offers attractive illustrations, example sentences, and context for each word, while designing enjoyable and comprehensive learning and practice sessions for learners. It also expands English articles, broadcasts, and other resources for learners to engage in diverse language practice activities based on specific themes in specific contexts. It is a highly representative mobile learning software designed using digital technology. The combination of various English vocabulary memory strategies can help scholars effectively enhance their vocabulary memory. In addition, the interactive learning model is conducive to allowing peer assistance to play a role, encouraging students to support one another, and fostering a positive learning environment for vocabulary development.

Wang and Liu[16] demonstrated in their comprehensive study that vocabulary learning applications with visual elements, due to their unique advantages, can provide learners with a more enriching, authentic, engaging, and timely context, mobilizing the participation of multiple senses. Furthermore, it intelligently sets scientific learning and review plans, improving vocabulary learning, memory effects, and students' enthusiasm for learning. Zhou Jierui, based on the theory of multimodal perspective, conducted an in-depth analysis of the efficiency and interest of the software design, which can arouse the interest of English learners in vocabulary learning. Qiao Wenhua examined the learner strategies included in English teaching methods from the perspective of multiple input method, situational method, word formation method, connection method, repetition method, communicative method, and metacognitive strategy method, thereby proving that this new learning method has mobility and vividness that traditional teaching does not have. Teachers should adapt to the changing times and adopt an open mindset to embrace this new learning method. Huang and Wu[17] concluded from their empirical investigation that mobile vocabulary learning applications significantly improved students' English vocabulary learning performance. In

addition, the data analysis of the questionnaire, reveals that the frequency of students in the experimental class using learning strategies is higher than that in the control class, indicating that the software for learning words helps improve students' ability to employ learning strategies. Beyond simple effectiveness measures, Yang, Chang, Hwang, and Zou[18] have demonstrated that the cognitive complexity of vocabulary applications significantly affects not only learning outcomes but also student anxiety levels and engagement behaviors, suggesting that app design features should be carefully calibrated to optimize learning experiences. To enhance students' vocabulary learning performance and their ability to use learning strategies, teachers should actively consider and apply the value of Baici learning software, incorporating it into their teaching process.

Scholars have conducted a multi-dimensional, universal, and practical analysis of the Bai CiZhan learning App. Research has suggested that it promotes the expansion of students' English vocabulary and improves their English proficiency. However, further research is needed on the effectiveness of the design and development of mobile learning software, such as the Bai CiZhan learning App, in enhnacing students' acquisition of English vocabulary through micro-level memory strategies. There is no further exploration of the specific aspects reflected in the application effect of the software, nor is no there an examination of the rationality and shortcomings of the software in its application based on theory. Therefore, this paper aims to explore the effectiveness of using Baicizhan learning software in vocabulary learning and analyze whether its application contributes to the acquisition of English vocabulary memory strategies, thereby helping learners effectively build up their English vocabulary inventory.

3. Methodology

Data were collected through a questionnaire and test. The method is mainly quantitative.

3.1. Research Design

This study employed a quasi-experimental design with a pre-test/post-test control group structure to investigate the effectiveness of the Bai CiZhan learning application on vocabulary acquisition and memory strategies. While proper randomization was not possible due to the intact class structure, systematic measures were implemented to ensure group equivalence and control for confounding variables.

3.2. Group Selection and Equivalence

Two intact classes (N = 100) of first-year senior high school students in Shangluo were assigned to experimental (n = 50) and control (n = 50) conditions. To establish baseline equivalence, the following measures were taken:

1. Both classes were taught by the same English teacher using identical textbooks (Compulsory High School English Course 1, Foreign Language Research Press)
2. Prior academic achievement was verified through analysis of middle school entrance examination English scores (experimental group: M = 72.6, SD = 8.3; control group: M = 73.1, SD = 7.9; t(98) = 0.31, p = 0.76), confirming no significant difference between groups
3. Gender distribution was balanced (experimental: 26 females, 24 males; control: 25 females, 25 males)
4. Age range was equivalent (experimental: 15–16 years, M = 15.4; control: 15–16 years, M = 15.5)
5. Pre-intervention vocabulary test scores showed no significant differences between groups (p = 0.82)

3.3. Intervention Procedures

The intervention was conducted over one 16-week semester with both groups following the same curriculum and receiving identical classroom instruction (3 hours per week) from the same teacher. The key experimental manipulation was structured as follows:

1. Experimental Group (Bai CiZhan)

Received 30 minutes of guided Bai CiZhan application use during twice-weekly multimedia classroom sessions (total: 16 hours)

Followed a structured vocabulary learning protocol with the application (detailed in "Implementation Procedure")

Assigned 15-minute daily self-directed app usage as homework, recorded through app usage logs

Actual average weekly app usage: 172 minutes (SD = 34.2)

2. Control Group (Traditional Instruction)

Received 30 minutes of traditional vocabulary instruc-

tion during twice-weekly sessions (total: 16 hours)

Used teacher-directed note-taking, word lists, and textbook exercises

Assigned equivalent 15-minute daily vocabulary homework using conventional methods

No access to the Bai CiZhan application during the study period

Both groups had equivalent smartphone access (92% ownership rate in each class) and were permitted to use devices only during English lessons and designated self-study periods. The experimental group's app usage was systematically monitored through:

1. Teacher observation during in-class sessions
2. Digital usage logs from the application (minimum 80% compliance required)
3. Weekly self-report completion forms

To control for potential Hawthorne effects, both groups were informed that they were participating in a study on vocabulary learning strategies, without emphasizing the comparative nature of the research design.

