A review of vocabulary learning applications: From the aspects of cognitive approaches, multimedia input, learning materials, and game elements

Fu Lee Wang
Hong Kong Metropolitan University, Hong Kong
Ruofei Zhang
Di Zou
The Education University of Hong Kong, Hong Kong
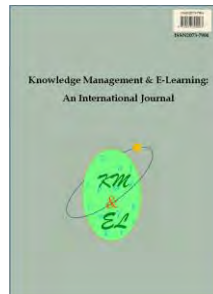**Oliver Tat Sheung Au**
Hong Kong Metropolitan University, Hong Kong
Haoran Xie
Lingnan University, Hong Kong
Leung Pun Wong
Hong Kong Metropolitan University, Hong Kong

A review of vocabulary learning applications: From the aspects of cognitive approaches, multimedia input, learning materials, and game elements

Fu Lee Wang* ⓘ

School of Science and Technology
Hong Kong Metropolitan University, Hong Kong
E-mail: pwang@hkmu.edu.hk

Ruofei Zhang ⓘ

Department of Mathematics and Information Technology
The Education University of Hong Kong, Hong Kong
E-mail: ruofeizh@gmail.com

Di Zou ⓘ

Department of English Language Education
The Education University of Hong Kong, Hong Kong
E-mail: dizoudaisy@gmail.com

Oliver Tat Sheung Au ⓘ

School of Science and Technology
Hong Kong Metropolitan University, Hong Kong
E-mail: oau@hkmu.edu.hk

Haoran Xie ⓘ

Department of Computing and Decision Sciences
Lingnan University, Hong Kong
E-mail: hrxie2@gmail.com

Leung Pun Wong ⓘ

School of Science and Technology
Hong Kong Metropolitan University, Hong Kong
E-mail: s1243151@hkmu.edu.hk

*Corresponding author

Abstract: In recent years, mobile applications (apps) have been increasingly used and investigated as a vocabulary learning approach. Despite the extensive use of commercial English as a Foreign Language (EFL) vocabulary learning apps in China, there is a lack of a review of these apps for a systematic

understanding of the components and usefulness of app-assisted vocabulary learning. To fill this knowledge gap, this study presents a systematic review of 15 EFL vocabulary learning apps that were most downloaded in China, focusing on how these apps help students develop word knowledge. The results of this study showed that most apps enabled students to access word knowledge through translating words into their native language. Notably, word knowledge was usually presented through text-plus-image and text-plus-image-plus-audio. Most of these mobile apps provided sentence examples as vocabulary learning materials. Many of these apps were integrated with game elements, especially in interactivity or feedback systems and reward systems. Based on the review results, we have provided three recommendations to vocabulary learning app developers concerning the use of video for the input of word knowledge, the efficiency of vocabulary learning, and the integration of more game elements.

Biographical notes: Fu Lee Wang is the Professor and Dean of the School of Science and Technology, Hong Kong Metropolitan University. He received his PhD in Systems Engineering and Engineering Management from The Chinese University of Hong Kong. Prior to joining HKMU, he was the Vice President of Caritas Institute of Higher Education and faculty member from the City University of Hong Kong. His research interests include e-business, e-learning, financial engineering, and information retrieval. He has over 200 publications and has received 16 grants with a total of more than $20 million Hong Kong dollars.

Ruofei Zhang is a research assistant at the Education University of Hong Kong. She received her bachelor's degree in Tongji University and master's degree in City University of Hong Kong. Her research interests include technology-enhanced language learning, game-based learning, and self-regulated language learning.

Di Zou is an Assistant Professor at The Education University of Hong Kong. Her research interests include second-language acquisition, technology-enhanced language learning, game-based language learning and flipped classroom. She has published about 100 research papers in international journals, conferences and books, including *Computers & Education, Computer Assisted Language Learning, Language Teaching Research, and British Journal of Educational Technology*.

