

Research article

University students' academic vocabulary development through mobile-assisted learning: Exploring the impacts on receptive and productive knowledge

Mahtab Mohammadi^a, Mohammadreza Valizadeh^b, Parisa Zohdi Jalal^c,
Ismail Xodabande^{d,*}

^a Islamic Azad University, Saveh, Iran

^b Hasan Kalyoncu University, Gaziantep, Türkiye

^c Ministry of Education, Tehran, Iran

^d Kharazmi University, Tehran, Iran

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ABSTRACT

This study explored the effectiveness of mobile-assisted vocabulary learning through digital flashcards on receptive and productive aspects of academic vocabulary knowledge among Iranian EFL university students. In a quasi-experimental design, 86 participants were divided into three groups: a digital flashcard group (DFs), a traditional paper flashcard (PFs) group, and a control group using word lists, to assess the impact of these methods on vocabulary acquisition over five weeks. The findings revealed that students utilizing DFs exhibited significant improvements in both receptive and productive vocabulary knowledge compared to those using PFs and the control method. Notably, the increase in receptive vocabulary was more substantial than in productive vocabulary, highlighting the differential effects of DFs on various aspects of vocabulary learning. This finding underscores the need for targeted strategies to enhance productive aspects of academic vocabulary specifically. The study supports the integration of DFs into English for Academic Purposes (EAP) programs to leverage their potential in boosting vocabulary acquisition effectively. However, the lesser gains in productive vocabulary suggest the necessity for complementary instructional methods, which focus on more active vocabulary learning tasks. Based on these findings, the study argues that mobile-assisted vocabulary learning should be considered a practical strategy for supporting academic vocabulary development among university students.

1. Introduction

With the global spread of English as the academic lingua franca for disseminating scientific knowledge [1,2], success in academia increasingly hinges upon acquiring proficiency in using this language to fulfill the diverse communicative needs associated with participating in academic discourse. Motivated by such practical considerations, teaching English for Academic Purposes (EAP) has emerged as an expanding and fast-growing area of research and pedagogy within Applied Linguistics [3–5]. Alongside this prominent place of EAP in the competitive landscape of higher education, developing university students' academic literacy is gaining increased

* Corresponding author.

E-mail address: ismail.kh.tefl@gmail.com (I. Xodabande).

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attention [6]. One crucial dimension of this literacy entails using discipline-specific and academic words which poses major challenges for both native and non-native speakers (and users) of academic English [7,8]. Accordingly, addressing the vocabulary learning needs of university students has been a consistent concern in language teaching programs [9,10].

Over the past years, developments in educational technology have provided new tools and evidence-based resources for a systematic focus on vocabulary development [11]. Relatedly, with the proliferation of corpus-based approaches to the study of academic discourse [12,13], EAP programs have access to valuable resources in terms of corpus-based wordlists for addressing university students' vocabulary learning needs [7,14]. Nevertheless, despite significant developments in our understanding with respect to academic and discipline-specific words across different disciplines [7], scaffolding the processes of academic vocabulary learning with educational technology among university students attracted insufficient attention [9,13,15]. Considering the pivotal role of academic vocabulary in reading and comprehension of academic texts, such undertakings are crucial for EFL university students who face serious challenges in reaching the lexical threshold required for adequate understanding of academic texts in English [16–19]. Additionally, while a wide range of tools including digital and paper-based flashcards might offer distinct affordances for learning academic vocabulary, there remains a paucity of research directly comparing their effectiveness in fostering both receptive and productive academic vocabulary knowledge among EFL university students [15].

To bridge this gap in the literature, the present study aimed to investigate the contribution of mobile-assisted learning in enhancing university students' receptive and productive knowledge of academic words. By addressing this issue, this research seeks to provide insights into potentially effective pedagogical strategies that might support EFL university students in developing their academic vocabulary skills. The findings of this study might have implications for EAP practitioners, curriculum designers, and educators in devising innovative approaches to vocabulary instruction that leverage the affordances of mobile technology. Building on this background, the present study aimed to investigate changes in Iranian university students' receptive and productive academic vocabulary following a mobile-assisted learning intervention. In doing so, the following research questions were addressed:

- 1 Does mobile-assisted learning result in significant developments in university students' academic vocabulary knowledge?
- 2 Which aspects of vocabulary knowledge (i.e., receptive and productive) benefit more from mobile-assisted learning intervention?

2. Literature review

2.1. Academic vocabulary

Academic vocabulary encompasses a group of medium-frequency and cross-disciplinary words which are employed extensively in academic texts mainly for writing about abstract ideas and complicated processes in science [20,21]. For example, *concept*, *consist*, *constitute*, *define*, *derive*, *distribute*, *evident*, *function*, *identify*, and *indicate* are among the most commonly used words in academic discourse [22]. This category of words provide a coverage ranging from 6% to around 14% in academic texts [21,23,24]. Consequently, academic terminology constitute a significant proportion of textbooks, research articles, and other texts that university students must read or write. More importantly, research in this area indicated that learning and using such words are associated with substantial challenges and considerable learning burdens for native and non-native speakers of English alike [25,26]. As a result, finding effective strategies to facilitate academic vocabulary learning contributes to university students' academic literacy development and their professional identity formation. In the same vein, by addressing the challenges associated with learning academic words, educators and researchers can support students in navigating the intricacies of scholarly communication. Moreover, such undertakings to find more effective pedagogical approaches and interventions could result in equipping students with the tools necessary for successful engagement with academic materials and the development of their scholarly identities.