3.4. Instrumentation

3.4.1. Vocabulary Learning Strategy Questionnaire (VLSQ)

Development and Adaptation

The Vocabulary Learning Strategy Questionnaire was developed through a multi-stage process:

1. Initial item pool generation based on Zhang and Zhang's[6] taxonomy of English vocabulary memory strategies and Hong Zhen's validated questionnaire.
2. Selection and adaptation of items to ensure relevance to the high school context and alignment with the seven target strategy dimensions.
3. Integration of cultural and educational context-specific elements based on recent reviews of innovative teaching strategies in Chinese EFL contexts[19].
4. Translation and back-translation by two bilingual experts to ensure conceptual equivalence between the English and Chinese versions.
5. Expert review by three senior high school English teachers and one educational measurement specialist to establish content validity.

Structure and Content

The final questionnaire contained 15 items distributed across seven vocabulary memory strategy dimensions:

- Spelling strategies (2 items): items assessing orthographic pattern recognition and word form practice
- Repetition strategies (2 items): items measuring mechanical rehearsal and spaced review
- Word formation strategies (2 items): items evaluating morphological analysis and affix recognition
- Contextual strategies (2 items): items assessing contextual inference and situational learning
- Association strategies (3 items): items measuring connection to images, similar words, and prior knowledge
- Flexible application strategies (2 items): items evaluating transfer to new contexts and productive use
- Metacognitive strategies (2 items): items assessing planning and monitoring of vocabulary learning

Sample items include

"I memorize new words by analyzing their prefixes, roots, and suffixes" (Word formation strategy)

"I connect new English words with pictures or images that represent their meanings" (Association strategy)

"I regularly evaluate my vocabulary learning progress and adjust my study methods" (Metacognitive strategy)

Scoring and Administration

Responses were recorded on a five-point Likert scale based on strategy use frequency:

1 = "This approach is completely or almost completely inappropriate for my situation"
2 = "This approach is generally inappropriate for my situation"
3 = "This approach is sometimes appropriate for my situation"
4 = "This approach is generally appropriate for my situation"
5 = "This approach is completely or almost completely suitable for my situation"

The questionnaire was administered in Chinese to avoid language proficiency confounds. Mean scores were calculated for each strategy dimension, with higher scores indicating greater frequency of strategy use.

Reliability and Validity

The questionnaire underwent rigorous psychometric validation:

Internal consistency: Cronbach's Alpha for the overall instrument was 0.83, with individual strategy dimensions ranging from 0.76 to 0.89

Test-retest reliability: r = 0.81 (n = 30, two-week interval)

Content validity: Established through expert review (Content Validity Index = 0.87)

Construct validity: Confirmed through Principal Component Analysis with Varimax rotation, which identified seven factors corresponding to the intended strategy dimensions, explaining 74.3% of total variance

Pilot testing: Conducted with 30 non-participant high school students to assess clarity and completion time (average 15 minutes)

3.4.2. Vocabulary Assessment Instruments

Pre-test Instrument

The pre-test was designed to establish baseline equivalence between groups:

Source: Adapted from standardized middle school entrance examination items

Structure: 25 items in three formats:

Multiple-choice vocabulary recognition (10 items, 10 points)

Sentence completion with appropriate vocabulary (5 items, 10 points)

Contextual cloze passage (10 items, 10 points)

Scoring: Each correct answer received 1 or 2 points based on item type, with no partial credit; maximum score = 30 points

Validity: Content validity is established through alignment with national curriculum standards and expert review

Reliability: Cronbach's Alpha = 0.78

Post-test Instrument

The post-test was designed to assess vocabulary knowledge dimensions comprehensively:

Development: Items were created to align with the Foreign Research Version curriculum and to assess multiple dimensions of vocabulary knowledge based on Nation's framework

Structure: 35 items across four categories:

Appropriate word form selection (10 items, 2 points each): testing morphological knowledge

English interpretation tasks (10 items, 2 points each): assessing semantic knowledge

Synonym group analysis (5 items, 2 points each): evaluating lexical relationship knowledge

Word spelling accuracy (10 items, 1 point each): measuring orthographic knowledge

Scoring: Standardized criteria were established for each item type; two independent raters scored constructed-response items with an inter-rater reliability of 0.92