Oliver Au is an Assistant Professor at Hong Kong Metropolitan University. He received his BA, MSc and PhD from York University, University of Toronto and Loughborough University respectively. He worked for IBM and a few other large companies in Canada for 12 years before pursuing a teaching career in Hong Kong. His research interests include requirements engineering, software development processes and education. He enjoys music, sports, travelling and the nature.

Haoran Xie is an Associate Professor at Lingnan University. His research interests include artificial intelligence, educational technologies, and big data. He has over 180 publications including 76 articles in international journals such as IEEE Intelligent Systems, IEEE Transactions on Affective Computing, Neural Networks, Information Sciences, Neurocomputing, Educational Technology and Society, and Interactive Learning Environments and so on. He has been a guest editor of nine journals and co-chair/committee member of more than 40 international conferences like International Conference on Web

Intelligence, International Conference on Web-based Learning, and so on.

Leung Pun Wong is a research student at Hong Kong Metropolitan University. He received his bachelor and master degree in The University of Hong Kong. His research interests include natural language processing, e-learning and language learning.

1. Introduction

Within the overwhelming amount of technology-enhanced language learning over recent years, mobile learning with the aid of mobile applications (apps) may have been investigated and applied most frequently (Shadiev & Yang, 2020; Zhang et al., 2020). Prior studies have widely investigated apps for language education, especially English as a Foreign Language (EFL) vocabulary learning, and reported the overall effectiveness of this tool from various aspects (e.g., Kohnke, Zou, & Zhang, 2019; Walter-Laager et al., 2017; Zhang & Zou, 2020b). Researchers found that vocabulary learning apps, featured by high accessibility, multimedia technology, and contextualisation (Zou & Xie, 2018; Zou, Xie, & Wang, 2018), could be an effective way of increasing learners' exposure to knowledge and exercises (Schmitt 2008), facilitating knowledge comprehension and memorisation (Laufer & Rozovski-Roitblat, 2011), improving learners' affective states in language learning (Zhang & Zou, 2020a), and, eventually, enhancing the efficiency of vocabulary acquisition (Chen, Zou, & Xie, 2020; Chen et al., 2020; Huang et al., 2016). In response to the popularity of this learning tool, an increasing number of both students and teachers have been using mobile apps for authentic EFL learning, which has led to a growing market for commercial vocabulary learning apps (Godwin-Jones, 2011; Kohnke, Zou, & Zhang, 2020), especially in China (Zhang, Zou, & Xie, 2021). The authors searched for the total number of downloads for EFL vocabulary learning applications in the Chinese market of the Apple App Store on May 13, 2019. The total number of downloads was around 7,800,000, which accounts for a considerable proportion of the entire App market.

Despite the expanding market and increasing use of commercial EFL vocabulary learning apps in China, few review studies have been conducted on these apps, and even fewer from the perspective of app components leading to vocabulary development. This lack of review may have narrowed the understanding of the usefulness and usability of app-assisted vocabulary learning in authentic contexts. To fill this gap, this study presents a systematic review of commercial EFL vocabulary learning apps in China, focusing on how app systems have helped students develop their word knowledge. By undertaking this review, we aimed to (1) present a comprehensive picture of how apps may help students learn words, and (2) provide app developers with implementations for their future development and improvement of vocabulary learning products.

2. Literature review

2.1. Mobile apps for vocabulary learning

In recent years, a growing number of EFL learners have been developing and practising their word knowledge via apps on mobile devices (e.g., smartphones, smartwatches, tablets, and PCs) (Rezaei, Mai, & Pesaranghader, 2014). This extensive usage has mainly

resulted from the effectiveness of app-assisted vocabulary learning (Zhang & Zou, 2020a). Empirical evidence was found in Yu (2018), who asked 107 EFL students to use mobile apps over a period of four months for vocabulary acquisition, and thereby identified significant effects of this learning approach. Nami (2020) surveyed 447 EFL students about their experiences of app-assisted vocabulary learning. The results showed that 86% of the students regarded mobile apps as powerful tools for vocabulary learning.

