Reading and Writing (2019) 32:1175–1195
https://doi.org/10.1007/s11145-018-9906-x

Multimedia-assisted self-learning materials: the benefits of E-flashcards for vocabulary learning in Chinese as a foreign language

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Published online: 18 September 2018

Abstract
In this study, we examined the effects of E-flashcards and paper flashcards on Chinese vocabulary learning and learning attitudes among students learning Chinese as a foreign language. One hundred fourth and fifth grade English-speaking students participated in two groups, E-flashcards (n = 50) and paper flashcards (n = 50), to learn 20 new Chinese words. E-flashcards (or digital flashcards through students' iPads) incorporate multimedia resources with comprehensive visual, verbal, and audio inputs while the paper flashcards provide only visual and verbal inputs. Results revealed that students who used E-flashcards statistically outperformed those who used paper flashcards on immediate post-tests of Chinese word reading and listening, as well as on 1-week delayed listening test. In addition, students who used E-flashcards demonstrated more positive learning attitudes toward Chinese word learning than those who used paper flashcards. Such findings support the audio application of multimedia on Chinese word recognition among novice Chinese language learners as an effective pedagogical approach. Instructional implications are discussed.

Keywords Chinese as a foreign language (CFL) · Vocabulary learning · Multimedia aids · Learning attitudes · E-flashcards

Introduction

According to U.S. Department of Education (2010), 97% of public elementary and secondary school teachers have one or more computers in their classroom. This statistic indicates that technology has been integrated into daily instruction to enhance students' learning and engagement in learning (Ertmer & Ottenbreit-Leftwich,

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2013). With emerging technology, coupled with the use of multimedia, students' receptive language skills (Alvarez-Marinelli et al., 2016) and productive language skills (Hwang et al. 2014, 2016) can be enhanced more effectively. From the psycholinguistic perspective, multimedia provides multi-sensory exposure to students (i.e., audio and visual). It has been reported that language learners who used multimedia learning material memorized more words than their peers who used paper-based learning material (Ahmadian, Amerian, & Goodarzi, 2015). Moreover, when being immersed in multimedia-assisted language instruction, students achieved higher word attainment than those in traditional classroom instruction (Tozcu & Coady, 2004). The students are also able to gain skills (e.g., learning autonomy and computer literacy) and practice information processing skills (Cerezo, Baralt, Suh, & Leow, 2014).

E-flashcards (or digital flashcards), one type of multimedia-assisted vocabulary learning material, have been found to positively impact second language (L2) learners' word attainment (Başoğlu & Akdemir, 2010; Chuang & Ku, 2011), as well as their learning attitudes (Chuang & Ku, 2011; Kim & Gilman, 2008; Lees & Mcnee, 2015; Low, Hew, & Wong, 2014). However, few empirical studies (e.g., Chuang & Ku, 2011; Zhu, Fung, & Wang, 2012) are available regarding the pedagogy of E-flashcards for word learning in Chinese as a second/foreign language. In addition, little research has been conducted on the difference between paper flashcards and E-flashcards on Chinese word learning and recall when measured by reading and listening tests among elementary English-speaking students. To address such limitation, in this current study we: (a) compared the effects of E-flashcards versus paper flashcards on elementary Chinese language learners' word learning and recall as measured by reading and listening tests; (b) discovered learners' attitudes toward the use of E-flashcards on Chinese word learning; and (c) discussed the pedagogy of multimedia-assisted vocabulary learning in the context of Chinese as a foreign language. We developed E-flashcards on iPads with three features: (a) audio (the sound of target Chinese words); (b) verbal (the written form of Chinese words); and (c) visual (a corresponding picture), so as to make the materials more accessible to students' Chinese learning.

Theoretical framework

The framework of this study is derived from the cognitive theory of multimedia learning (Mayer, 2009). Mayer (2009) defined multimedia learning as the idea that new knowledge can be learned through electronic instructional materials presented in both verbal and visual forms. Mayer proposed three assumptions of cognitive theory in multimedia learning: dual channels, limited capacity, and active processing. The assumption of dual channels is that humans use audio and visual channels to process information. The assumption of limited capacity is that

through each channel human beings can process a limited amount of information. The assumption of active processing is that human beings actively engage in cognitively processing information by selecting incoming information, organizing selected incoming information, and integrating selected incoming information with prior knowledge. Studies have recognized pedagogical values of multimedia materials on foreign word learning (Khezrlou, Ellis, & Sadeghi, 2017; Mohsen, 2016). For example, multimedia materials provide a productive source of language input that potentially promotes foreign language learners' semantic development (Mohsen, 2016). Also, multimedia materials can enhance learners' bilingual language awareness by providing multisensory exposure to the phonology, prosody, semantics, typography, and graphic communication of the target language (Edwards, Monaghan, & Knight, 2000).

