



Ismail Xodabande*, Vahid Asadi and
Mohammadreza Valizadeh

Teaching vocabulary items in corpus-based wordlists to university students: comparing the effectiveness of digital and paper-based flashcards

<https://doi.org/10.1515/jccall-2022-0016>

Received June 13, 2022; accepted November 22, 2022; published online December 14, 2022

Abstract: The present study explored the relative effectiveness of digital flashcards used on smartphone devices when compared with traditional paper-based materials in teaching vocabulary items from recently developed corpus-based general and academic word lists. The participants were 71 English as a foreign language (EFL) students studying at two universities in Iran. Following an initial assessment of vocabulary knowledge (i.e., pretest), the participants were assigned into experimental and control learning conditions based on their own preferences. Those participants in the experimental group used flashcard applications with built-in spaced repetition technology to learn 1,600 general services and 963 academic words. Those in the control group employed traditional paper-based flashcards to learn the same words. The treatment lasted for around five months, and to document learning gains, the participants' vocabulary knowledge was measured at the end of the academic semester (i.e., posttest). Additionally, a follow-up delayed posttest was administered after around four months to investigate the delayed effects of the treatments. Statistical analysis of the scores obtained by the participants on the vocabulary knowledge tests revealed a main effect for time in both learning conditions. The results also indicated a main effect for learning vocabulary with digital flashcards on mobile devices, and the participants in the experimental group outperformed those in the control group in the posttests and delayed posttests. The study provided empirical evidence for the affordances of smartphone devices and digital flashcards for scaffolding significant developments in the vocabulary

*Corresponding author: **Ismail Xodabande**, Kharazmi University, Tehran, Iran,
E-mail: ismail.kh.tefl@gmail.com

Vahid Asadi, University of Siena, Siena, Italy, E-mail: vahidasadi700@gmail.com

Mohammadreza Valizadeh, Hasan Kalyoncu University, Gaziantep, Turkey,
E-mail: mrvalizadeh2015@gmail.com

knowledge of EFL learners, highlighting a number of implications for teaching/learning vocabulary items in corpus-based word lists to university students.

Keywords: academic words; CALL; corpus-based language education; e-learning; flashcards; MALL; vocabulary; word cards

1 Introduction

The prominent role of vocabulary knowledge as the most important aspect of language use has been widely acknowledged in the expanding literature related to English language teaching (Clenton & Booth, 2020; Nation, 2001, 2013; Schmitt et al., 2017; Webb & Nation, 2017). Nevertheless, given the huge number of words, deciding on which vocabulary to focus on in language teaching programmes or the development of instructional materials has remained a consistent concern. In one of the more widely employed pedagogical frameworks for teaching vocabulary, different words in English have been grouped under four major categories: high frequency (general service), academic, technical and low-frequency words (Coxhead & Nation, 2001; Nation, 2001). Having the largest coverage, the high-frequency vocabulary accounts for around 80% of the words in most of the spoken and written texts in English (Nation, 2001, 2013). This makes learning this category of words an important goal for beginner English language learners (Nation & Waring, 1997). The next category—academic vocabulary—encompasses the words occurring with reasonably higher frequency across different academic genres (such as research articles) but with much lower frequency in non-academic texts (Coxhead & Nation, 2001). Previous research has indicated that academic words cover from 6–14% of academic texts and, hence, are considered to be very important for university students studying in different subject areas (Browne et al., 2013b; Coxhead, 2000, 2011; Gardner & Davies, 2014). Beyond these words, technical words are closely tied to specific fields, and low-frequency vocabulary refers to the rarely used words in all texts and discourse types. Consequently, learning the first two categories of words in English is deemed essential for university students because the knowledge of such words significantly contributes to their second language literacy development and to understanding academic discourse in general.

Recently, in line with significant developments in the application of new technologies in language teaching, corpus-informed pedagogy has been impacting language education in many ways (Römer, 2011), which includes the development of a number of corpus-based word lists to inform vocabulary learning components in language education programmes (Browne et al., 2013a, 2013b; Dang et al., 2017; Gardner & Davies, 2014). The corpora employed for the

development of the most recent lists were much larger and more representative compared with the ones used for the creation of the earlier lists, including the old General Service List (GSL) and the well-known Academic Word List (AWL) (Coxhead, 2000; West, 1953). In this regard, newly developed lists for general service and academic vocabulary provide language teaching programmes with valuable resources for addressing vocabulary learning needs systematically and more efficiently. However, despite much progress in corpus-based studies of vocabulary in different domains of language use and proliferation of specifically developed word lists (Coxhead, 2018; Dang, 2019; Nation, 2016), only a few studies connected the findings with language teaching practices (Chambers, 2019; Coxhead, 2019). This has created a gap in the current corpus-informed second language education, where most of the corpus-based vocabulary studies remain mostly descriptive, with only a few attempts to teach the words in the compiled lists to those students who need to learn specific vocabulary items.