Researchers have also analysed the quality of vocabulary learning apps using various theoretical frameworks. We suggested an adapted version of Ma and Kelly's (2006) Efficacy Model for Computer-assisted Vocabulary Learning Programmes as a useful model for investigating how mobile apps' systems and different components could facilitate vocabulary learning. According to the model, vocabulary learning apps may help students develop word knowledge from four main perspectives: cognitive approaches, multimedia input, learning materials, and game elements (see Fig. 1).
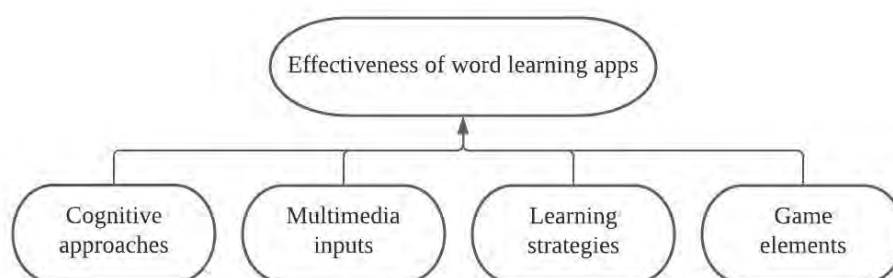

Fig. 1. Efficacy model of vocabulary learning apps

The cognitive approach refers to how learners cognitively access the target word knowledge (Ma & Kelly, 2006). In mobile apps, word knowledge is mostly presented in three forms: lexical form in target languages (L2), translation of the L2 lexicon in learners' native languages (L1), and conceptual form. Corresponding to these three forms, learners accessed word knowledge through three cognitive approaches (Lotto & de Groot, 1998; Schmitt & Schmitt, 2020); specifically, (a) word association that refers to assess to the target words through L1 translations, (b) concept mediation that refers to assess to the target words through the connections between the L2 lexicons and concepts, and (c) multimedia association that refers to assess to the target words through the connection between L2 lexicons and L1 translation of the target words and the multimedia presentation of word concepts (see Fig. 2).

Multimedia input refers to the presentations of word concepts using multimedia technologies (Zhang et al., 2021). It plays a significant role in technology-enhanced language learning activities (Zhang & Zou, 2020a, 2020b) by helping to "monitor and control user actions" (Ma & Kelly, 2006, p. 22). Prior research has reported that the application of multimedia technologies in presenting word knowledge may significantly enhance the effectiveness of app-assisted vocabulary learning apps (Subramanya, 2014). There are five main types of multimedia input: (a) text (i.e., the written word), (b) image (i.e., static imagery of the word concept), (c) GIF (i.e., dynamic imagery of the word concept), (d) audio (i.e., the spoken word), and (e) video (i.e., the combination of dynamic imagery of the word concept and the spoken word).

Learning materials are the instructional contents provided to enrich learners' word knowledge and facilitate their understanding and memorisation of words (Ponce et al.,