2.2. Receptive and productive vocabulary

The acquisition of vocabulary plays a pivotal role in English language learning in general [27]. This long-term process involves developments in both receptive and productive aspects of vocabulary knowledge [16]. Receptive vocabulary is characterized by the recognition and comprehension of words encountered in diverse contexts [28]. It entails understanding the meanings, usages, and subtleties of words, enabling individuals to comprehend written or spoken language more effectively. Furthermore, receptive vocabulary knowledge serves as the foundation for language and acts as a crucial facilitator for further language development [29]. Extensive reading, exposure to authentic materials, and meaningful interactions with the language contribute to the strengthening of receptive vocabulary knowledge [16]. Productive vocabulary on the other hand, encompasses the ability to effectively use and produce words in meaningful communications [27]. It entails not only understanding the meanings of words but also possessing the skills to retrieve and employ them accurately in appropriate contexts [28]. Through activities such as speaking, writing, and participating in discussions, learners solidify their grasp of vocabulary and enhance their language production skills [30].

The acquisition and proficient use of academic vocabulary hold significant importance in university students' academic literacy development [7]. A robust receptive knowledge of these words equips students with the ability to comprehend academic texts effortlessly and extract intended meanings from the specialized language employed in their respective disciplines [31]. Furthermore, a strong productive knowledge of academic words empowers students to articulate their ideas and arguments more effectively in written assignments, presentations, and academic discussions. By utilizing discipline-specific vocabulary accurately and appropriately, students can convey their understanding of intricate concepts, engage in scholarly conversations, and establish their credibility within the academic community [32]. Consequently, receptive and productive vocabulary knowledge holds paramount importance in English

language learning, especially within the academic context. In this regard, a strong receptive knowledge allows students to comprehend academic materials effectively, while productive knowledge empowers them to express their ideas coherently and confidently. With significant developments in educational technology applications in recent years, mobile-assisted learning might be considered a noteworthy approach for augmenting receptive and productive vocabulary knowledge among university students [15,33].

2.3. Mobile assisted vocabulary learning

With the significant developments in mobile technologies, Mobile-Assisted Language Learning (MALL) is becoming a widely used pedagogical approach in language education [34–37]. The expanding body of research on MALL indicates that this pedagogical approach has been especially effective in facilitating second language (L2) vocabulary knowledge development [38–42]. Within this line of research, studies have investigated the outcomes from mobile-assisted learning when the focus is on academic and disciplinary words [33,43–47]. For example, Dizon [47] explored the effectiveness of Quizlet, an online study tool in enhancing the acquisition of academic vocabulary among Japanese university students. The research involved nine EFL students, and over a period of ten weeks, the participants utilized Quizlet to study Academic Word List (AWL) [22]. Pre- and post-tests were administered to measure the progress made in vocabulary acquisition, and the results of these assessments indicated statistically significant improvements. Furthermore, the researcher administered a questionnaire to explore the students' perceptions regarding the use of Quizlet for L2 vocabulary learning. The questionnaire encompassed three dimensions: perceived usefulness, perceived ease of use, and behavioral intention to use Quizlet. The findings revealed that the students held positive attitudes towards using Quizlet. Moreover, The study conducted by Kohnke et al. [44] aimed to investigate the retention of discipline-specific vocabulary by L2 learners within the context of higher education. The researchers focused on the use of an in-house mobile application in Hong Kong. A total of 159 students from four different disciplines participated in the study. They underwent a pre- and post-test, which consisted of 120 words categorized into four difficulty levels specific to their fields of study. The purpose was to assess the retention of discipline-specific vocabulary. The results indicated that the participants demonstrated greater acquisition of vocabulary at the intermediate and advanced levels compared to the beginner and elementary levels. This finding sheds light on the effectiveness of MALL and the role of vocabulary acquisition mobile applications in supporting university students' academic studies through discipline related vocabulary development.