Building on this background, the current study aimed to help Iranian EFL university students learn vocabulary items from the New General Service List (NGSL) and New Academic Word List (NAWL) (Browne et al., 2013a, 2013b). The present research is significant because previous studies on vocabulary development and growth in EFL contexts have indicated that language learners generally fall short of learning the most frequently used words in English (Rahmani et al., 2022; Schmitt, 2008; Webb & Chang, 2012; Xodabande et al., 2022b; Zakian et al., 2022), and insufficient vocabulary knowledge continues to be a major challenge when EFL learners start their university studies, where they need to read textbooks and research articles in English (Hsu, 2013; Tavakoli & Tavakol, 2018; Ward, 2009; Xodabande & Atai, 2022; Xodabande et al., 2022a). Accordingly, bridging this vocabulary gap might significantly benefit students and language teaching programmes. Furthermore, vocabulary instruction receives insufficient attention in language classrooms because of a number of factors, including time shortages and an inadequate focus on vocabulary in instructional materials (Webb & Nation, 2017). This situation makes familiarising language learners with effective vocabulary learning strategies and promoting autonomous learning outside the classroom a worthwhile (and necessary) undertaking (Nunan & Richards, 2015; Richards, 2015). Accordingly, the findings of the present study contribute to our growing understanding of the learning outcomes from digital and traditional materials, providing implications for teaching vocabulary in EFL contexts.

2 Review of the literature

Second language vocabulary development occurs either incidentally or intentionally (Webb & Nation, 2017). In the former, there is no explicit focus on learning words because the process takes place as a by-product of communicative interactions associated with plenty of meaningful input (Nation, 2013). Despite the advantages of incidental learning in terms of the quality of the acquired knowledge and automaticity in recalling and using words, language learners in EFL contexts generally have limited contact with the target language outside the classroom. This lack of sufficient input negatively impacts the chances of incidental vocabulary learning, which means that second language learners have to rely on deliberate and intentional learning mechanisms and strategies for most of the developments in their vocabulary knowledge (Laufer, 2005). More specifically, it has been argued that, to help language learners achieve acceptable levels of comprehension in using language in a variety of contexts, explicit and direct attention to vocabulary should be prioritised over implicit learning mechanisms (Vilkaitė-Lozdienė & Schmitt, 2019). The available sources for intentional vocabulary learning are diverse, but the most notable examples include dictionaries, course books, flashcards, wordlists, pedagogical tasks, serious games and fill-in-the-blank activities (Lei & Reynolds, 2022; Li & Hafner, 2022; Webb et al., 2020). As one of the effective strategies for intentional vocabulary learning, flashcards (in digital or traditional formats) have remained among the most attractive mediums, with positive outcomes for developing both receptive and productive vocabulary knowledge (Lei & Reynolds, 2022; Li & Hafner, 2022; Nakata, 2011, 2019). Although the flashcard learning strategy is based on paired-associate learning (connecting form to meaning) and vocabulary items are often presented in a decontextualised format (Nakata, 2019), empirical evidence suggests that this strategy might be more effective than learning vocabulary from context (Laufer & Shmueli, 1997; Webb, 2007).

In recent years, with mobile devices becoming more accessible to a large number of language learners around the world, research focusing on mobile-assisted language learning (MALL) and various affordances provided by such platforms for language learning has been gaining increased attention (Burston & Giannakou, 2022; Nazari & Xodabande, 2022; Stockwell, 2022). A close examination of the available literature on MALL shows that researchers have investigated the impacts of a wide variety of mobile applications and tools for teaching vocabulary. Here, the most commonly employed technologies include (1) SMS/MMS tools (Hayati et al., 2013; Lin & Yu, 2017), (2) context aware mobile applications (Chen & Li, 2010; Hwang & Chen, 2013; Sandberg et al., 2011, 2014), (3) gaming

applications (Castañeda & Cho, 2016; Rachels & Rockinson-Szapkiw, 2018), (4) mobile applications designed by the researchers (Wu, 2014, 2015a, 2015b), and (5) digital flashcards (Lei & Reynolds, 2022; Seibert Hanson & Brown, 2020; Xodabande & Atai, 2022; Xodabande et al., 2022a; Yüksel et al., 2022). Collectively, the findings from a large majority of these studies have shown that the use of technological resources for vocabulary instruction has resulted in significant and improved learning gains compared with traditional paper-based materials (Yu & Trainin, 2022). Additionally, the affordances of mobile devices for extending vocabulary learning to anytime and anywhere has been identified as a key factor contributing to increased learning outcomes (Hao et al., 2021; Lin & Lin, 2019; Xodabande et al., 2022b; Zakian et al., 2022). However, in a recent systematic review, Lin and Lin (2019) concluded that, because of small sample sizes and research design limitations in terms of short treatment time and lack of control groups, the overall and long-term effectiveness of vocabulary learning via mobile devices remained inconclusive. Such observations foreground the need for conducting more empirical research into both short- and long-term learning outcomes resulting from mobile-assisted vocabulary learning compared with using traditional materials and strategies.

As one of the main strands of mobile-assisted vocabulary learning studies, recent years have witnessed a growing interest in the use of digital flashcards installed and used on portable devices (Fathi et al., 2018; Kose & Mede, 2018; Lei & Reynolds, 2022; Rahmani et al., 2022; Xodabande & Atai, 2022; Xodabande et al., 2022a, 2022b; Yüksel et al., 2022; Zakian et al., 2022). This body of research has examined the impacts of digital and paper cards on learning different types of vocabulary items, including general, academic and technical words. The impacts of vocabulary learning with digital flashcards on language learners' motivation and other psychological variables and associated capacities have also been investigated in the literature. For example, Kose and Mede (2018) examined the impact of using a digital flashcard application for smartphone devices and traditional notebooks on EFL learners' vocabulary learning and motivation in Turkey. The study also explored the perceptions of teachers and students with respect to the integration of mobile devices into language teaching. The results of vocabulary tests (pre- and posttest) and motivation questionnaires revealed that students who used digital flashcards not only improved their vocabulary knowledge, but also experienced higher levels of motivation, and both teachers and students positively perceived the integration of mobile devices into the classrooms.