Literature review

Visual, verbal, and audio support in second/foreign language learning

Vocabulary knowledge (Silverman & Hines, 2009) and vocabulary size (Qian, 2002) are the foundation of reading comprehension skills. Vocabulary knowledge acts as one of the critical factors in predicting language learners' reading comprehension (Prior, Goldina, Shany, Geva, & Katzir, 2014). With limited vocabulary size, language learners often feel overwhelmed and find it hard to comprehend content concepts. For this reason, it is critical for language learners to build their vocabulary knowledge and size. Understanding and practicing vocabulary learning strategies is a prerequisite because it increases word recognition, and, consequently, increases vocabulary knowledge and size (Min, 2008; Silverman & Hines, 2009). Vocabulary learning strategies are actions taken by learners to help them better understand and memorize the meaning of each word, which should encourage them to use the strategies for future vocabulary learning (Oxford, 1990).

Most studies have emphasized the importance of verbal and visual inputs on vocabulary learning strategies (e.g., keyword method or dual coding approach), which facilitate both receptive and productive learning (Beaton, Gruneberb, Hyde, Shufflebottm, & Sykes, 2005; Hatch & Brown, 1995; Shen, 2010; Wyra, Lawson, & Hungi, 2007). For example, the keyword method is used to identify a segment of the word as a keyword, translate the keyword into the learners' native language, and associate it with the new word along with images intended to be optimal for future recall (Atkinson, 1975). A large-scale experimental study on the keyword method (Sagarra & Alba, 2006) reported that English-speaking college learners of Spanish as a L2, when receiving both verbal and visual stimuli, recalled more Spanish words than those learners receiving verbal stimuli only. The authors argued that such differences were caused by the methods, not the presentation order of the stimuli. This importance of verbal representations and visual images on word learning is also emphasized in the dual coding approach (Paivio, 1971).

Oxford (1990) recommended the use of word learning techniques to assist language learners in memorizing new words, such as: creating mental linkages (e.g., grouping the words by themes); applying images and sounds (e.g., flashcards); and employing an action to help learn words. A flashcard is a card containing words and their relevant information on either or both sides of the card (Komachali & Khodareza, 2012; Nicholson, 1998). One of the commonly used types of flashcards for Chinese language learners is a paper card containing a target Chinese word (e.g., 樹), its Chinese pronunciation (i.e., shù), its picture, and its corresponding meaning in the student's native language (i.e., tree for a native English speaker). The use of paper flashcards has been found beneficial on L2 word learning because these flashcards provide verbal and visual cues for the L2 learners to quickly review and recall the learned words (Laufer & Goldstein, 2004). Moreover, flashcards utilize both the student's native language and the target language, which could provide the initial form-meaning link for students to learn and review the words (Nation, 2006; Schmitt, 2008).

These paper flashcards, however, do not incorporate audio. Concerning the nature of word memorization, Goldstein (2011) argued that when people learn a new word, they will repeatedly pronounce the word so as to memorize. He also stated that audio or phonological presentation as a cue could enhance short-term memory, and thus facilitate the learners in word retrieval. His argument was supported by an earlier study (Mayer & Moreno, 2002) that students stood a higher chance of storing information in their working memory with additional audio presentation and graphic presentation. To make flashcards more effective and functional, multimedia is suggested to be incorporated, i.e., E-flashcards which provide comprehensive audio and visual inputs in vocabulary building (Nakata, 2011).

The importance of verbal, visual, and audio support in Chinese vocabulary learning

The non-alphabetical nature of the Chinese language poses extra difficulties in character learning and recognition for learners whose native language is alphabetic. Chinese orthography contains complex visual characteristics (Shen, 2010), so picture presentation along with the word plays an important role in Chinese word learning and recognition (Chen et al., 2013; Chung, 2008; Ju & Jackson, 1995). Empirical studies have demonstrated positive effects of the visual input on the recognition, differentiation, and memorization of Chinese vocabulary words (e.g., Chen et al., 2013; Chuang, 1975; McBride-Chang, Chow, Zhong, Burgess, & Hayward, 2005; Shen, 2010). Additionally, in Shen's (2010) study with dual coding approach, it was found that the simultaneous use of both verbal and visual codes was more effective than the use of verbal code only in college students' retention of Chinese words.

In addition to the importance of the visual input, the sound of Chinese characters is considered an additional component that can facilitate word retrieval (Chan & Siegal, 2001), because 80–90% of Chinese words are phono-semantic compounds

that present both phonology and meaning (Leong, 1997; Yeung et al., 2013). For example, 媽 (ma1) is a phono-semantic word with one phonological radical (馬 'ma3') and one semantical radical (女 'nu3'). Additionally, 馬 (ma3) and 女 (nu3) are pictograms. By using the phonological code of 馬 (ma) rather than the tone of it, Chinese language learners can encode the word 媽 (ma). According to Chan and Siegel (2001), young native Chinese readers apply their phonological processing skills more than their visual memory to predict the sound of a new word. Similarly, novice Chinese language learners rely on audio supports more so than visual supports for vocabulary word learning (Chung, 2008; Shen, 2010; Wu, 2014; Xu, 2011). Sung (2014) and Shen (2005) also reported that novice learners prefer using the strategy of sounding out a newly learned word to assist in memorizing that word. The critical role of the sound of a word in Chinese is, therefore, evident.