Validity: Content validity established through expert review (n = 3); construct validity confirmed through factor analysis showing distinct loading on four vocabulary knowledge dimensions

- Reliability: Cronbach's alpha = 0.85 for the overall instrument, with subscale reliability ranging from 0.77 to 0.86

Quality Control Procedures

To ensure measurement fidelity:

1. Both instruments were pilot-tested with 30 non-participant high school students
2. Test administration was standardized across all sessions
3. Scoring was conducted by two trained raters blind to participant group assignment
4. All tests were administered under controlled classroom conditions with consistent time limits

Measuring Instruments

The research utilized three primary instruments:

1. Vocabulary Strategy Questionnaire

A 15-item questionnaire adapted from Lv Wenpeng's classification criteria and Hong Zhen's vocabulary strategy questionnaire. Items assessed the frequency of strategy use across seven dimensions: spelling, repetition, word form analysis, context understanding, association, flexible application, and metacognitive strategies. Reliability analysis yielded acceptable internal consistency (Cronbach's α = 0.83).

2. Pre-test Vocabulary Assessment

Comprised of:

10 multiple-choice items (10 points)

5 sentence completion items (10 points)

Cloze passage with 10 blanks (10 points)

Total possible score: 30 points

3. Post-test Vocabulary Assessment

Designed to evaluate four dimensions of vocabulary knowledge aligned with the Foreign Research Version curriculum:

1. Appropriate word form (10 items, 20 points)
2. English interpretation (10 items, 20 points)
3. Synonym group analysis (5 items, 10 points)
4. Word spelling (10 items, 10 points)
5. Total possible score: 60 points

Content validity was established through review by three senior English teachers. A pilot test with 30 students from a non-participating class yielded acceptable reliability (Cronbach's $\alpha = 0.85$). The development process for these assessment instruments was informed by recent advances in vocabulary testing for EFL contexts[20], ensuring comprehensive and valid measurement of vocabulary knowledge dimensions.

Ethical Considerations

Prior to implementation, ethical clearance was obtained from the school administration. Informed consent was secured from all participants and their guardians, with a clear explanation that participation would not affect academic standing. Data confidentiality was maintained through coding systems that protected student identities.

Data Collection and Analysis

Data collection involved:

1. Pre-test and post-test vocabulary assessments administered under standardized conditions
2. Strategy questionnaires completed during regular class time
3. App usage data collected through the application's tracking system

Statistical analysis was conducted using SPSS 24.0 software, employing:

1. Descriptive statistics for demographic data and test scores
2. Independent sample t-tests to compare between-group differences
3. Paired sample t-tests to assess within-group changes
4. Statistical significance was established at $p < .05$

4. Results

4.1. Overview of Findings

Statistical analyses were conducted to examine the effect of the Bai CiZhan Learning App on vocabulary acquisition and memory strategies. All statistical assumptions were verified prior to analysis: normality was confirmed using Shapiro-Wilk tests (all $p > .05$), and homogeneity of variance was established through Levene's tests (all $p > .05$). Below, we present findings on (1) vocabulary test performance comparisons between groups, (2) differences in strategy use, and (3) performance across specific vocabulary knowledge dimensions.

4.2. Vocabulary Test Performance

Descriptive statistics and between-group comparisons for vocabulary test performance are presented in **Table 1** and visualized in **Figure 1**. Independent samples t-tests revealed that students in the experimental group (using Bai CiZhan) scored significantly higher on the post-test ($M = 36.20$, $SD = 5.76$) than those in the control group ($M = 32.31$, $SD = 6.20$), $t(98) = 3.27$, $p < .001$, $d = 0.65$. This medium-to-large effect size indicates a meaningful practical advantage for the experimental group. These improvement patterns mirror findings from studies on augmented-reality-enhanced vocabulary learning, which similarly reported significant retention advantages through multimodal presentation methods[21]. Paired samples t-tests indicated significant improvement from pre- to post-test for both the experimental group, $t(49) = 8.76$, $p < .001$, $d = 1.24$, and the control group, $t(49) = 6.03$, $p < .001$, $d = 0.85$. However, the experimental group demonstrated a larger improvement effect.

As shown in **Figure 1**, both groups demonstrated improvement from the pre- to post-test; however, the experimental group exhibited a substantially larger gain. The difference in improvement between groups was statistically significant with a large effect size ($d = 1.03$), indicating that the Bai CiZhan application had a meaningful impact on vocabulary acquisition beyond what was achieved through traditional methods. Notably, while both groups began with nearly identical pre-test scores, the experimental group attained a post-test mean that was 3.89 points higher than the control group.