Furthermore, Xodabande and Atai [33] investigated the use of a mobile application, AWL builder, for self-directed learning of academic vocabulary among English as a Foreign Language (EFL) university students in Iran. The researchers compared the effectiveness of the mobile application with traditional materials and assessed the long-term impacts of mobile-assisted vocabulary learning. The study involved 38 third- and fourth-year university students, with 20 students in the experimental group using the AWL builder app and 18 students in the control group using traditional materials. The participants' vocabulary knowledge was evaluated through pre-, post-, and a delayed post-test. The findings of the study revealed that although both groups showed improvements in vocabulary knowledge, the experimental group using the mobile application achieved significantly better results in the post-test and the delayed post-test. The findings also indicated a significant effect of time for mobile-assisted vocabulary learning, as a significant proportion of the learning gains persisted over time. The study highlighted the potential of mobile applications in facilitating self-directed learning of academic vocabulary. In a similar study, Xodabande et al. [46] explored the effectiveness of mobile-assisted vocabulary learning using digital flashcards (DFs) among Iranian university students. The participants of this study were 86 students majoring in psychology, and they were divided into three groups: one using a DF app (i.e., NAWL builder), one using paper flashcards, and a control group. All groups were taught a list of 361 academic words, and their receptive knowledge was assessed before and after the treatment. The findings showed that using DFs increased university students' engagement in learning discipline-specific academic vocabulary. More specifically, the group using the NAWL builder app performed better than the other groups. These results support the effectiveness of DF platforms for learning academic vocabulary among university students when compared to traditional materials.

2.4. The present study

The existing literature underscores a critical role of academic vocabulary in developing university students academic literacy [9,15,19]. The existing studies also emphasize the burgeoning role of mobile-assisted learning in enhancing both receptive and productive vocabulary knowledge among EFL learners [38]. Nevertheless, despite the advancements and empirical evidence supporting the efficacy of Mobile Assisted Language Learning (MALL), the literature reveals conspicuous gaps, notably in the long-term retention and active application of acquired vocabulary in academic discourse [9,19,33,43]. Particularly, developments in university students' productive vocabulary knowledge through mobile-assisted interventions delineates a significant area for further investigation [48]. This gap is critical, considering the indispensable role of productive vocabulary skills in academic success, where learners must not only comprehend but also adeptly utilize academic terminology in their scholarly communications.

Considering these gaps, the current study sets out to investigate the impact of digital and paper-based flashcards on the academic vocabulary development of Iranian university students, with a focus on both receptive and productive vocabulary knowledge. By adopting a comparative analysis between digital flashcards (DFs), traditional paper-based flashcards (PFs), and conventional word lists, this research aims to offer a deeper understanding of how different instructional modalities influence different aspects of vocabulary acquisition. This methodological approach is predicated on the hypothesis that mobile-assisted learning, particularly through the use of DFs, may provide a superior scaffold for not only enhancing vocabulary knowledge but also fostering the ability to actively employ these words in productive academic tasks. Through this lens, the study endeavors to contribute to the extant body of literature by illuminating effective pedagogical strategies that leverage technological affordances for vocabulary learning, thereby aiding EFL learners in surmounting the challenges inherent in academic discourse.

3. Method

3.1. Study design

The present study adopted a quantitative, comparative research design [49] to investigate the effectiveness of digital and paper-based flashcards on academic vocabulary development among Iranian EFL university students. This design facilitated a systematic comparison between three distinct learning conditions: (1) digital flashcards (DFs), (2) paper-based flashcards (PFs), and (3) traditional word lists (control group), over a period of five weeks. The rationale for employing three groups lies in the objective of the study to compare the impacts of technology-enhanced learning (DFs) with traditional learning methods (PFs and word lists) on both receptive and productive vocabulary knowledge. This approach allowed for a more in-depth analysis of the specific contributions of each method to academic vocabulary acquisition. To ensure the replicability of the study, detailed descriptions of the materials, instruments, and mobile applications used are provided in the subsequent sections.

3.2. Participants

The participants of this study were originally 86 Iranian EFL university students (22 males and 64 females), selected based on their availability in the study context from five intact classes at a university in Iran. The mean age of the students was 22 years. To ensure a homogeneous sample in terms of English language proficiency, all participants were assessed using the Cambridge Quick Placement Test [50], which confirmed that the majority were at the B1–B2 intermediate level according to the Common European Framework of Reference (CEFR) for languages [51]. This assessment was crucial to align the requirements of the study with participants' language proficiency levels, aiming to minimize proficiency-related variability in the outcomes. Furthermore, classes were assigned randomly to the three learning conditions to mitigate selection bias and ensure that the findings of the study could be attributed with greater confidence to the interventions themselves rather than pre-existing differences among participants. Specifically, two classes were assigned to the digital flashcards (DFs) group (N = 34), one class to the paper-based flashcards (PFs) group (N = 27), and two classes served as the control group, using word lists (N = 25). This distribution was designed to reflect a balanced representation of each learning condition while accommodating the constraints of the available sample. The study followed common ethical considerations in educational research. In this regard, prior to the commencement of the study, informed consent was obtained from all participants. They were assured of their anonymity, the confidentiality of their responses, and their right to withdraw from the study at any time without penalty or negative consequences.

3.3. Materials and instruments

The primary material used in this study was the Academic Word List (AWL) [22], which is a corpus-derived list of 570 word families deemed essential for academic study in English-speaking environments. The AWL was chosen due to its extensive application in English for Academic Purposes (EAP) contexts, including material development and vocabulary assessment [24,52,53]. For the purpose of this study, a subset of 100 words was selected from the AWL based on their frequency and relevance to the academic texts the participants were likely to encounter [54]. This selection process was guided by criteria aiming to ensure the words' applicability across various disciplines and their potential to impact academic literacy significantly.