Regarding the other psychological factors contributing to significant learning gains, some studies have reported that using digital flashcards improves language learners' self-regulation and self-efficacy in vocabulary learning. Here, Fathi et al. (2018) investigated vocabulary learning and self-regulatory capacity in vocabulary

acquisition using a flashcard mobile application in Iran. Over the course of a semester, the students in the experimental group used the application for learning new vocabulary, while the control group employed traditional learning materials; in the study, mobile applications helped students in the experimental group in improving their vocabulary learning, contributing to their self-regulating capacity significantly compared with the students in the control group. More recently, Seibert Hanson and Brown (2020) studied the impacts of a flashcard application (i.e., Anki) on improving university students' Spanish vocabulary over a semester. The findings indicated a positive relationship between time spent on learning vocabulary with the mobile application and students' Spanish performance at the end of the semester, even after controlling for some other variables, including motivation, self-efficacy, and beliefs. Despite these positive outcomes, the study found that most students reported low enjoyment using the application and, hence, were reluctant to do so. However, by the end of the semester, the participants reported increased motivation and more effort-based or incremental beliefs towards using digital flashcards. The findings of these studies have suggested that, compared with traditional materials, the use of digital flashcards is associated with increased motivation and, hence, spending more time on vocabulary learning. These observations also point to the inherent motivational impacts of using digital technologies for language learning (Stockwell, 2013).

Despite the reported effectiveness of digital flashcards in scaffolding vocabulary knowledge development, only a limited number of studies have investigated their potential for addressing the learning needs of language learners, which involves focusing on teaching a substantial number of words over longer interventions. These endeavours inevitably need long-term treatment periods; nonetheless, considering the difficulties associated with longitudinal research in this area (Lin & Lin, 2019), only a few studies have explored the impacts of using mobile devices for long-term vocabulary development. Among such studies, Rahmani et al. (2022) explored the contribution of digital flashcards for teaching 1,500 high-frequency vocabulary in English. The findings of the study showed that, after using the flashcards for three months, the vocabulary test scores of the participants demonstrated around 18% improvement, pointing to significant learning gains in a short time period. The results of a delayed posttest administered two months later confirmed the long-term impacts of the intervention. Similarly, Zakian et al. (2022) also reported both short- and long-term benefits associated with using digital flashcards for learning high-frequency words in English for EFL learners. In another study conducted over a one-year period with a repeated measures design, Xodabande et al. (2022b) exposed EFL learners to digital and paper cards, testing their receptive knowledge of high-frequency vocabulary in English. The results indicated that, although both mediums resulted in significant

learning gains over time, the participants in the experimental group who used digital flashcards outperformed the control group on the post- and delayed posttests and mastered a substantial proportion of the target words. According to the authors, the built-in spaced repetition feature in digital flashcards has resulted in the effective learning of vocabulary items. Taken together, the findings of these studies underscore the affordances of mobile devices and digital flashcards in bridging the vocabulary knowledge gap for EFL learners.

Given the importance of academic and technical vocabulary in EFL university students' second language literacy and professional identity developments, some studies have explored the contribution of digital flashcards for learning vocabulary items beyond high-frequency words. Yüksel et al. (2022) compared the effects of digital flashcards and wordlists on learning technical vocabulary among 57 undergraduate pharmacy students. Using pre- and posttreatment surveys and two technical vocabulary tests, the study revealed that students learned more vocabulary using digital flashcards. Moreover, students had positive perceptions regarding the use of digital flashcards for learning vocabulary, which was a predictor of their success in learning technical words. The study concluded that teacher-made digital flashcards resulted in better learning of technical vocabulary. In another study, Xodabande and Atai (2022) explored the use of digital and paper-based flashcards in the autonomous and self-directed learning of academic vocabulary by EFL university students. The study revealed that both interventions contributed to developments in the participants' vocabulary knowledge and that the learning gains attained from digital flashcards were significantly higher compared with traditional materials. The findings also pointed to the long-term impacts of mobile-assisted vocabulary learning measured in a follow-up delayed posttest. Furthermore, Xodabande et al. (2022a) integrated mobile-assisted vocabulary learning into an English for specific purpose (ESP) course and investigated the relative effectiveness of digital flashcards compared with traditional cards for learning 361 discipline-related academic words. The findings indicated that using digital flashcards resulted in increased engagement and more effort for learning academic vocabulary. Considering that, in most EFL learning contexts, many students have significant gaps in their high-frequency vocabulary knowledge (Webb & Chang, 2012; Zakian et al., 2022), there is a need for systematic interventions targeting a wider range of vocabulary items rather than just academic or technical words.