2018). Four types of learning materials were frequently applied for vocabulary education: example sentences that show how target words could be used contextually in complete, meaningful sentences (Kim & Kwon, 2012; Tu, Zou, & Zhang, 2020); exercises that are practices to trigger students' application and consolidation of target word knowledge (Zhang et al., 2021); roots and affixes that are morpheme information of words; and semantic mapping that is "a categorical structuring of information in graphic form" used to support students' comprehension of target knowledge (Johnson, Pittelman, & Heimlich, 1986).
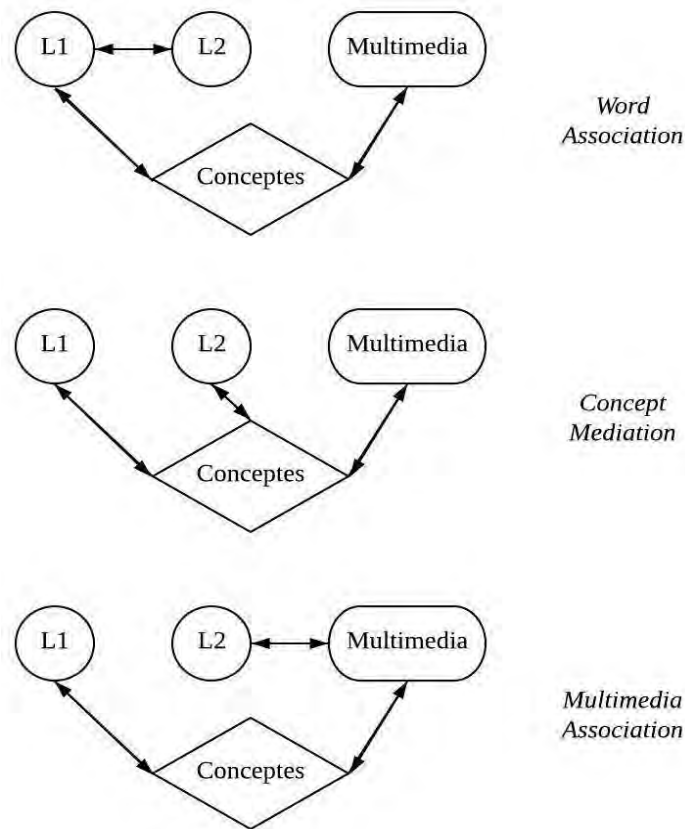
Fig. 2. Three cognitive approaches

Game elements are mechanisms used to render the vocabulary learning process to be playful and game-like (Annetta, 2010; Liu, Wang, & Lee, 2021). Prior studies reported that game elements might significantly facilitate students' acquisition of word knowledge by promoting their motivation as well as raising and sustaining their engagement in vocabulary learning activities (Zou, Huang, & Xie, 2021; Zou, 2020). Common game elements for vocabulary learning apps include time limits, rewards, interactivity/feedback, characters, and challenges/levels (Danowska-Florczyk & Mostowski, 2012; Xu et al., 2019; Yang et al., 2020).

2.2. Previous review studies related to vocabulary learning apps

Researchers have conducted review studies of vocabulary learning apps from diversified perspectives. For example, Kim and Kwon (2012) presented an in-depth review of 87 EFL mobile apps, with foci on their strengths, weaknesses, and common and distinctive features in improving language development. They reported that the main features of the apps could be placed into content and design, L2 approaches, and technology. The app-assisted EFL was advantageous in terms of providing students with a personalised learning environment and rich opportunities for contextualised exercises. However, limitations of this innovative learning approach were also identified concerning the lack of a "situated, field-dependent, and collaborative form of learning" (p. 31).

Gangaiamaran and Pasupathi (2017) conducted a systematic review of 28 mobile apps for second language learning at primary, secondary, and tertiary levels. They identified six main systems for these apps: iPhone, iPad, iPod, iPod touch, iOS, and Android. The apps focused on students' development of language skills (i.e., listening, speaking, reading, and writing) and may be the most effective at enhancing listening proficiency.

Tu et al. (2020) identified ten EFL apps used most frequently by Chinese students in Hong Kong through questionnaire surveying of 60 EFL students. After analysing the components of the ten apps, the researchers suggested six main factors to evaluate the quality of EFL apps: content quality, multimedia presentation, engagement maintenance, personalisation, repetition, and usability.