Beyond overall vocabulary performance, this study also examined differences in strategy use between groups. **Table 2** presents a detailed comparison of vocabulary memory strat-

egy use between the experimental and control groups. The results reveal that while both groups showed similar baseline strategy use before the intervention, the experimental group demonstrated significantly enhanced use of specific strategies after using the Bai CiZhan application, particularly in spelling strategies (M = 4.13, SD = 0.67), association strategies (M = 4.26, SD = 0.64), and word formation strategies (M = 4.05, SD = 0.73), all with large effect sizes (d > 0.70)

Table 1. Comparison of Vocabulary Performance between Experimental and Control Groups.

Variable	Experimental Group (n = 50)		Control Group (n = 50)		Between-Group Comparison		
	M	SD	M	SD	t	p	d
Pre-test	21.34	4.82	21.56	4.73	0.23	0.82	0.05
Post-test	36.20	5.76	32.31	6.20	3.27	<0.001*	0.65
Improvement	14.86	3.91	10.75	4.06	5.14	<0.001*	1.03

Note: Maximum possible score = 60 points. d = Cohen's d effect size (0.2 = small, 0.5 = medium, 0.8 = large). p < 0.001.

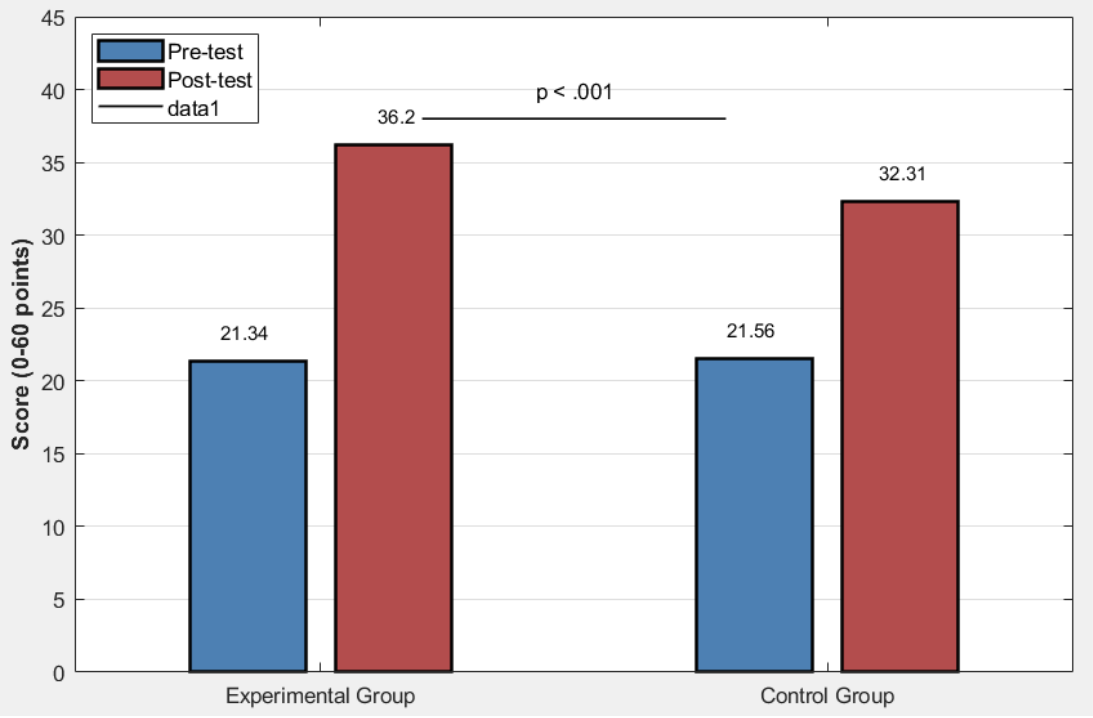

Figure 1. Comparison of Vocabulary Memory Strategy Use between Groups.

Table 2. Comparison of Vocabulary Memory Strategy Use between Groups.

Strategy Type	Experimental Group (n = 50)		Control Group (n = 50)		Between-Group Comparison		
	M	SD	M	SD	t	p	d
Spelling strategies	4.13	0.67	3.58	0.74	3.92	<0.001	0.78
Repetition strategies	3.86	0.82	3.68	0.76	1.24	0.217	0.25
Word formation strategies	4.05	0.73	3.51	0.78	3.58	0.001	0.72
Contextual strategies	3.32	0.88	3.15	0.83	1.00	0.319	0.20
Association strategies	4.26	0.64	3.71	0.70	4.17	<0.001	0.83
Flexible application	3.18	0.91	3.04	0.87	0.78	0.438	0.16
Metacognitive strategies	3.15	0.95	3.02	0.92	0.66	0.512	0.13

Note: Strategy use was measured on a 5-point Likert scale (1 = rarely used, 5 = frequently used). d = Cohen's d effect size (0.2 = small, 0.5 = medium, 0.8 = large). p < 0.05 after Bonferroni correction for multiple comparisons (α = 0.007).