Empirical studies using E-flashcards in Chinese vocabulary word learning

E-flashcards have been applied to Chinese language teaching in a few empirical studies. For example, Zhu et al. (2012) found that E-flashcards have a positive impact on word learning for Chinese language learners. They reasoned that audio support on E-flashcards would be more helpful than visual support only for Chinese language learners during word memorization. However, their finding of visual support is questionable because they failed to consider the complex nature of Chinese word creation, and therefore misapplied the technique of visual mnemonics word learning. Furthermore, their vocabulary tests were not developed to closely measure the features of E-flashcards that are embedded with audio and visual stimuli. In another empirical study, Chuang and Ku (2011) examined the effects of two different types of E-flashcards. One type of E-flashcard provides a Chinese word, an associated picture, and the written meaning in English; another type provides a Chinese word, an associated picture, and audio of the meaning in English. Chuang and Ku (2011) collected their data from an immediate test and a 1-week delayed test. However, they did not obtain baseline scores from the participants, which made it difficult to ascertain the impact of these two types of E-flashcards on Chinese vocabulary word learning. Given the limitations of these two studies, and considering the features of E-flashcards and the nature of Chinese word creation, we propose that an optimal layout on E-flashcards should include a Chinese word along with the sound of that word (rather than the meaning of the word in audio form) and an associated image of the word. Accordingly, any accompanying vocabulary tests should measure both listening and reading performance.

Students' attitudes toward E-flashcards in Chinese vocabulary word learning

Not only can E-flashcards enhance students' Chinese learning, but they can also improve students' learning attitudes as a result of computer technology-supported multimedia (Chuang & Ku, 2011; Nakata, 2011; Sydorenko, 2010; Yun, 2011) and mobile technology-supported multimedia (Başoğlu & Akdemir, 2010; Low et al., 2014). We adopted the theoretical framework of Chang and Lehman (2002) and Keller (1979)

regarding multimedia-assisted materials on learning attitudes. It posits that an external condition (i.e., instructional materials) in response to the ARCS model (attention, relevance, confidence, and satisfaction) can facilitate students' learning attitudes (Keller, 1979). When immersed in a multimedia-assisted L2 learning environment, students' learning attitudes can be enhanced (Chang & Lehman, 2002). Chuang and Ku (2011) and Low et al. (2014) reported that Chinese language learners exhibited positive attitudes toward the use of E-flashcards to learn Chinese vocabulary words; moreover, they felt more motivated to concentrate on vocabulary word learning. Based on these findings, we postulate that information processing with multimedia aids can account for the positive effects of acoustic–phonetic priming on attitudes of learning Chinese as a foreign language.

Summary and research questions

Given the nature of the Chinese language, E-flashcards with multiple modalities (i.e., visual, verbal, and audio) are expected to have a stronger effect on Chinese word learning than do paper flashcards. Unfortunately, none of the aforementioned studies examined the integration of the nature of Chinese word creation, and E-flashcards with three modalities, into Chinese word learning; little research has been conducted on how iPads can be used to assist novice Chinese language learners with Chinese word self-learning, especially at elementary school level. In fact, in search of articles published in major journals (e.g., the Computer Assisted Language Learning and the Journal of Language Teaching Research) in the past 10 years, less than five studies focused on elementary Chinese language learners, and none of these studies addressed the effects of technology-enhanced materials on Chinese word self-learning. Additionally, there have been no peer-reviewed studies examining elementary Chinese language learners' attitudes toward technology-enhanced materials such as E-flashcards embedded with audio (the sound of the Chinese words), visual (the picture of the words), and verbal (the written words) support on Chinese word recall as measured by reading and listening tests. Therefore, we created E-flashcards with multiple modalities exclusively for use on iPads; in our study, we explored the effects of these self-learning E-flashcards on Chinese language learners' attitudes, as well as on their Chinese word recall. More specifically, we sought to answer the following three research questions:

(1) Which type of flashcard is more effective in helping Chinese language learners learn and recall words in reading, E-flashcards or paper flashcards?
(2) Which type of flashcard is more effective in helping Chinese language learners learn and recall words in listening, E-flashcards or paper flashcards?
(3) Is there a significant difference between the use of E-flashcards and paper flashcards on students' attitudes toward Chinese word learning?

Method

Participants and Research Context

Based on a convenience sampling, we recruited 50 fourth grade and 50 fifth grade students from one elementary school in a small city in Central Texas, U.S. According to the Texas Education Agency (2015), during the school year 2013–2014, White (46.6%) and Hispanic (42.4%) represented a majority of the student population from kindergarten through fifth grade. Of the total student population, 44% received free or reduced-price lunch, and 13.7% were English language learners. These 100 students were enrolled in either a dual language, a regular or a gifted program. Participation in this Chinese enrichment program was completely voluntary. Among these 100 participants, there were 48 girls and 52 boys. Prior experiences in learning the Chinese language ranged from 1 month (fourth graders) to 1 year (fifth graders). More specifically, the fourth graders didn't have any exposure to the Chinese language before they were enrolled in the program. Fifth grade participants had been in the program for almost a year, when they were in the fourth grade. These fifth grade participants could briefly introduce themselves in Chinese, and they had some knowledge about Chinese culture and history. All fourth and fifth grade participants were familiar with Pinyin, a phonological coding system, prior to the intervention. Therefore, they were able to pronounce an unfamiliar Chinese character when its Pinyin was provided. These basic characteristics are presented in Table 1. We examined the difference on gender distribution between the two groups and identified a homogeneity of the characteristics ($\chi^2(1) = .641$, $p > .05$).