In order to test the participants' vocabulary knowledge, the study used receptive and productive vocabulary tests [55]. In this regard, to test the homogeneity of the sample before the treatment, the New Vocabulary Levels Test (NVLTL) [53] was administered to all participants. Considering the close connection between vocabulary knowledge and proficiency in English [56], this test acted as a criterion measure to assess the student's general vocabulary knowledge before the treatment. Next, the participants' receptive vocabulary knowledge of the target academic words was assessed using a multiple-choice tests (two parallel tests for pre- and post-tests with 50 items) developed specifically for this study to align with the selected AWL subset. In each question, the target word was presented to the participants in a meaningful but none-defining context, and they had to select one of the four definitions provided for the vocabulary items. The following is a sample item representing receptive knowledge test:

Authority: The police officer had the authority to enforce the law.

- a) power or right to give orders
- b) document or written proof
- c) creation or invention of new rules
- d) understanding or comprehension of the law

The productive vocabulary test used translations and forced elicitation techniques [55], and the scores for the participants represented their mean scores on both tests. In translation questions, the participants were required to provide English equivalents for the academic words translated into their first language. This test also had 50 items and the same version was given to the participants in pre- and post-test. The forced elicitation questions (two parallel tests with 50 items) required the participants to write appropriate words in the blank spaces within the complete sentences representing written academic language use. The following are sample items representing forced elicitation technique:

The professor's extensive knowledge and expertise in the subject area gave her **auth**_____ when discussing complex theories.

According to the **auth**_____ in the field of psychology, individuals' behavior is influenced by a combination of genetic and

environmental factors.

The development and validation of these instruments involved a pilot study with a separate group of EFL learners to ensure their reliability and appropriateness for measuring the intended constructs. Feedback from the pilot study was used to refine the tests before their application in the main study.

3.4. Procedures

The study was conducted over a five-week period, following a structured timeline to ensure consistency across all groups. Initially, all participants underwent the pre-test assessments to establish baseline knowledge of the target academic vocabulary. This initial phase was critical for confirming the homogeneity of the groups regarding their vocabulary knowledge. In the first week, an orientation session was held for each group to introduce the study procedures and the materials or tools they would be using. For the digital flashcards (DFs) group, a detailed tutorial on how to use the Anki application [57] was provided, highlighting features relevant to vocabulary learning, such as spaced repetition and personalized learning pace. Participants in this group were instructed to download the Anki app onto their smartphones and were provided with a pre-made deck of digital flashcards based on the selected 100 AWL words.

The paper-based flashcards (PFs) group received a set of printed flashcards, each card displaying one of the target words, its definition, and an example sentence on one side, and the word alone on the back. Instructions on how to effectively use the flashcards for spaced repetition study were also provided to ensure methodological consistency with the DFs group. Participants in the control group were given printed word lists, which included the target words, their definitions, and example sentences. They were advised to study these lists in a manner consistent with their usual study habits, without the spaced repetition strategy emphasized in the experimental groups.

Throughout the study period, participants were asked to dedicate a specific amount of time each week (at least 30 min daily) to study their assigned materials. This instruction was intended to standardize the amount of exposure each participant had to the target vocabulary. At the conclusion of the five-week intervention, post-tests were administered to all participants to assess gains in both receptive and productive vocabulary knowledge. The post-test mirrored the pre-test in format but with different items to measure learning outcomes accurately without test-retest bias. Data collected from the pre- and post-tests were then prepared for analysis, adhering to the protocols for confidentiality and ethical handling of participant information.

3.5. Data analysis

The collected data from the vocabulary knowledge tests were analyzed using IBM SPSS Statistics software, version 25. Descriptive statistics (mean values, standard deviations, and standard error of means) were first computed to provide an overview of the participants' performance in each group (DFs, PFs, and word lists) across the pre- and post-tests. This initial analysis aimed to identify general trends in vocabulary acquisition among the different learning conditions. Subsequently, a mixed between-within subjects analysis of variance (ANOVA) [58] was conducted to examine the effects of the learning condition (digital flashcards, paper-based flashcards, and word lists) on vocabulary knowledge over time (pre-test vs. post-test). This statistical approach allowed for the assessment of both the main effects of the learning condition and the interaction effects between learning condition and time on