Figure 2 illustrates the comparative use of vocabulary memory strategies between the experimental and control groups. The radar chart reveals distinct patterns of strategy adoption, with the experimental group demonstrating significantly higher use of three key strategies: spelling strategies, word formation strategies, and association strategies. These

differences were statistically significant with large effect sizes ($d > 0.70$), suggesting that the Bai CiZhan application effectively promoted these specific cognitive approaches to vocabulary acquisition. In contrast, both groups demonstrated similar levels of engagement with repetition, contextual, flexible, and metacognitive strategies.

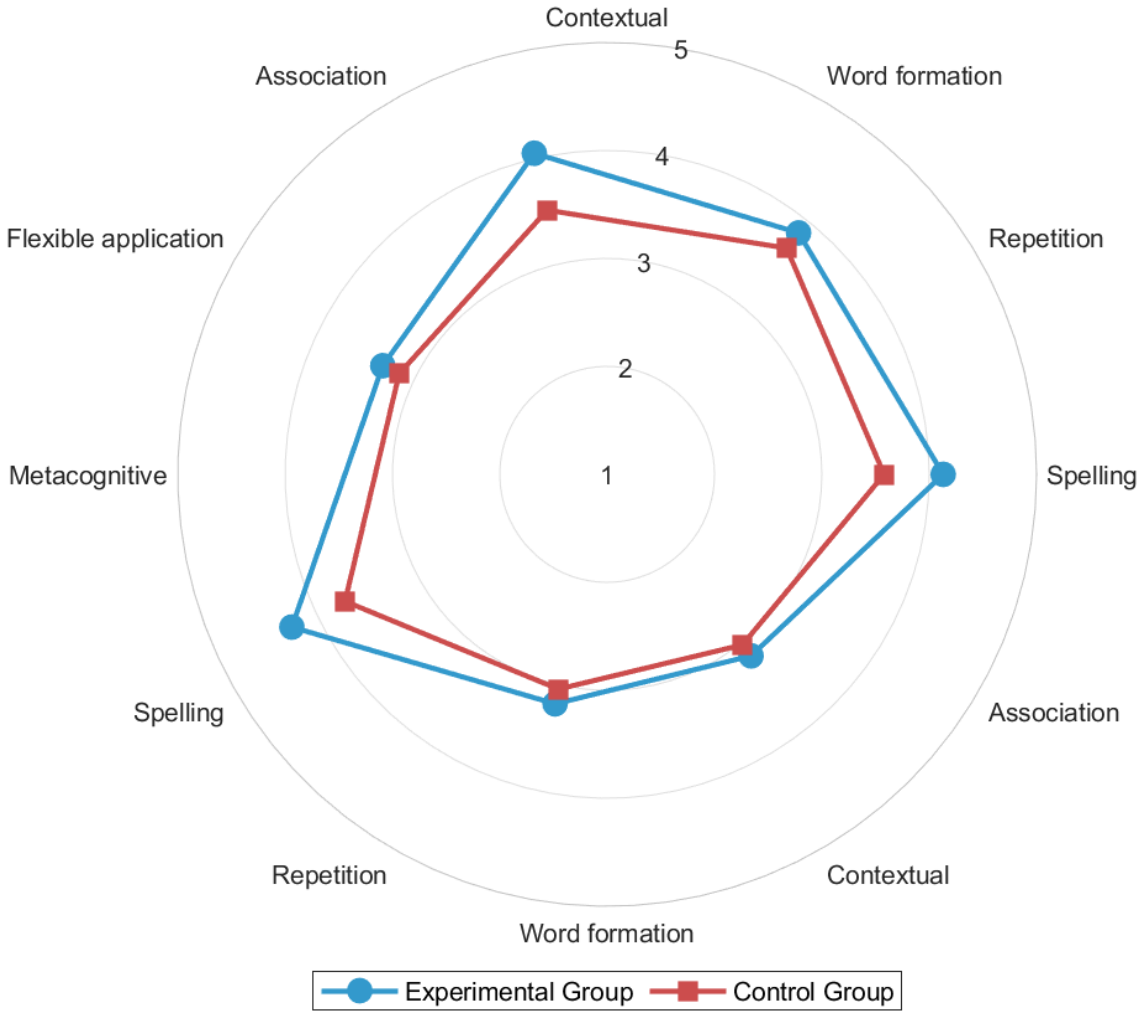

Figure 2. Radar Chart of Strategy Use.

As shown in **Table 3**, significant between-group differences were found in three of four vocabulary knowledge dimensions, with the experimental group excelling in English interpretation, synonym analysis, and word spelling(all $p < 0.05$).

An independent sample T-test was conducted to verify whether there was a significant difference in vocabulary scores between the experimental and control classes. The results are shown in **Table 4**.

Table 3. Comparison of Performance on Vocabulary Knowledge Dimensions Between Groups.