This voluntary Chinese enrichment program is ongoing and has been in place on that elementary school campus for 7 years with enthusiastic support and commitment from the school administrators, as well as a strong interest from the students and their parents. The program is open to fourth and fifth grade students only during regular school hours (every Friday afternoon for 45 min). The purpose of this enrichment program is to increase native English speakers' awareness of, and exposure to, Chinese language and culture. The curriculum and learning materials for the

Table 1 Descriptive statistics on learners' characteristics by group

Group	Grade	n (%)	Gender	n (%)	Average months of learning Chinese
E-flashcards	4th grade	25 (25%)	Boys	11 (44%)	1 month
			Girls	14 (56%)	0.9 month
	5th grade	25 (25%)	Boys	13 (52%)	10.6 month
			Girls	12 (48%)	11 month
Paper flashcards	4th grade	25 (25%)	Boys	13 (52%)	1 month
			Girls	12 (48%)	0.9 month
	5th grade	25 (25%)	Boys	15 (60%)	11 month
			Girls	10 (40%)	10.8 month

program were developed by the researchers of this study based on World-Readiness Standards for Learning Languages (National Standards Collaborative Board, 2015) and Children's Chinese Competency Guideline, supported by the Taiwan government (Steering Committee for the Test of Proficiency-Huayu, 2015). The curriculum was also aligned with Texas Framework for Languages Other Than English (Texas Education Agency, 1997). In this enrichment program, traditional Chinese words and Pinyin are used in the instruction. Pinyin is the Romanization of Chinese characters to facilitate pronunciation. The teacher in this program is a native Chinese speaker with 6 years of experiences teaching Chinese as a second/foreign language, and over 10 years of experiences teaching English as a second/foreign language. He holds a doctoral degree in educational psychology with an emphasis in bilingual education.

Selection of target Chinese words

In this study, we began with our selection of Chinese words based on the Chinese–English word list of Basic Level provided by Children's Chinese Competency Certification (2015), which is a Chinese language proficiency test for young learners of Chinese as a second/foreign language between ages 7 and 12. From that word list, we selected 100 Chinese words by themes (e.g., family, occupation, and weather/season). These 100 Chinese words were high-frequency compound nouns and adjectives. Within these 100 Chinese words there were more than 200 single Chinese characters; 100% of these single characters contained explicit semantic radicals, and 81% contained explicit phonological radicals.

From these 100 words, we selected the final 20 target Chinese words. The criteria for selecting the 20 words were as follows: familiarity with the corresponding English translation, unfamiliarity with the Chinese words, and a cluster of ten words by theme. We used a probe test which was adopted from Vocabulary Knowledge Scale (Paribakht & Wesche, 1992). On the probe test, there were two sections: the first section contained 100 Chinese vocabulary words; the second section contained 100 English words that were the corresponding translation of those 100 Chinese words. On the probe test, for each word item students had to choose one out of five categories that best described their familiarity with the word, from category 1, "I don't remember having seen this word before" to category 5, "I can use this word in a sentence: _____." Their responses were rated by three graduate students majoring in education from a university located within proximity of the research setting. These raters coded each word in their respective category based on frequency, i.e., 1 = completely unfamiliar with the Chinese/English word; 2 = somewhat unfamiliar; 3 = neutral; 4 = somewhat familiar; and 5 = completely familiar. Further, the raters also evaluated responses in category 5 to identify if the sentence provided by the student truly reflected an understanding of the target vocabulary word. Interrater reliability (kappa) was reached at .93. The final 20 target words (about 40 single characters) all contained explicit semantic radicals; about 85% of the characters contained explicit phonological radicals. Because these 20 target Chinese words were identified as unfamiliar words to all students, pre-test scores of two groups

(e-flashcard and paper flashcard) were not statistically different from one another for both reading $t(98) = .218$, $p > .05$, and listening $t(98) = .883$, $p > .05$.

Procedure

The 100 participants were randomly assigned to the E-flashcard and paper flashcard groups. In consideration of the different amount of time spent learning Chinese between fourth and fifth graders, each grade had one E-flashcard group and one paper flashcard group. For this study, treatments were given during 45-min school day sessions on two successive Fridays. On the first Friday, 25 fourth graders received a set of 20 E-flashcards and self-learned the 20 target words; the other 25 fourth graders received a set of 20 paper flashcards with the same 20 words. On the second Friday, 25 fifth graders received a set of 20 E-flashcards and self-learned the 20 target words which were different from the words the fourth graders learned. The other 25 fifth graders received a set of 20 paper flashcards with the same 20 words. The fourth and fifth graders received different sets of words because as was mentioned earlier, the fifth graders had already been in the program for a year and demonstrated familiarity with some Chinese words in the probe test.