In sum, the literature shows that mobile-assisted learning with digital flashcards is a practical and effective strategy for teaching general and specialised vocabulary to EFL learners (Lei & Reynolds, 2022). Additionally, the learning gains reported for both paper and digital formats are considerable and noteworthy, with digital flashcards being associated with better vocabulary learning and increased

motivation (Xodabande & Atai, 2022; Xodabande et al., 2022a). However, the implementation of mobile technologies in language learning in general has been associated mostly with short-term interventions, and vocabulary-related studies have also focused on teaching only a limited number of words (Burston, 2013; Chwo et al., 2018; Hwang & Fu, 2019). Consequently, it is not still clear what long-term learning outcomes might be attained from using such platforms to address language learners' vocabulary learning needs in terms of general service (high frequency) and academic words. Additionally, the use of standard and validated tests of vocabulary knowledge remains limited in the literature, hence further restricting the possibility of comparing learning outcomes from using different mobile technologies. To address these gaps, the current study aimed to investigate the use of mobile application flashcards in teaching general service and academic words. Accordingly, the study was conducted over two academic semesters, and standard vocabulary tests were employed to measure learning gains. The following research questions were addressed:

RQ 1: Does using digital flashcards result in increased learning outcomes and improvements in university students' knowledge of general and academic vocabulary compared with using traditional materials?

RQ 2: Do the learning gains in mobile-assisted vocabulary learning persist over time?

3 Methods

3.1 Participants

The participants of the present study were first- and second-year university students (mean age: 20, 38 males and 33 females) majoring in chemistry, mathematics and psychology and who were selected based on their availability to the researchers from two universities in Iran. To have a homogenised group of students for the interventions, the following criteria were implemented: First, the study focused on those students with no background in taking ESP courses at the university level (which exposes them to advanced reading materials in their subject area). Second, the participants were selected from one linguistic background (L1 Persian) and from students taught by one of the researchers. Third, given the strong correlation between English vocabulary knowledge and general proficiency level in this language (Alderson, 2006; Morris & Cobb, 2004; Qian, 2002), data obtained from those participants who had similar vocabulary sizes were analysed. A standard vocabulary knowledge test (i.e., the updated vocabulary levels test) (Webb et al.,

2017) was administrated to 109 university students. After analysing the results, those individuals who scored 10 points above or below the mean score of the whole population were identified, and their data were excluded from subsequent analysis. Accordingly, this process resulted in 71 participants. It should also be noted that general English courses are compulsory for university students in Iran, and most students take such courses in their first and second years before taking ESP courses. To comply with ethical considerations in educational research, informed consent was obtained from the students participating in the study.

3.2 Materials and instruments

3.2.1 Digital and paper flashcards

Two freely available digital flashcard applications (i.e., the NGSL and NAWL builder) and associated paper-based word cards were used as the main materials for learning general service and academic vocabulary in English. The NGSL Builder is a mobile application developed by EFL technologies (<http://efltechnologies.com/>) for learning the New General Service List (Browne et al., 2013a). The NAWL builder, also designed by EFL technologies, helps learners in learning the items in the NAWL (Browne et al., 2013b). Both applications use intelligent flashcard technology with a feature for spaced repetition of the target vocabulary items. This mechanism lessens the possibility of forgetting newly learned words by recycling them in specific time intervals (Kornell, 2009; Roediger & Butler, 2011). The employed applications had a simple and user-friendly interface; they provided part of speech information, pronunciation of the target words by a native speaker of English and had word definitions written in simple English. The paper-based word cards were created for the same vocabulary items in the digital flashcards, and they contained the same information, with the exception of pronunciation information, which was provided in phonetic symbols.

3.2.2 NGSLT and NAWLT

The study employed two standard tests to measure the written receptive knowledge of the NGSL and NAWL. Here, the New General Service Lists Test (NGSLT) (Stoeckel & Bennett, n.d.-b) was employed to test the participants' general vocabulary knowledge before and after the treatment. The NGSLT contains 100 items, in which 20 items represent each of the five bands of the NGSL with approximately 560 words (the NGSL contains 2,818 words). By testing smaller groups of words, the test helps identify with greater accuracy the point at which the

learners no longer have sufficient mastery of the majority of words. This feature was especially helpful in the context of the current study, where there is a large gap in the participants' knowledge of high-frequency words. The current study also used the New Academic Word List Test (NAWLT) (Stoekel & Bennett, n.d.-a) as a diagnostic measure of written receptive knowledge of the academic words in the NAWL. The NAWLT comprises 40 items and tests the knowledge of 963 words in the NAWL that are frequently and widely used in academic discourse. The NGSLT and NAWLT were developed based on sound specifications, and the items in each of the tests provided a sample target word followed by short sentences containing the word in a natural yet nondefining context. Both tests were piloted extensively in the development phase through Rasch analysis. Accordingly, because the NGSLT has more items, it consistently demonstrated a high reliability index (Cronbach's $\alpha = 0.90$); however, the reliability of the NAWL was lower (but still acceptable) as a result of having fewer items (Cronbach's $\alpha = 0.75$).