Table 1

Descriptive statistics for pre- and post-test scores across groups.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
New Vocabulary Levels Test (5k) (Criterion measure)	Digital Flashcards	34	65.56	6.316	1.083	63.36	67.76
	Paper Flashcards	27	65.81	5.691	1.095	63.56	68.07
	Control	25	66.60	4.848	0.970	64.60	68.60
	Total	86	65.94	5.676	0.612	64.72	67.16
Pre-test (Receptive)	Digital Flashcards	34	11.09	2.906	0.498	10.07	12.10
	Paper Flashcards	27	10.93	2.908	0.560	9.78	12.08
	Control	25	11.96	2.979	0.596	10.73	13.19
	Total	86	11.29	2.926	0.316	10.66	11.92
Pre-test (productive)	Digital Flashcards	34	6.09	2.179	0.374	5.33	6.85
	Paper Flashcards	27	7.22	2.309	0.444	6.31	8.14
	Control	25	6.84	2.249	0.450	5.91	7.77
	Total	86	6.66	2.268	0.245	6.18	7.15
Post-test (Receptive)	Digital Flashcards	34	20.32	2.637	0.452	19.40	21.24
	Paper Flashcards	27	14.93	2.319	0.446	14.01	15.84
	Control	25	11.28	2.441	0.488	10.27	12.29
	Total	86	16.00	4.519	0.487	15.03	16.97
Post-test (Productive)	Digital Flashcards	34	12.85	2.808	0.482	11.87	13.83
	Paper Flashcards	27	7.56	2.887	0.556	6.41	8.70
	Control	25	6.76	2.204	0.441	5.85	7.67
	Total	86	9.42	3.858	0.416	8.59	10.25

participants' vocabulary acquisition. Such an analysis was pivotal in determining whether the type of learning material significantly impacted the learners' academic vocabulary development. Post-hoc analyses, employing the Bonferroni correction method for multiple comparisons, were conducted to further explore significant differences identified by the ANOVA. These analyses provided detailed insights into how each learning condition specifically contributed to changes in the participants' vocabulary knowledge, allowing for a nuanced understanding of the effectiveness of digital and paper-based flashcards compared to traditional word lists. Additionally, to ensure the robustness of the findings, effect sizes were calculated for significant results to quantify the magnitude of the differences observed between groups.

4. Results

The results of the descriptive statistics for the pre- and post-test scores are provided below in Table 1. Initially, the New Vocabulary Levels Test (5k) revealed no significant differences among the groups, indicating homogeneity in terms of baseline vocabulary levels. In the pre-test phase, concerning receptive vocabulary knowledge, the control group exhibited slightly higher mean scores compared to both the DFs and PFs groups. However, for productive vocabulary knowledge, the PFs group scored higher on average than the DFs and control groups. Notably, post-intervention results demonstrated a substantial improvement in both receptive and productive vocabulary knowledge for the DFs group, surpassing the gains observed in the PFs and control groups. This shift suggests that the intervention with digital flashcards may have a more pronounced effect on vocabulary acquisition.

To examine the participants' performances on the criterion measure (i.e., New Vocabulary Levels Test), a Levene test was conducted to assess the homogeneity of variances for the scores among the three groups (DFs, PFs, and control). The results of Levene's test indicated no significant differences in variances among the groups, with the statistic being non-significant across all test variations, confirming the homogeneity of variances assumption ($F(2, 83) = 1.960, p = 0.147$). These outcomes underscore the appropriateness of conducting further analysis using ANOVA by affirming that the groups were comparable at the outset of the study in terms of their vocabulary levels. Subsequent to verifying the homogeneity of variances, an Analysis of Variance (ANOVA) was employed to explore differences in NVLT scores among the DFs, PFs, and control groups. The ANOVA results indicated that group membership did not significantly affect NVLT scores, $F(2, 83) = 0.248, p = 0.781$. This finding establishes a baseline equivalence among the groups, ensuring that any post-intervention differences can be attributed with greater confidence to the instructional interventions themselves rather than pre-existing discrepancies in vocabulary knowledge.

The results of the within-subjects effects are provided in Table 2. The tests of within-subjects effects were conducted using a multivariate approach, analyzing the effects of the independent variable (i.e., time: pre-test and post-test) within the participants scores. The results indicated that the time factor had a significant effect on the dependent variables, as evidenced by the Wilks' Lambda value of 0.398 ($F = 61.957, p < 0.001$). The partial eta squared value of 0.602 suggests that 60.2% of the variance in the dependent variables can be attributed to the effect of the time factor. Additionally, the interaction effect between time and group variables was also found to be significant, as indicated by the Wilks' Lambda value of 0.329 ($F = 30.493, p < 0.001$). The large partial eta squared value of 0.645 suggests that 64.5% of the variance in the dependent variables can be attributed to the interaction between time and group variables.

The tests of within-subjects contrasts examined the linear effects of the time factor and the interaction effect between time and group on the receptive and productive aspects of the dependent variables (Table 3). The results revealed that the linear effect of time was highly significant for both the receptive ($F = 89.484, p < 0.001, \text{partial eta squared} = 0.519$) and productive ($F = 36.368, p < 0.001, \text{partial eta squared} = 0.305$) aspects. This indicates that changes over time significantly influenced the dependent variables in both aspects. Moreover, the interaction effect between time and group was highly significant for both the receptive ($F = 43.392, p < 0.001, \text{partial eta squared} = 0.511$) and productive ($F = 35.603, p < 0.001, \text{partial eta squared} = 0.462$) aspects. This suggests that the combined influence of time and group had a substantial impact on the dependent variables in both aspects.