E-flashcards were made by the teacher and saved on each student's iPad. E-flashcards contained verbal (i.e., Chinese word, its logograph and pinyin), visual (i.e., picture), and audio cues (i.e., pronunciation of the Chinese word and English translation of the Chinese word). An example of a teacher-made E-flashcard is shown in Fig. 1. Paper flashcards were also made by the teacher. The paper flashcards contained the same verbal (i.e., Chinese word, its logograph, pinyin, and English translation) and visual (i.e., picture) cues as in the E-flashcards but without audio support. An example of a teacher-made paper flashcard is shown in Fig. 2.

In a 45-min session, 5 min were allocated for introduction on what the participants were going to do, 10 min on a pre-test, 15 min on new word learning, 10 min

Fig. 1 A teacher-made E-flashcard

Fig. 2 Front and back of a teacher-made paper flashcard

on a post-test, and 5 min on a survey. In the 15-min new word learning session, the participants self-learned the 20 target words (45 s on each word). At the end of every 45 s, the teacher directed the participants to move on to the next flashcard. No teacher-led vocabulary instruction was given to the participants, and students were encouraged to pronounce each target word while they used E-flashcards and paper flashcards. A week after learning, a delayed test (1-week delayed test) was also given to the participants.

Procedure of E-flashcard learning

There were five steps involved in the E-flashcard learning. First, iPads and headphones were placed on students' desks. Twenty E-flashcards were saved on the iPads. Second, students received instruction on what they were going to do and how they would use these E-flashcards on their iPads. Third, students were reminded that

they had 45 s to self-learn each word. Fourth, students began using E-flashcards to learn words. The teacher and two assistants monitored students' learning and ensured each student was exposed to and learned all target words within the time frame. Finally, every 45 s students were instructed to move on to the next card.

Procedure of paper flashcard learning

There were five steps involved in paper flashcards learning. First, a set of 20 paper flashcards were placed on students' desks. Second, students received instruction on what they were going to do and how they would use these flashcards. Third, students were reminded that they had 45 s to self-learn each word. Fourth, students began using flashcards to learn words. The teacher and two assistants monitored students' progress and ensured each student was exposed to and learned all target words within the time frame. Finally, every 45 s students were instructed to move on to the next card.

Instruments

For the purpose of this study, we administered two instruments: vocabulary test and survey. The vocabulary test was given at the beginning, end, and 1-week after the intervention, and was in a multiple-choice question format developed by the researchers. It contained two sections: reading (20 items) and listening (20 items) to measure students' recognition and memorization of the 20 target words. In the reading section, students read the Chinese words, and were then asked to circle the corresponding English translation. One example is 春天, with the following choices: (a) winter, (b) spring, (c) fall, and (d) summer. The correct answer is (b) spring. In the listening section, the teacher read the word to the students. The word was not shown on students' answer sheets; only Chinese choices were shown. Students were asked to circle the correct Chinese word based on what they heard. For example, the teacher would pronounce "dong(1) tian(1)", and the choices were: (a) 春天, (b) 夏天, (c) 秋天, and (d) 冬天. The correct answer is (d) 冬天. Kuder–Richardson coefficient (internal consistency reliability) of our vocabulary test was .86. Regarding content validity of the vocabulary test, it was reviewed by two native Chinese speakers who were university faculty with expertise in bilingual education and educational measurement. They both concluded that the contents were aligned with learning goals and objectives.

To measure students' learning attitudes, we adapted the Instructional Materials Motivation Survey (IMMS, Keller, 1993), which was developed to "measure learners' reactions to self-directed instructional materials" (Keller, 2009, p. 277). The original IMMS contains 36 items to address the four types of motivation (i.e., attention, relevance, confidence, and satisfaction). Each item includes five choices (not true; slightly true; moderately true; mostly true; and completely true)". Sample items under each subscale follow: "the quality of the material helped to hold my attention throughout the course (attention subscale)"; "for me, the content of the material is clearly related to things I already know (relevance subscale)"; "when I first looked at

this lesson, I had the impression that it would be easy for me (confidence subscale)"; and "I really enjoyed studying in this course (satisfaction subscale)."

In our adapted version of IMMS, some items were re-worded so as to be more relevant to this study, which also facilitated participants' understanding. For example, under the confidence subscale, the original item described above was revised to "when I first looked at the topic of today and the materials, I had a feeling that it would be easy for me to learn." We gave the participants six choices to score each item (not true = 0; slightly true = 1; moderately true = 2; often true = 3; mostly true = 4; and completely true = 5). The reliability coefficients (Cronbach α) of the four subscales of the adapted IMMS based on the sample of this study are .96 (attention; 12 items), .97 (relevance; 9 items), .95 (confidence; 9 items), and .95 (satisfaction; 6 items), with an overall reliability of .96. These reliability indicators are all higher than those reported in the original IMMS.

Results

In this section, we presented results in the order of the research questions proposed in this paper. To address Research Questions 1 and 2, a two-way analysis of variance (ANOVA) with repeated measures was conducted. This 2 by 3 ANOVA includes Approach (i.e., E-flashcard vs. paper flashcard) and Time (i.e., pre-test, vs. immediate post-test vs. 1-week delayed test). Approach is the between-subject variable, and time is the within-subject variable. To address Research Question 3, a series of t tests were conducted. Effect size in the form of Cohen's *d* was reported to quantify statistical significance.