3.2.3 Updated vocabulary levels test

As a standard test of general vocabulary knowledge in English, the present study also used the updated vocabulary levels test (UVLT) (Webb et al., 2017) in the pre-, post- and delayed posttests. The UVLT was developed into five sections to measure the receptive knowledge of English vocabulary at 1,000, 2,000, 3,000, 4,000 and 5000 frequency levels based on BNC/COCA base lists (Nation, 2012). Each of the five sections consisted of 30 items in a multiple matching format. The test allows for profiling the vocabulary knowledge of English language learners at particular levels, and currently, this test is one of the widely employed instruments among language teachers and researchers (Kremmel & Schmitt, 2017). Because the test is available in two equivalent and similar versions, it is possible to use different forms in repeated measurements to mitigate learning from taking tests and associated memory effects. Moreover, because the NGSLT and NAWLT are available in single versions, the UVLT was employed to control for any possible testing and memory impact on the vocabulary knowledge of the participants. Additionally, because the UVLT measures the knowledge of the 5,000 most frequent words in English, it provides a more complete account of the developments in vocabulary knowledge.

3.3 Procedures

To help the university students bridge their vocabulary gap and prepare them for advanced reading courses, in coordination with programme directors, a vocabulary learning component was added to the existing general English course offered

in the study context. This component aimed at helping students learn essential and academic vocabulary using digital and paper-based flashcards. To select the target vocabulary items, the participants' vocabulary learning needs were determined by a pretest that involved administering the NGSLT and NAWLT. Given the results of the pretests (provided in the results section), around 1,600 items from the NGSL (around 50% of the items in the list) and all 963 items from the NAWL were selected for the interventions. Additionally, to have a different baseline for documenting the changes in the participants' vocabulary knowledge during the study, version A of the UVLT was administered as a criterion measure in the pretest. The use of multiple tests ensured obtaining a more transparent picture of the participants' vocabulary knowledge, which helped in triangulating the results using different sources for the collected data. Following the pretests, the participants were assigned to experimental and control groups based on their own preferences for using digital or paper cards. Accordingly, the students were given the option for choosing the materials, and 38 individuals opted for mobile-assisted learning (i.e., the experimental group), and the remaining 33 participants preferred paper-based cards (i.e., the control group). This procedure ensured the alignment of the interventions with the participants' learning styles.

Before the treatments, the participants in the experimental group were instructed on installing the NGSL and NAWL builder applications and added the target words to their learning lists. The control group received ready-made paper-based cards with a guide on the spaced repetition strategy. Additionally, all participants received a one-hour training session on using flashcards for vocabulary learning. After familiarising them with the assigned materials, the participants in both learning conditions were asked to spend at least 20 min every day for five days a week studying the target vocabulary items. The participants used flashcards for learning general and academic vocabulary during an academic semester, and those in the experimental group were asked to send weekly reports to their teacher using a built-in feature available on the mobile applications. Those in the control group kept study logs. Moreover, to sustain the long-term engagement and motivation for vocabulary learning with flashcards, sending progress reports (or handing in study logs) to the instructor on a weekly basis and the results for the end-of-the-semester vocabulary tests (posttests) accounted for 30% of the students' overall course evaluation. The posttests were administered at the end of the semester (NGSLT, NAWLT, UVLT (version B)). Finally, to assess the long-term impacts of the interventions, the participants were asked to take the same vocabulary tests one semester later.

3.4 Data analysis

The data obtained via different tests were analysed for descriptive and inferential statistics. To this end, using IBM SPSS (version 25), the test scores were analysed for mean values and standard deviations. Moreover, for investigating the differences in the scores obtained by the experimental and control groups, mixed between-within analysis of variance was used to compare the scores on the pre-, post- and delayed posttests. The between-group variable in the present study had two levels (namely experimental or control learning conditions), and the within-group variable was vocabulary tests conducted three times (pre-, post- and delayed posttest).

4 Results

The results of the descriptive statistics for the scores obtained on the pre-, post- and delayed posttests are shown in Table 1. For the pretests, the vocabulary test scores obtained by the two groups on the three measures—namely NGSLT, NAWLT and UVLT—were largely similar but with minor differences. As for the posttests, the participants in the experimental group scored higher on all three measures compared with those in the control group. For example, on the UVLT, the mean value for the scores obtained by the experimental group was 84.39 ($SD = 8.25$), which is considerably higher than the mean score for the control group ($M = 76.27$, $SD = 5.86$). Moreover, the results of the delayed posttests revealed that the scores obtained by the participants were lower compared with the posttests; however, the participants in the experimental group obtained higher scores compared with those in the control group. Additionally, the delayed posttest scores were higher than the scores obtained on pretests.

To investigate the results for any pre-existing differences in the participants' vocabulary knowledge before the treatments, the scores obtained on the pretests were compared by conducting independent samples *t*-test (Table 2). The results indicated that there were no statistically significant differences in the scores obtained on the NGSLT, NAWLT and UVLT among the experimental and control groups.

To analyse the scores for within- and between-subjects variables (i.e., time and group), a mixed between-within subjects analysis of variance was performed. To this end, (1) Levene's test of equality of error variances as the assumption of homogeneity of variances and (2) Box's test of equality of covariance matrices as the assumption of equality of covariance matrices were examined, and no

Table 1: Descriptive statistics.