The tests of between-subjects effects were conducted to examine the impact of the independent variable group on the transformed average scores for the receptive and productive aspects of the dependent variables (Table 4). For the receptive aspect, the main effect of group was highly significant ($F = 40.315, p < 0.001, \text{partial eta squared} = 0.493$). This indicates that the different groups had a substantial influence on the receptive aspect of the dependent variable. Similarly, for the productive aspect, the main effect of group was also highly significant ($F = 20.561, p < 0.001, \text{partial eta squared} = 0.331$). This suggests that the different groups significantly influenced the productive aspect of the dependent variable.

As the results pointed to significant differences among the groups following the treatments, post-hoc tests were conducted to find out the exact place of the differences (Table 5). In this regard, data analysis showed that the participants using DFs outperformed those

Table 2
Multivariate^{a,b} tests of within-subjects effects.

Within Subjects Effect (Wilks' Lambda)	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Time	0.398	61.957 ^c	2.000	82.000	0.000	0.602
Time * Group	0.329	30.493 ^c	4.000	164.000	0.000	0.427

d. The statistic is an upper bound on F that yields a lower bound on the significance level.

^a Design: Intercept + Group Within Subjects Design: Time.

^b Tests are based on averaged variables.

^c Exact statistic.

Table 3

Tests of within-subjects contrasts.

Source	Measure	Time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Receptive	Linear	740.428	1	740.428	89.484	0.000	0.519
	Productive	Linear	231.345	1	231.345	36.368	0.000	0.305
Time * Group	Receptive	Linear	718.087	2	359.044	43.392	0.000	0.511
	Productive	Linear	452.957	2	226.479	35.603	0.000	0.462
Error (Time)	Receptive	Linear	686.779	83	8.274			
	Productive	Linear	527.979	83	6.361			

Table 4

Tests of between-subjects effects.

Transformed Variable: Average								
Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	
Intercept	Receptive	30441.077	1	30441.077	4704.158	0.000	0.983	
	Productive	10517.185	1	10517.185	1810.020	0.000	0.956	
Group	Receptive	521.765	2	260.882	40.315	0.000	0.493	
	Productive	238.941	2	119.470	20.561	0.000	0.331	
Error	Receptive	537.101	83	6.471				
	Productive	482.275	83	5.811				

using PFs and the control group that used word lists in receptive and productive vocabulary tests. Additionally, the findings of the study revealed that the participants learning academic words via PFs outperformed the control group in receptive tests but not in the productive academic vocabulary test.

To summarize, the results of the study demonstrated significant developments in participants' receptive and productive vocabulary knowledge through the application of digital and paper-based flashcards, with digital flashcards (DFs) showing a notably stronger effect. Both within-subjects and between-subjects analyses revealed substantial improvements in academic vocabulary learning over time, indicating that the instructional methods significantly influenced learning outcomes. The interaction between time and group variables was highly significant for both receptive and productive aspects, suggesting that the type of learning material (DFs, PFs, or control) had a distinct impact on the improvement of vocabulary knowledge. The main effect of group on vocabulary development was also highly significant, with post-hoc analyses indicating that participants using DFs outperformed those using PFs and the control group in both aspects of vocabulary knowledge. The development in participants' receptive vocabulary knowledge was particularly pronounced, as evidenced by the significant linear effects of time and the interaction effects between time and group. The DFs group achieved higher mean scores in the post-test for the receptive aspect, demonstrating a substantial increase compared to the PFs group and the control group (Fig. 1).

Similarly, the productive vocabulary knowledge of participants also saw improvements, with the DFs group showing the greatest gains, while other groups showed minimal and non-significant gains (Fig. 2).

Table 5

Post-hoc comparisons of group effects on receptive and productive vocabulary.

Measure	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Receptive	DFs	PFs	2.780 ^a	0.464	0.000	1.647	3.913
		Control	4.086 ^a	0.474	0.000	2.928	5.244
	PFs	DFs	-2.780 ^a	0.464	0.000	-3.913	-1.647
		Control	1.306 ^a	0.499	0.032	0.086	2.526
	Control	DFs	-4.086 ^a	0.474	0.000	-5.244	-2.928
		PFs	-1.306 ^a	0.499	0.032	-2.526	-0.086
Productive	DFs	PFs	2.082 ^a	0.439	0.000	1.008	3.155
		Control	2.671 ^a	0.449	0.000	1.573	3.768
	PFs	DFs	-2.082 ^a	0.439	0.000	-3.155	-1.008
		Control	0.589	0.473	0.650	-0.567	1.745
	Control	DFs	-2.671 ^a	0.449	0.000	-3.768	-1.573
		PFs	-0.589	0.473	0.650	-1.745	0.567

Based on estimated marginal means.

^a The mean difference is significant at the .05 level.

^b Adjustment for multiple comparisons: Bonferroni.