Because each grade had two groups (i.e., E-flashcard group and paper flashcard group), a series of one-way ANOVAs were conducted to examine whether the fourth and fifth graders were performing differently within their respective groups. More specifically, in the E-flashcard group, no difference was found between fourth and fifth graders on the three reading tests: (a) reading pre-test, $F(1, 48) = 2.97$, $p > .05$; (b) immediate reading post-test, $F(1, 48) = .039$, $p > .05$; (c) 1-week delayed reading test, $F(1, 48) = .107$, $p > .05$. Also, no difference was found on the three listening tests: (a) listening pre-test, $F(1, 48) = 0.485$, $p > .05$; (b) immediate listening post-test, $F(1, 48) = .553$, $p > .05$; (c) 1-week delayed listening test, $F(1, 48) = .163$, $p > .05$. In the paper flashcard group, no difference was found between fourth and fifth graders on the three reading tests: (a) reading pre-test, $F(1, 48) = .011$, $p > .05$; (b) immediate reading post-test, $F(1, 48) = 1.428$, $p > .05$; (c) 1-week delayed reading test, $F(1, 48) = .033$, $p > .05$. Also, no difference was found on the three listening tests: (a) listening pre-test, $F(1, 48) = 0.455$, $p > .05$; (b) immediate listening post-test, $F(1, 48) = .807$, $p > .05$; (c) 1-week delayed listening test, $F(1, 48) = .501$, $p > .05$. These preliminary findings revealed that fourth and fifth graders in our study performed at equivalent levels within their group (i.e., E-flashcard and paper flashcard) on the reading and listening measures, and there was not a grade effect. Even though fifth graders were more advanced in Chinese learning as compared to their fourth-grade peers, the 20 target words were unfamiliar to all participants according to

the selection criteria. Separate analyses were also conducted by grade which yielded the same results. Therefore, for the ease and brevity of reporting findings, we aggregated the two grade levels by group for data analysis to address the following research questions.

Research Question 1

The first research question was to examine which type of flashcard was more effective for Chinese language learners to learn and recall words on reading tests. Table 2 shows mean scores and standard deviations of each reading test for each approach. The scores refer to the number of correct words. Results from 2 by 3 ANOVA suggested: (a) a significant main effect of approach (E-flashcard approach vs. paper flashcard approach), $F(1, 98) = 56.333$, $p < .01$; (b) a significant main effect of test (pre-test, immediate post-test, vs. 1-week delayed test), $F(2, 196) = 1499.563$, $p < .01$; and (c) a significant approach by test interaction effect, $F(2, 196) = 30.062$, $p < .01$. Post-hoc comparison revealed that students in E-flashcard group statistically outperformed students in paper flashcard group on the immediate post-test, $F(1, 98) = 51.946$, $p < .01$, Cohen's $d = 1.44$. Regarding within-subject effect of test occasion on both E-flashcard approach and paper flashcard approaches, post hoc test showed that students' vocabulary scores were the highest on immediate post-test, followed by on 1-week delayed test, and pre-test.

Table 2 Descriptive statistics of reading vocabulary tests by group

Test	Group	Grade	M	SD	n
Pre-test	E-flashcard	4	0.23	0.47	25
		5	0.21	0.35	25
		Total	0.22	0.41	50
	Paper Flashcard	4	0.21	0.45	25
		5	0.19	0.54	25
		Total	0.20	0.50	50
Immediate post-test	E-flashcard	4	9.24	1.15	25
		5	9.08	1.68	25
		Total	9.16	1.42	50
	Paper flashcard	4	7.05	1.96	25
		5	6.39	1.90	25
		Total	6.72	1.93	50
1-week delayed test	E-flashcard	4	4.48	1.49	25
		5	4.64	1.95	25
		Total	4.56	1.72	50
	Paper Flashcard	4	4.46	1.32	25
		5	4.38	1.52	25
		Total	4.42	1.42	50

Research Question 2

The second research question was to examine which type of flashcard was more effective for Chinese language learners to learn and recall words on listening tests. Table 3 shows mean scores and standard deviation of each listening test for each approach. The scores refer to the number of correct words. Results from 2 by 3 ANOVA suggested: (a) a significant main effect of approach (E-flashcard approach *vs*. paper flashcard approach), $F(1, 98) = 493.203$, $p < .001$; (b) a significant main effect of test (pre-test, immediate test, vs. 1-week delayed test), $F(2, 196) = 799.948$, $p < .001$; and (c) a significant approach by test interaction effect, $F(2, 196) = 163.58$, $p < .001$. Post-hoc comparison revealed that students in E-flashcard group statistically outperformed students in paper flashcard group on the immediate post-test, $F(1, 98) = 543.017$, $p < .01$, Cohen's $d = 4.6$, as well as on the 1-week delayed test, $F(1, 98) = 96.795$, $p < .01$, Cohen's $d = 1.94$. Regarding within-subject effect of test occasion on both E-flashcard approach and paper flashcard approaches, post hoc test showed that students' vocabulary scores were the highest on immediate post-test, followed by on 1-week delayed test, and pre-test.