		Group	N	Mean	Std. deviation	Std. error mean
Pretest	NGSLT	Experimental	38	54.45	4.524	0.734
		Control	33	53.67	5.956	1.037
	NAWLT	Experimental	38	11.05	2.977	0.483
		Control	33	10.52	2.841	0.495
	UVLT (Version A)	Experimental	38	61.24	5.567	0.903
		Control	33	60.94	5.761	1.003
Posttest	NGSLT	Experimental	38	84.37	6.934	1.125
		Control	33	75.00	6.005	1.045
	NAWLT	Experimental	38	27.63	4.857	0.788
		Control	33	21.52	2.575	0.448
	UVLT (Version B)	Experimental	38	84.39	8.258	1.340
		Control	33	76.27	5.859	1.020
Delayed posttest	NGSLT	Experimental	38	74.53	7.248	1.176
		Control	33	62.52	5.557	0.967
	NAWLT	Experimental	38	20.74	4.025	0.653
		Control	33	16.85	3.043	0.530
	UVLT (Version A)	Experimental	38	74.08	6.270	1.017
		Control	33	66.55	5.858	1.020

violation of the assumptions of the analysis of variance (ANOVA) was noted. The results obtained for multivariate tests (Table 3) indicated that there was a significant interaction effect among the time and group variables (Wilks' Lambda = 0.63, $F(6, 272) = 11.86$, $p \leq 0.001$, $\eta_p^2 = 0.21$). The observed interaction effect indicated that the changes in the scores over time were different for the two groups. Furthermore, the results also revealed that there was a significant main effect for the within-subjects variable (i.e., time) (Wilks' Lambda = 0.75, $F(6, 272) = 120.37$, $p \leq 0.001$, $\eta_p^2 = 0.73$). These findings generally mean that the observed differences in the scores were statistically significant across the three testing times from the pretest to the delayed posttest, with the findings pointing to a very large effect size based on the criteria proposed by Cohen (1988).

The results for the tests of between-subjects effects (Table 4) revealed that there were significant main effects resulted from the two learning conditions (i.e., digital and paper flashcards) on NGSLT ($F(1, 2891) = 81.89$, $p \leq 0.001$, $\eta_p^2 = 0.54$), NAWLT ($F(1, 654) = 43.07$, $p \leq 0.001$, $\eta_p^2 = 0.384$) and UVLT ($F(1, 1498) = 39.36$, $p \leq 0.001$, $\eta_p^2 = 0.36$). Here, the findings of the study provided empirical evidence for the effectiveness of mobile-assisted vocabulary learning via digital flashcards compared with traditional materials. Accordingly, the

Table 2: Independent samples t-test for the scores on the pretest.

		Independent samples test				t-test for equality of means				
		Levene's test for equality of variances								
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Lower	Upper
NGSLT	Equal variances assumed	4.387	0.040	0.626	69	0.533	0.781	1.246	-1.705	3.267
	Equal variances not assumed			0.615	59.23	0.541	0.781	1.270	-1.761	3.322
NAWLT	Equal variances assumed	0.034	0.854	0.775	69	0.441	0.537	0.694	-0.846	1.921
	Equal variances not assumed			0.778	68.36	0.439	0.537	0.691	-0.842	1.917
UVLT	Equal variances assumed	0.119	0.731	0.221	69	0.826	0.297	1.346	-2.388	2.983
	Equal variances not assumed			0.220	66.90	0.826	0.297	1.350	-2.396	2.991

Table 3: Tests of within-subjects effects.

		Multivariate ^{a,b}					
Within-subjects effect		Value	<i>F</i>	Hypothesis df	Error df	Sig.	Partial Eta squared
TIME	Pillai's Trace	0.944	40.831	6.000	274.000	0.000	0.472
	Wilks' Lambda	0.075	120.374 ^c	6.000	272.000	0.000	0.726
	Hotelling's Trace	12.108	272.435	6.000	270.000	0.000	0.858
	Roy's Largest Root	12.087	551.985 ^d	3.000	137.000	0.000	0.924
	Pillai's Trace	0.385	10.875	6.000	274.000	0.000	0.192
TIME * Group	Wilks' Lambda	0.628	11.868 ^c	6.000	272.000	0.000	0.207
	Hotelling's Trace	0.572	12.865	6.000	270.000	0.000	0.222
	Roy's Largest Root	0.534	24.372 ^d	3.000	137.000	0.000	0.348

^aDesign: Intercept + Group. Within-Subjects Design: TIME; ^bTests based on averaged variables; ^cExact statistic;

^dThe statistic is an upper bound on *F*, which yields a lower bound on the significance level.

interventions resulted in significant improvements in the vocabulary knowledge of all participants; however, those in the experimental group outperformed the control group and learned more vocabulary items. Moreover, the effect size for the observed difference was very large.

5 Discussion

The present study examined the relative effectiveness of digital flashcards over traditional materials for learning vocabulary items in two corpus-based word lists of general and academic words. Accordingly, the first research question investigated changes in the participants' knowledge of general service and academic vocabulary following different treatments. The findings indicated that using both paper and digital flashcards significantly contributed to improvements in the participants' vocabulary knowledge from the pretest to posttest. Additionally, the results also provided empirical evidence for the relative effectiveness of the digital flashcard applications used on mobile learning over paper-based materials for learning general and academic vocabulary in English. The findings are in line with the earlier studies that reported increased learning outcomes and the effectiveness of mobile devices and associated applications for learning vocabulary in general (Wu, 2014, 2015a, 2015b) and digital flashcards applications

Table 4: Tests of between-subjects effects for comparing the two groups.