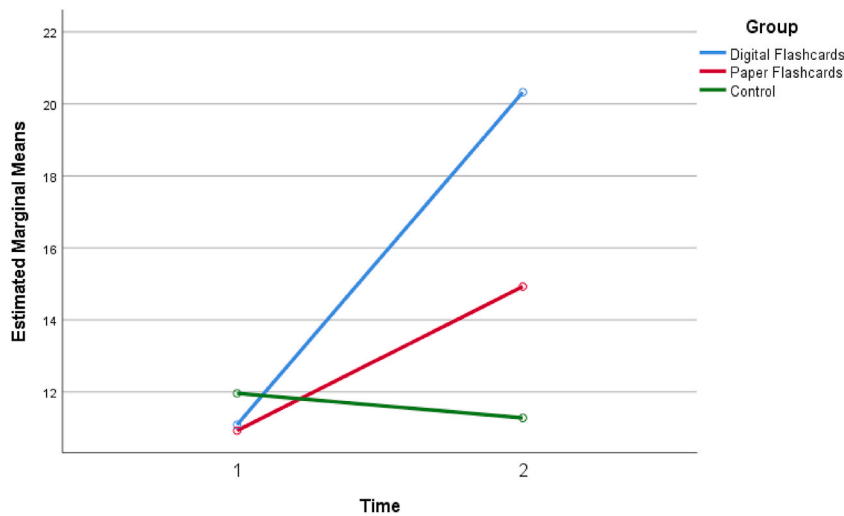


Fig. 1. Estimated marginal means of receptive academic vocabulary tests.

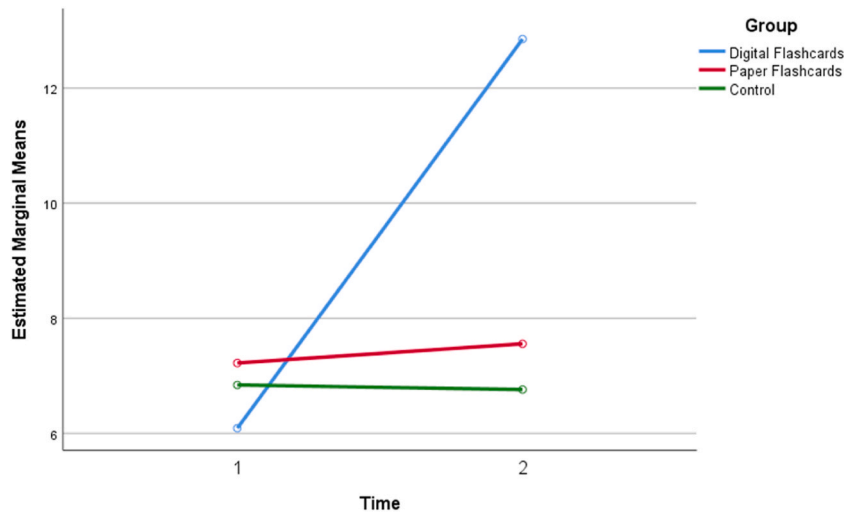


Fig. 2. Estimated marginal means of productive academic vocabulary tests.

5. Discussion

The first research question was concerned the effectiveness of mobile-assisted vocabulary learning in scaffolding university students' academic vocabulary developments. The findings revealed that the mobile assisted intervention effectively boosted Iranian University students' knowledge of the target academic words. More specifically, the participants who used DFs on their mobile devices outperformed those using traditional materials (PFs) and the control group. Accordingly, the findings of the current study align with the earlier studies investigating the effectiveness of mobile-assisted learning in developing the knowledge of academic words [33,46,47], reinforcing the argument that technological integration in language learning can elevate learner engagement and motivation [58], thereby leading to improved educational outcomes. The improvements observed in the vocabulary knowledge of the DFs users might have resulted from the following factors. First, it has been argued that applying new technologies into language teaching programs boosts learners' motivation and engagement with the learning content [59]. Consequently, mobile-assisted learning has resulted in the participants' increased motivation for vocabulary learning which might contributed to heightened engagement and learning efficacy [40–42]. Second, a key factor in L2 vocabulary development is repeated encounters with the target words [16]. In this regard, DFs provided the learners with a significant affordance for learning academic vocabulary via the built-in spaced repetition feature in the Anki application, thus aligning with evidence supporting the role of spaced repetition in enhancing long-term learning [60,61]. Lastly, the advantages observed in DFs users could also stem from the intentional learning mechanism, which is crucial for academic vocabulary less frequently encountered in everyday contexts, suggesting intentional strategies might yield better outcomes than incidental learning [27,61].

The second research question compared the developments in the participants' receptive and productive knowledge of academic words. The findings indicated that learning from DFs and PFs effectively develops receptive vocabulary knowledge (Tables 2 and 3). As shown in Fig. 1, these interventions both resulted in considerable vocabulary gains among the participants. However, DFs led to greater variability in post-test scores, indicating that individual learning preferences [27,62] and strategies significantly influence vocabulary gains, which supports the notion that one-size-fits-all approaches may not suit diverse learner profiles. Data analysis also indicated that when it comes to receptive vocabulary knowledge development, DFs are considerably more effective than traditional materials and vocabulary learning strategies (i.e., PFs and wordlists), highlighting the need for personalized learning environments that cater to individual preferences and styles.