Knowledge Dimension	Experimental Group (n = 50)		Control Group (n = 50)		Between-Group Comparison		
	M	SD	M	SD	t	p	d
Appropriate word form	10.86	2.24	10.12	2.27	1.64	0.104	0.33
English interpretation	12.38	2.68	10.65	2.71	3.24	0.002*	0.65
Synonym group analysis	6.86	1.42	5.98	1.45	3.12	0.002*	0.62
Word spelling	6.10	1.31	5.11	1.34	3.78	<0.001*	0.75

Note: Maximum possible scores: Appropriate word form (20 points), English interpretation (20 points), Synonym group analysis (10 points), Word spelling (10 points). d = Cohen's d effect size (0.2 = small, 0.5 = medium, 0.8 = large). $p < 0.05$ after Bonferroni correction for multiple comparisons ($\alpha = 0.0125$).

Table 4. T-test Table for Independent Samples of Vocabulary Scores.

		F	Sig.	t	df	Sig. (Bilateral Value)	Mean Difference	Standard Error	Lower Limit	Upper Limit
Appropriate Word Form Variance	if equal	0.417	0.508	0.626	107	0.529	0.352	0.562	-0.764	1.478
	if unequal			.625	105.411	0.528	0.352	0.569	-0.771	1.476
English Interpretation Variance	if equal	1.646	0.203	3.874	107	0.000	2.455	0.624	1.218	3.716
	if unequal			3.832	99.012	0.000	2.463	0.634	1.213	3.728
Synonym Group Analysis Variance	if equal	0.025	0.868	3.201	107	0.002	1.317	0.426	0.471	2.158
	if unequal			3.126	106.519	0.002	1.317	0.424	0.479	2.152
Word Spelling Variance	if equal	0.481	0.493	12.498	107	0.000	3.126	0.251	2.568	3.641
	if unequal			12.782	103.408	0.000	3.126	0.248	2.716	3.637

According to the table, Sig (bilateral value) in the appropriate form of words is 0.529, more significant than 0.05, and zero is included in the upper and lower limits of the 95% confidence interval, which indicates that there is no significant difference between the experimental class and the control class in appropriate word form. Sig. (bilateral value) in the synonym group analysis is 0.002, excluding zero in the upper and lower limits of the 95% confidence interval. As for English interpretation and word spelling, Sig The (bilateral) values are both 0.000, excluding zero in the upper and lower limits of the 95% confidence interval. The finding suggests a remarkable difference in vocabulary scores between the experimental and control classes in terms of English interpretation, synonym phrase discrimination, and word spelling.

4.3. English Vocabulary Memory Strategies

An independent sample T-test is used to compare and analyze the current situation of English vocabulary memory strategies used by two classes of students from the perspectives of mean score, standard deviation, full range, and Sig value. The test results are shown in **Table 5**.

Table 5. Independent sample T-test on the use of English vocabulary memory strategies in experimental and control classes (pre-test).

Vocabulary Memory Strategy	Class	N	Average Score	Standard Deviation	t	Sig.(Bilateral Value)
Spelling strategy	Experimental control	50 50	2.452 2.417	0.601 0.550	0.281	0.776
Repetition strategy	Experimental control	50 50	3.418	0.707 0.739	0.667	0.586
Association strategy	Experimental control	50 50	2.478 2.466	0.602 0.566	0.093	0.924
Formation strategy	Experimental control	50 50	2.448 2.430	0.504 0.503	-0.124	0.900
Context strategy	Experimental control	50 50	2.460 2.549	0.644 0.533	-0.656	0.512
Flexible strategy	Experimental control	50 50	2.409 2.498	0.638 0.533	-0.667	0.512
Metacognitive strategy	Experimental control	50 50	2.461 2.448	0.683 0.640	-0.077	0.937

The author conducted independent sample t-tests on the use of seven types of English vocabulary memory strategies in both the experimental and control classes prior to the experiment. The following conclusions were drawn: First, the employment of various vocabulary memory strategies by students in the two classes before using the Baicizhan App suggested that the p-values of each strategy were greater than 0.05, indicating that there was no significant difference in the use of various English vocabulary memory strategies between the two classes. The situation is consistent between these two classes.

Second, it can be observed that the two classes of students have the highest average scores in repetition strategies, with 3.418 in the experimental class and 3.236 in the control class, based on the average scores of various English vocabulary memory strategies. Other strategies, such as the association strategy, word formation strategy, and contextual strategy, all have significant disadvantages, resulting in lower average scores. This suggests that most high school students have not yet mastered the ability to memorize words through association and the use of root affixes, nor have they developed the ability to infer the meaning of words based on context. Their most common method is to memorize words from a vocabulary list repeatedly. The average score of the flexible application strategy is also very low, as it is even more difficult for them to accept. They fail to effectively input and process the original vocabulary, resulting in output difficulties in extracting vocabulary information.

After one semester of English vocabulary memory strategy training for high school students, the author surveyed the English vocabulary memory strategies used by students in the experimental and control classes, respectively. The survey results are shown in **Table 6**.