Tests of between-subjects effects							
Transformed variable: average							
Source	Measure	Type III sum of squares	df	Mean square	F	Sig.	Partial Eta squared
Intercept	NGSLT	963399.363	1	963399.363	27290.416	0.000	0.997
	NAWLT	69051.572	1	69051.572	4545.209	0.000	0.985
	UVLT	1055745.741	1	1055745.741	27733.857	0.000	0.998
Group	NGSLT	2891.137	1	2891.137	81.898	0.000	0.543
	NAWLT	654.313	1	654.313	43.069	0.000	0.384
	UVLT	1498.304	1	1498.304	39.360	0.000	0.363
Error	NGSLT	2435.821	69	35.302			
	NAWLT	1048.259	69	15.192			
	UVLT	2626.625	69	38.067			

in particular (Fathi et al., 2018; Kose & Mede, 2018; Rahmani et al., 2022; Seibert Hanson & Brown, 2020; Xodabande & Atai, 2022; Xodabande et al., 2022a; Yüksel et al., 2022; Zakian et al., 2022). Moreover, the findings have indicated that the participants in the experimental group outperformed those in the control group in all three measures. Consequently, the current study showed that mobile applications have considerable potential for teaching a large number of vocabulary items to EFL learners. Given that the target words selected for the current study were based on systematically developed corpus-based word lists for EFL learners, the vocabulary gains attained by the participants are pedagogically valuable, and their increased vocabulary knowledge helped contribute to their successful language use for general and academic purposes, facilitating the process of second language learning in general (Webb & Nation, 2017).

The second research question explored the persistence of learning gains in mobile-assisted vocabulary learning over time. Here, the findings revealed that the differences in the mean scores on NGSLT, NAWLT and UVLT in both the post- and delayed posttests were significantly higher than the scores on the pretests. Considering that the delayed posttests were administered four months following the posttests, the findings indicated that the gains in mobile-assisted learning might be persistent in the long term. Nevertheless, it should be noted that the decline in the scores from the posttests to delayed posttests was also statistically significant. A closer look into the obtained scores on the three measures of vocabulary knowledge employed in the current study and comparing the results for the posttests to the delayed posttests show that the decline in the participants'

scores on all tests was disproportionate to their gains from the pretests to posttests. Given that the students were not receiving any training for learning the target words after the posttests, the fact that they retained most of their learned items was significant. The use of different versions of the UVLT also ensured minimising learning from taking the same tests, and the changes in the scores on the NGSLT and NAWLT were also reflected in the scores obtained on the UVLT.

There might be some explanations for the considerable and significant gains in the knowledge of general and academic vocabulary attained by the participants in the present study. First, with respect to higher vocabulary gains by the experimental group, because the employed applications had built-in spaced repetition technology, the university students studied the target words with increased efficiency, and they had plenty of chances to practice newly learned words through the recycling function. Given that repeated encounters with target words is one of the important conditions for vocabulary learning (Webb & Nation, 2017), this feature contributed to the developments in vocabulary knowledge observed in the present study. Second, compared with the paper flashcards, the mobile applications had a native speaker's pronunciation of the target words embedded in the flashcards. Previous research has indicated that auditory presentation of content contributes significantly to the retention of verbal information (Baddeley et al., 1998; Li & Hafner, 2022). Third, it has been argued that introducing new digital technologies in language education brings an inherent motivational state that facilitates learning (Stockwell, 2013). In this regard, using digital flashcards on mobile devices seems to be motivating for learners compared with paper-based word cards or wordlists. Fourth, the portability of mobile devices and easy access to the learning materials, in addition to some useful features in the mobile applications (including grammatical information, pronunciation and using easy English definitions for the target items), might have further contributed to the learners' significant vocabulary gains over time. These affordances of the mobile devices increase study times, and in the long term, they contribute to significant learning and development (Xodabande & Hashemi, 2022). Additionally, the integration of mobile-assisted vocabulary learning into formal educational programmes further contributed to sustained engagement with the learning materials, with impacts on the overall vocabulary development.

The present study has some pedagogical implications for EFL vocabulary teaching. First, the findings of the present study indicated that using digital flashcards resulted in significant vocabulary gains over a period of four months. The time spent by the participants studying the NGSL and NAWL items might be considered a long-term intervention in MALL studies, but it is too short when compared with the time needed for second language vocabulary development, which normally takes many years and requires substantial learning efforts