As for developments in the participants' productive vocabulary knowledge, data collected and analyzed in this study pointed to a considerable advantage for DFs. This discrepancy suggests that while DFs can significantly impact receptive vocabulary due to their design and the cognitive processes they engage [62], productive vocabulary development may require more extensive practice and time [16], given the complexity of actively using new words. The involvement load hypothesis (ILH) [63] provides a theoretical framework that could explain the differential impact on receptive and productive knowledge, as tasks with higher involvement loads, typical of DFs usage, promote deeper processing and thus, better retention and recall [64]. However, the default mode of most flashcard applications emphasizing meaning and definition retrieval may not sufficiently challenge learners to produce the target words, potentially explaining the lesser gains in productive knowledge. Lastly, the study's duration might have been too brief to observe more substantial effects on productive vocabulary, suggesting longer intervention periods could yield more pronounced improvements.

6. Implications of the study

The study has some implications for teaching academic vocabulary to university students and facilitating their academic literacy development. The effectiveness of digital flashcards (DFs) in enhancing both receptive and productive vocabulary knowledge underscores the potential of mobile-assisted learning (MAL) tools in EFL settings. From a theoretical standpoint, this study reinforces the cognitive and motivational theories underpinning the use of technology in language learning [35,61], highlighting how digital tools can scaffold vocabulary acquisition more effectively than traditional methods [33].

Practically, the findings suggest several actionable strategies for EAP teachers and curriculum designers. Firstly, given the inherent motivational benefits and the effectiveness of DFs observed in this study [59], it is recommended that teachers incorporate such technologies into English for Academic Purposes (EAP) courses. The integration of DFs not only aligns with contemporary digital learning trends but also caters to the diverse learning preferences of university students, potentially increasing engagement and outcomes in vocabulary learning. Secondly, the capacity of DFs to support self-regulated learning outside the classroom presents a valuable opportunity to augment traditional classroom instruction [9,65]. Given the often limited classroom time dedicated to vocabulary development [16], DFs can serve as an essential complementary tool, enabling students to extend their learning beyond the classroom boundaries [40]. This approach supports the notion of lifelong learning and underscores the importance of learner autonomy in language acquisition. Furthermore, while the study demonstrated that DFs significantly facilitate the development of receptive vocabulary knowledge, the findings also indicate notable but comparatively smaller gains in productive vocabulary knowledge. This discrepancy highlights a crucial area for future research and suggests the need for more nuanced instructional designs that specifically target productive vocabulary skills [66].

Additionally, the disproportionate gains between receptive and productive vocabulary knowledge underscore the importance of considering different learning outcomes when implementing MAL tools. For curriculum designers and language learning app developers, the results advocate for the inclusion of features that promote both types of vocabulary knowledge, perhaps by integrating tasks that require active word production in addition to recognition. Lastly, the implications for longer-term interventions are clear. The study hints at the potential for even greater vocabulary development with extended exposure to DFs, suggesting that longer-term studies and interventions could yield more profound insights into the efficacy of MAL tools in vocabulary acquisition.

7. Conclusion

This study set out to examine the impact of mobile-assisted language learning (MALL), specifically through digital flashcards (DFs), on the academic vocabulary development of Iranian EFL university students. The findings revealed that participants utilizing DFs significantly outperformed their peers using traditional paper flashcards (PFs) and those in the control group, demonstrating the efficacy of DFs in enhancing both receptive and productive vocabulary knowledge. This underscores the potential of integrating mobile technology into vocabulary learning strategies to facilitate academic literacy development among university students. However, the conclusions of the study might be tempered by some limitations. Firstly, the use of convenience sampling from a single institution may limit the generalizability of the findings to other populations and contexts. The relatively short duration of the intervention also raises questions about the long-term effects of MALL on vocabulary acquisition, suggesting the need for further research over extended periods [36]. Additionally, focusing primarily on quantitative measures of vocabulary knowledge might overlook other critical aspects of lexical competence [27,67], such as usage in context and collocational knowledge, pointing to the necessity of a broader evaluative lenses in future studies. Given these considerations, future research should aim to explore the efficacy of MALL across other educational settings and longer time frames for the interventions. Investigating other dimensions of vocabulary knowledge through both quantitative and qualitative methodologies could provide a more comprehensive understanding of the MALL outcomes in language learning. Moreover, delving into students' perceptions and attitudes towards mobile-assisted vocabulary learning can offer valuable

insights into the motivational and pedagogical aspects of using digital tools in educational contexts.

Ethics approval

Ethical review and approval was not required 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.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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CRediT authorship contribution statement

Mahtab Mohammadi: Writing – original draft, Methodology, Investigation, Conceptualization. **Mohammadreza Valizadeh:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Parisa Zohdi Jalal:** Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ismail Xodabande:** Writing – review & editing, Visualization, Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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