The author conducted independent sample t-tests to examine the use of various English vocabulary memory strategies by students in the experimental and control classes. The following results were obtained. Among the seven English vocabulary memory strategies trained using the Bai Cizhan app, the Sig values of the spelling, association, and word formation strategies are all less than 0.05, indicating a significant difference in the use of such English vocabulary memory strategies between the students of the two classes. In contrast, the Sig values of repetitive, contextual, flexible, and metacognitive strategies remained greater than 0.05, indicating no significant difference in this category of strategies before and after the teaching experiment. It can be seen that the students in the experimental class are more effective at employing spelling, association, and word formation strategies to memorize words compared to the control class. However, after using the software for some time, there were no significant changes in repetition strategies, contextual strategies, flexible strategies, or metacognitive strategies either classes. It means that the software could not improve the application of these strategies in word memory.

After a semester of vocabulary teaching experiment, a paired sample T-test was used to analyze the pre- and post-test scores of the experimental class students. The data results are shown in **Table 7**.

Table 6. Independent Sample T-test on the Use of English Vocabulary Memory Strategies (Post-test).

Vocabulary Memory Strategy	Class	N	Average Score	Standard Deviation	t	Sig.(Bilateral Value)
Spelling strategy	Experimental Control	50 50	3.179 2.686	0.625 0.561	7.018	0.034
Repetition strategy	Experimental Control	50 50	3.196 3.278	0.638 0.701	1.612	0.513
Association strategy	Experimental Control	50 50	3.287 2.477	0.563 0.542	5.810	0.000
Formation strategy	Experimental Control	50 50	3.421 2.628	0.598 0.571	6.295	0.000
Context strategy	Experimental Control	50 50	2.656 2.549	0.657 0.543	1.581	0.108
Flexible strategy	Experimental Control	50 50	2.475 2.581	0.635 0.519	-1.451	0.156
Metacognitive strategy	Experimental Control	50 50	2.896 2.478	0.633 0.501	-0.482	0.121

Table 7. Paired sample T-test (pre and post test comparison).

Vocabulary Memory Strategy	Class	N	Average Score	Standard Deviation	t	Sig.(Bilateral Value)
Spelling strategy	Pre post	50 50	2.452 3.179	0.601 0.625	-7.201	0.040
Repetition strategy	Pre post	50 50	3.418 3.196	0.707 0.638	0.817	0.416
Association strategy	Pre post	50 50	2.478 3.287	0.602 0.563	-7.108	0.000
Formation strategy	Pre post	50 50	2.448 3.421	0.504 0.598	-7.660	0.000
Context strategy	Pre post	50 50	2.460 2.656	0.644 0.657	-2.307	0.125
Flexible strategy	Pre post	50 50	2.409 2.475	0.638 0.635	-5.33	0.596
Metacognitive strategy	Pre post	50 50	2.461 2.896	0.683 0.633	-0.165	0.123

Based on the analysis of the above data, the author concludes as follows: Firstly, among the English vocabulary memory strategies listed in the table, the sig of spelling strategy, association strategy, and word formation strategy are all $p < 0.05$, indicating significant differences in the pre and post test scores of experimental class students in these types of strategies. Moreover, it's evident that the application of the Baicizhan app has significantly improved students' use of traditional vocabulary memory methods and promoted the diversified selection and use of vocabulary memory strategies among students. However, their contextual strategy, flexibility strategy, and metacognitive strategy Sig were all greater than 0.05, suggesting that there was no significant difference in the pre- and post-test scores of the experimental class. The reasons are that Baicizhan APP still has one-sidedness and limitations in software design, and its functions still need to be improved. In addition, it is about the output characteristics of the strategy itself. Learners should utilize the above strategies to effectively construct their vocabulary learning system, based on the processing and understanding of new vocabulary, combined with the connection between new and existing knowledge, thereby promoting the overall improvement of learners' English learning ability.

5. Discussion

5.1. Critical Interpretation of Findings

This study demonstrates that the Bai CiZhan application had significant but selective effects on vocabulary acquisition among senior high school students. The differential impact across memory strategies is particularly noteworthy: spelling, word formation, and association strategies improved significantly, while repetition, contextual, flexible application, and metacognitive strategies remained largely unaffected. This pattern reflects the design priorities of Bai CiZhan: the app emphasizes visual representation (supporting association strategies), morphological analysis (enhancing word formation), and spelling practice (strengthening orthographic knowledge), but provides limited support for contextual embedding and metacognitive regulation.

The minimal progress in metacognitive strategies is especially concerning. According to Schmitt and Schmitt's [22] updated theoretical framework, metacognitive regulation is crucial for long-term vocabulary retention. While Bai CiZhan effectively delivers content, it inadequately fosters self-regulated learning skills, contrasting with Chen's study of another application that explicitly incorporated metacognitive scaffolding. This limitation potentially undermines learners' autonomous learning capacity and long-term vocabulary retention.