(Nation, 2013; Webb & Chang, 2012; Webb & Nation, 2017). In this regard, the use of digital flashcards can help learners shorten this long-term process and boost their vocabulary knowledge effectively. Second, given the prominent role of general service and academic vocabulary in EFL learners' language literacy development and the so-called vocabulary knowledge gap observed for these learners (Hsu, 2013; Ward, 2009), employing mobile devices and flashcard applications (with spaced repetition features) can provide a viable approach to bridge the vocabulary knowledge gap for EFL university students. Given the pivotal place of vocabulary knowledge in the successful development of all language skills (Clenton & Booth, 2020; Nation, 2001, 2013), the implementation of this vocabulary learning strategy has significant potential to contribute to their language proficiency development in general. Third, it has been argued that formal instructional contexts, such as language learning classrooms are resistant to change and the employment of modern educational technologies; hence, the true potential of mobile devices may be realised best outside the classroom (Lai & Gu, 2011). Because vocabulary learning tends to receive less attention from teachers compared with other language skills (Webb & Nation, 2017), the use of digital flashcards for out-of-the-classroom vocabulary learning can compensate for this situation, potentially helping language teachers and learners set realistic vocabulary learning goals. By focusing on established corpus-based wordlists, the time spent learning vocabulary with digital flashcards can benefit learners in additional ways, including the mastery of the most important words for their general and academic language use. Finally, it should be noted that attrition of the learned vocabulary items, even with the spaced repetition method, is significant in the long term. The limited exposure of EFL learners to the target language further accelerates this attrition. Hence, after learning vocabulary items with digital flashcards, the learners need to review the learned items or use them in their speaking and writing to minimise the weakening and loss of vocabulary knowledge.

6 Conclusion

The current study investigated the contribution of digital and paper flashcards in learning general service and academic words in English, tracing the persistence of the learning gains over time. The results indicated that digital flashcards employed on mobile devices were more effective compared with traditional materials in promoting university students' knowledge of general and academic words (around 30% and 37.5% improvements in the NGSL and NAWL test scores, respectively) over an academic semester. The results of the delayed posttests, which were

administered four months following the posttests, confirmed that a considerable proportion of the participants' learning gains persisted over time. Nonetheless, the amount of attrition in their vocabulary knowledge was also significant. The study employed three standard tests for measuring changes in the participants' vocabulary knowledge, and the findings provided additional empirical support for the relative long-term effectiveness of mobile-assisted vocabulary learning. More importantly, the current study used updated and freely available corpus-based word lists and digital flashcard applications to help EFL university students in learning core and academic vocabulary, showing that the use of mobile devices and well-designed applications informed by corpus-based vocabulary research have considerable advantages over traditional materials in bridging the gap in their vocabulary knowledge. The current study also highlighted some implications for teaching/learning vocabulary in EFL contexts using mobile devices.

The present study has some limitations. First, similar to most studies in educational contexts, intact classes were used, so random assignment was not possible. Nevertheless, the use of a repeated measure design with a variety of instruments to test the gains in vocabulary knowledge compensated for these shortcomings to some extent. Second, the current study was concerned with only one aspect of vocabulary knowledge: written receptive knowledge. Because this was justified by the learning needs of the participants (to read English texts), it should be highlighted that vocabulary knowledge entails other components (Nation, 2001, 2013) that are also important. More specifically, although research has indicated that using flashcards results in significant developments in both receptive and productive vocabulary knowledge (Li & Hafner, 2022; Nakata, 2019), there is a need for more studies focusing on the productive aspects of vocabulary knowledge, such as developing knowledge of collocations. Finally, considering the longitudinal nature of the study, which lasted over two academic semesters, it was not possible to control for the participants' exposure to English language input beyond the specific materials employed for teaching vocabulary. Although easy access to English beyond the classrooms was difficult in the context of the study, the proliferation of the English media in its various forms, which is easily available for language learners via diverse platforms, should be accounted for in interpreting the findings. Related to this concern, it should also be noted that, because there are a wide range of variables that might influence the findings in long-term interventions, ensuring the same learning condition for the participants was not possible. With all these limitations, the current study has provided empirical evidence for the short- and long-term effectiveness of mobile-assisted vocabulary learning, which was associated with better learning outcomes compared with traditional materials. However, given the diversity of vocabulary learning tools and resources (Ma & Mei, 2021), there is a need for more research to

shed additional light on the nuances involved in learning vocabulary with mobile devices and digital flashcards, along with studies using both quantitative and qualitative measures that investigate learning gains alongside the learners' perceptions and attitudes, which can greatly benefit this line of research.

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Bionotes

Ismail Xodabande

Kharazmi University, Tehran, Iran
ismail.kh.tefl@gmail.com

Ismail Xodabande is a PhD candidate in Applied Linguistics at Kharazmi University, Tehran, Iran. He is interested in doing research on the role of various educational technologies in foreign language education, mobile-assisted language learning (MALL) and the application of corpus linguistics in ELT. He has published in these areas in *Computer Assisted Language Learning*, *Open Learning*, *Journal of Computers in Education*, *Education and Information Technologies*, *Frontiers in Psychology*, and the *Asian-Pacific Journal of Second and Foreign Language Education*.

Vahid Asadi

University of Siena, Siena, Italy
vahidasadi700@gmail.com

Vahid Asadi holds an MA in Language, Mind-linguistics and Cognitive Studies from the University of Siena, Italy. His areas of interest include natural language processing (NLP), machine translation (MT) and computer-assisted language learning. His research has appeared in *Frontiers in Psychology*.

Mohammadreza Valizadeh

Hasan Kalyoncu University, Gaziantep, Turkey
mrvalizadeh2015@gmail.com

Mohammadreza Valizadeh holds a PhD in TEFL from Gazi University, Ankara, Turkey. He has published several articles in scholarly journals such as *Journal of Computers in Education*, *Journal of Language and Education*, and the *Asian-Pacific Journal of Second and Foreign Language Education*. His areas of interest include corrective feedback, flipped learning, learning strategies, learner autonomy, task-based language teaching and individual differences in language learning.