Research Question 3

The third research question was to discover if there was a significant difference between the use of E-flashcards and paper flashcards on students' attitudes toward Chinese vocabulary word learning. The adapted IMMS was used to measure

Table 3 Descriptive statistics of listening vocabulary tests by group

Test	Groups	Grade	M	SD	n
Pre-test	E-flashcard	4	0.24	0.43	25
		5	0.16	0.37	25
		Total	0.20	0.40	50
	Paper Flashcard	4	0.30	0.51	25
		5	0.26	0.48	25
		Total	0.28	0.50	50
Immediate post-test	E-flashcard	4	9.76	1.23	25
		5	9.20	1.81	25
		Total	9.48	1.52	50
	Paper Flashcard	4	3.89	.87	25
		5	3.67	.86	25
		Total	3.78	.87	50
1-week delayed test	E-flashcard	4	4.84	1.67	25
		5	4.64	1.80	25
		Total	4.74	1.74	50
	Paper flashcard	4	1.84	1.10	25
		5	2.04	0.93	25
		Total	1.94	1.02	50

students' attitudes toward the use of E-flashcards and paper flashcards. Because there were four different constructs (attention, relevance, confidence, and satisfaction) as dependent variables, an independent samples *t* test was performed to compare the mean between two groups (E-flashcard and paper flashcard) on each dependent variable. Table 4 shows mean and standard deviation of the four outcomes by group. Students who used E-flashcards scored significantly higher on the construct of attention than those who used paper flashcards, $t(98) = 3.040$, $p < .01$, Cohen's $d = .62$. On the construct of relevance, students who used E-flashcards scored significantly higher than those who used paper flashcards, $t(98) = 2.624$, $p < .01$, Cohen's $d = .53$. On the construct of confidence, students who used E-flashcards scored significantly higher than those who used paper flashcards, $t(98) = 3.576$, $p < .01$, Cohen's $d = .72$. On the construct of satisfaction, students who used E-flashcards scored significantly higher than those who used paper flashcards, $t(98) = 4.042$, $p < .01$, Cohen's $d = .80$. Finally, on the overall survey means, the E-flashcard group scored significantly higher than the paper flashcards group, $t(98) = 3.430$, $p < .01$, Cohen's $d = .69$. Because of the multiple comparisons that might have inflated type I error, we used Sequential Bonferroni Tests (Holm, 1979) to adjust the significant level of α at .0125, 0.017, 0.025, and 0.05 for the comparison on attention, relevance, confidence, and satisfaction, respectively. The calculated *p* values were still smaller than these critical values, suggesting a statistically significant positive effect in favor of E-flashcard with medium to large effect sizes (Cohen, 1988) even after the Bonferroni correction.

Meaningful subscale information about E-flashcards follows: on the subscale of *Attention*, 89% of the students reported that E-flashcards were relevant to their needs for Chinese vocabulary word learning. 90% of the students enjoyed using E-flashcards to learn Chinese words because of the audio, visual, and verbal features. Among these students, 58% thought the audio input was the most attractive feature, 32% thought that the visual input was the most attractive feature, and 10% thought the verbal input was the most attractive feature.

On the subscale of *Relevance*, 92% of students reported it was important that E-flashcards showed them how to correctly pronounce Chinese words. 93% of

Table 4 Descriptive statistics of revised IMMS survey by group

Construct	Group	M	SD	n
Attention	E-flashcards	3.40	0.69	50
	Paper flashcards	3.02	0.53	50
Relevance	E-flashcards	3.35	0.62	50
	Paper flashcards	3.05	0.51	50
Confidence	E-flashcards	3.38	0.60	50
	Paper flashcards	2.98	0.51	50
Satisfaction	E-flashcards	3.48	0.57	50
	Paper flashcards	3.04	0.53	50
Average	E-flashcards	3.40	0.58	50
	Paper flashcards	3.02	0.52	50

students said that the layout of E-flashcards is relevant to their interests. 91% of students said that E-flashcards are useful to them for learning new words, and 9% reported that E-flashcards were more difficult than they expected for learning new words.

On the subscale of *Confidence*, 92% of the students reported that E-flashcards showed them how to pronounce words confidently, which was important to them. 90% of students reported that the layout of E-flashcards helped them gain confidence that they would learn new words. 92% of students reported that E-flashcards were less difficult for learning new words than they expected them to be.

On the subscale of *Satisfaction*, 91% of students reported that it was a pleasure to work with well-designed E-flashcards. 93% of students enjoyed using E-flashcards to learn Chinese words and hoped to use this way of learning in their future Chinese word learning, and 13% reported that there was too much information on each E-flashcard, which they found irritating.

It is worth noting that although students in the paper flashcard condition had lower mean scores on the survey, they also demonstrated positive attitudes toward the use of paper flashcards in their learning of Chinese words. For example, over 80% of students expressed a pleasure to work with well-designed paper flashcards, and 83% reported that the use of paper flashcards helped them gain confidence in learning new words.

Discussion

The purpose of this study was to explore the effects of self-learning E-flashcards and paper flashcards on Chinese language learners' Chinese word learning and recall, as well as their learning attitudes. Our literature review identified a scarcity on how to create meaningful E-flashcards with audio, visual, and verbal features to effectively teach Chinese vocabulary words. Our results indicated that E-flashcards accommodated students' needs and yielded greater gains in students' Chinese word recall. In addition, these Chinese language learners' attitudes toward word learning were enhanced. We discuss our findings below.