The uneven development across vocabulary knowledge dimensions further reveals the app's characteristics: semantic knowledge, lexical relationships, and spelling accuracy improved significantly, while morphological application showed limited gains. This differential development aligns with research by González-Fernández and Schmitt [23], who demonstrated that various components of vocabulary knowledge develop at different rates and through different learning

mechanisms, suggesting that technology-enhanced learning may accelerate some aspects while having a limited impact on others. This phenomenon aligns with Zou and Yan's [24] observation that mobile applications tend to emphasize meaning recognition over productive application, potentially limiting students' ability to use new vocabulary in authentic communication. Additionally, Boers et al. [25] highlight the critical role of form-meaning-fit in second language vocabulary acquisition, which may explain the stronger results in association strategies where the app explicitly connects visual representations with lexical forms.

5.2. Theoretical and Practical Implications

The findings contribute to mobile-assisted vocabulary learning theory in three ways. First, the results support Stockwell and Pegrum's [26] ecological framework for MALL design, demonstrating how technology-mediated learning may privilege specific cognitive processes while neglecting others. Second, the study challenges the assumption that technological exposure automatically enhances all vocabulary knowledge dimensions [27], aligning instead with Teng and Zhang's [28] multidimensional model of vocabulary knowledge. Third, the research extends Wu's socio-cognitive theory by showing how an application's technological affordances shape vocabulary processing and strategic management. These findings also contribute to our understanding of how different types of vocabulary knowledge types influence language performance, building on recent explorations by Loewen and Sato [29] regarding the complex relationship between vocabulary knowledge and productive language skills.

At the practical level, this study suggests educators should implement Bai CiZhan as a component of a balanced instructional approach rather than a standalone solution. The app's limitations necessitate supplementary activities to strengthen contextual understanding and metacognitive regulation. For developers, the research identifies clear directions for improvement, including increasing the use of context-rich examples, metacognitive prompts, and opportunities for productive vocabulary use. For policymakers, the results caution against overreliance on technology at the expense of comprehensive pedagogical principles [30].

5.3. Limitations and Future Research Directions

Key limitations include the 16-week intervention period, which may be insufficient to observe long-term changes in complex strategies, particularly metacognitive ones. The quasi-experimental design ensures ecological validity but introduces potential confounds. Additionally, quantitative measurements provide comparative data but lack insight into learning experiences.

Future research should employ mixed methods to explore how students integrate applications into their broader learning ecology; conduct longitudinal studies examining the sustainability of strategy gains; and compare applications with different design features to determine which functions most effectively support balanced development.

6. Conclusion

This study demonstrated that the Bai CiZhan application significantly enhanced vocabulary acquisition among senior high school students, with three key patterns emerging from the results. First, the application selectively promoted specific vocabulary memory strategies (spelling, word formation, and association) while having minimal impact on others (repetition, contextual, flexible application, and metacognitive). Second, vocabulary knowledge development was similarly uneven, with significant improvements in semantic understanding, lexical relationships, and orthographic accuracy, but limited gains in morphological application. Third, strategy use patterns were strongly correlated with performance outcomes, particularly for association strategies ($r = 0.67$), highlighting the relationship between multimodal representation and vocabulary retention.

The study makes three principal contributions to the field. Theoretically, it extends our understanding of how technological affordances influence the adoption of cognitive strategies in vocabulary learning, thereby supporting Stockwell and Pegrum's (2023) ecological framework for MALL design. Methodologically, it demonstrates the value of examining multiple dimensions of vocabulary knowledge rather than treating vocabulary acquisition as a unitary construct. Pedagogically, it illustrates how mobile applications can effectively complement traditional instruction while revealing

specific limitations that require supplementary pedagogical attention.

Based on these findings, we recommend that: (1) educators implement Bai CiZhan as part of a balanced instructional approach that includes explicit metacognitive training and contextualized application opportunities; (2) app developers enhance contextual embedding features and incorporate more explicit strategy training components, particularly for metacognitive regulation; and (3) researchers explore longitudinal impacts of mobile vocabulary applications to determine whether initial strategy preferences persist or evolve.

This research significantly advances the field of mobile-assisted vocabulary learning by moving beyond simplistic effectiveness questions to a more nuanced understanding of how specific application features selectively shape cognitive processes and knowledge development, providing a foundation for more theoretically informed and pedagogically balanced application design and implementation in language education.

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Institutional Review Board Statement

Ethical clearance for this study was obtained from the school administration of the participating senior high school in Shangluo. The study was conducted in accordance with the Declaration of Helsinki, with informed consent obtained from all participants and their guardians prior to data collection.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. As the participants were senior high school students under 18 years of age, written informed consent was obtained from their parents or legal guardians prior to participation. All participants were also informed that their participation was voluntary and would not affect their academic standing.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions, as they contain information that could compromise the privacy of research participants (minor students).

Conflicts of Interest

The author declares no conflict of interest.

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