First, we found that novice Chinese language learners' word recall on the immediate post-tests was significantly improved through the use of both types of flashcards. Because of the graphical and semantic priming provided by paper flashcards and E-flashcards, learners were supported with a dual channel to code information for storage in memory. This finding corroborates with previous research (e.g., Beaton et al., 2005; Shen, 2010; Wyra et al., 2007), and further supports the positive effects of flashcards with both verbal and imagery codes on learning Chinese words among elementary level English speakers.

More importantly, our results showed that compared to paper flashcards, E-flashcards could better assist novice Chinese language learners with Chinese word recall in reading and listening. Such positive effects of E-flashcards can be explained by Mayer and Moreno's (2002) cognitive theory of multimedia learning. According to Mayer and Moreno (2002), learning outcomes result from sensory memory; successful vocabulary word learning accounts for both verbal and audio (non-verbal)

priming. The learners perceive and process some or all of the incoming information through a phonological loop or visual-spatial sketchpad, which turns into relevant symbolic cues for memorization (Mayer, 2009). Due to a lack of prior knowledge about the written form of Chinese characters, young learners require more guidance and information from the learning materials per se (e.g., practice pronouncing new words so as to become more familiar with their sound). When assisted by multimedia instructional materials embedded with audio, visual, and semantic inputs, word learning can be more easily accessible for novice learners (Nakata, 2011; Yun, 2011).

The advantage of using E-flashcards was further reflected on the delayed listening test. This was because E-flashcards provided the audio input, and therefore allowed for stronger audio word retention. Our finding is aligned with the existing literature that novice Chinese language learners rely on audio support more than visual support to recall words (Chung, 2008). Due to the irregular correspondence between the sounds and the printed forms of most Chinese characters, novice Chinese language learners cannot rely on the forms of Chinese characters to correctly pronounce the words; however, the sounds of words can act as a code, which is likely to enhance the memorization of target words (Chan & Siegel, 2001).

Finally, we found that compared to novice Chinese language learners who used paper flashcards, learners who used E-flashcards demonstrated higher levels of attention, relevance, confidence, and satisfaction in Chinese word learning. More specifically, students who used E-flashcards in this study paid more attention to Chinese word learning, because E-flashcards with multiple features supported by multimedia were more engaging and met students' learning needs (e.g., practicing the sound of words and correctly pronouncing the words). Additionally, we believe that the multiple features of E-flashcards, especially the audio feature, sparked students' learning interests, because 91% of the students reported that they felt more connected to the learning materials. Further, E-flashcards with multiple inputs provided the students with more opportunities to explore useful and meaningful information, which assisted them in learning and memorizing Chinese words. As a result, students' level of confidence, sense of accomplishment, and satisfaction were elevated. These findings were consistent with previous research (e.g., Başoğlu & Akdemir, 2010; Chuang & Ku, 2011; Hui, Hu, Clark, Tam, & Milton, 2008; Martin-Michiellot & Mendelsohn, 2000) on how multimedia enhances the presence of materials, which subsequently influences students' performance, and attention, relevance, confidence, and satisfaction about their learning. In summary, given the limited prior research about E-flashcards on Chinese word learning, this study contributes to the field by providing empirical evidence on the integration of paper flashcards with multimedia sources to create E-flashcards and to address learners' attitudes in learning Chinese as a foreign language among elementary English-speaking students.

Instructional implications

Three pedagogical implications are derived from this study on Chinese language teaching and learning. First, E-flashcards can be beneficial to both teachers and

students because students can review and practice the sounds of the target words by themselves; teachers can incorporate audios and videos to teach abstract words and can assist students to effectively memorize these words. Second, we recommend that in Chinese as second/foreign language learning classrooms, teachers can use E-flashcards to draw their students' attention to a selected cluster of words, and thus increase students' vocabulary knowledge. We believe that this instructional strategy will also serve as a tool for Chinese language teachers to develop their lesson plans, especially in the field of Chinese vocabulary instruction. Third, we suggest that E-flashcards be included in students' homework. For example, students can use a microphone with their iPad to verbally repeat the word as the audio input for a flashcard. By creating their own E-flashcards, learners will have a chance to review and reinforce their learning of the target words.

Limitations and future directions

There are several limitations in our study. First, the participants were fourth and fifth grade native English speakers; therefore, results of this study cannot be generalized beyond the grade level of students who are novice Chinese language learners. Future studies are encouraged to include learners from other grade levels so as to examine if a positive effect of E-flashcards can also be detected. Second, the use of iPads could be a confounding variable on students' learning attitudes as they are generally interested in the device. However, these students have already been exposed to iPads at school for an average of 2 years. Therefore, we anticipate such confounding effect to be minimal. Further, given the purpose of this study which is to investigate how self-learning Chinese word flashcards can be made to be more meaningful and accessible through the use of multimedia to young Chinese language learners, we did not focus on the comparison between the modality. We are currently conducting a study to compare students' Chinese word learning between groups with and without the audio input on iPads. Findings from this comparison will provide more valid information regarding the effect of multimedia-assisted learning on the vocabulary learning of Chinese as a foreign language.

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