2.3. Research questions

Despite the previous review studies on vocabulary learning mobile apps, few researchers have analysed how the apps' system and components have helped students develop their word knowledge. To facilitate the critical selection and efficient application of app-assisted vocabulary learning, it might have been valuable to provide EFL teachers and researchers with explicit information of commercial vocabulary learning apps that include cognitive approaches, multimedia input, learning materials, and game elements that involve vocabulary learning. Additionally, by reviewing app systems, we may suggest some limitations therein and provide recommendations for app developers in their future developments and adjustments of products. Thus, five questions have been used to guide this line of study:

1) What cognitive approaches were used for vocabulary learning in the reviewed apps?

2) Which types of multimedia input were used for vocabulary learning in the reviewed apps?

3) What learning materials were used for vocabulary learning in the reviewed apps?

4) What game elements were integrated into vocabulary learning in the reviewed apps?

5) What recommendations may be provided to the developers of vocabulary learning apps?

3. Method

We conducted a three-step method for reviewing EFL vocabulary learning apps; specifically, searching for apps, selecting apps, and coding app information. The app searching was conducted in the Chinese market of the Apple App Store, with "word (单词)" as the keyword.

We searched the sample apps in the Chinese market of the Apple App Store because this platform might have had a massive number of users, presented explicit, credible downloading numbers of apps, and provided a wide range of vocabulary learning apps that are compatible with various systems (e.g., iPhone, iPad, iPod, iPod touch, and iOS) (Gangaiamaran & Pasupathi, 2017). Although the Android market is also huge, it has been customised for users of different smartphone brands (e.g., Huawei, XiaoMi, OPPO, etc.) (Wang et al., 2018). Thus, reviewing apps from the Android market might be ungeneralisable. Additionally, we did not use Google Play Store as the database because Google services are not available in mainland China and few Chinese students have downloaded apps from this platform. The database for app search was finalised with the Chinese market of the Apple App Store.

The search was conducted on May 13, 2019. We listed the search results in descending order according to the number of apps that were downloaded, and thereby obtained the 30 vocabulary learning apps that were downloaded the most by Chinese students. To ensure the close relevance of the apps to the concerned topic, we further examined the 30 apps and made a selection based on two inclusion criteria. First, the app should be a tool for EFL vocabulary acquisition. Second, the target users of the apps should be general students with no special needs or requirements due to the considerable differences between education in general and special education (Scott & Windsor, 2000). The selection ended with 15 apps for further coding. They were: Shanbay (扇贝单词), Hujiang Cichang (沪江开心词场), Maimemo (墨墨背单词), Baicizhan (百词斩), Wordsend (边走边听背单词), Youdao Recite (有道背单词), iWordnet (知米背单词), English Vocabulary Cards (英语单词卡), Drops, Bbdc (不背单词), iLeci (乐词), Roots & Affixes (词根词缀字典), Kuaibei (快背单词), Super Word King (超级单词王), and Towords (拓词) (see Fig. 3 and Appendix I).

The 15 apps were further analysed based on a coding scheme adapted to Ma and Kelly's (2006) Efficacy model. It included four clusters of categories as follows:

1) Cognitive approach. The category fell into three types: word association, concept mediation, and multimedia association.
2) Multimedia input. It consisted of four sub-categories: text, image, GIF, audio, and video.
3) Learning materials. It fell into example sentences, exercises, roots and affixes, semantic mapping, and others.
4) Game elements. It included five sub-categories: time limits, rewards, interactivity/feedback, challenges/levels, characters, and others.

Two authors with expertise in language learning research and experience in conducting review studies worked on the data analyses. They first analysed five apps together to reach an agreement on the coding methods and then coded the remaining ten apps independently. Their coding results were compared, reaching satisfactory agreement (Pearson's r = 0.95). The remaining differences were solved via discussion and consultation with a third researcher.

Fig. 3. The reviewed apps

4. Results and discussions

This section presents the results of reviewing the commercial EFL vocabulary learning apps, which include cognitive approaches, multimedia input, learning materials, and game elements, followed by discussions on how these components are effective in enhancing vocabulary learning.

4.1. Cognitive approaches

This review found that most vocabulary learning apps helped students develop word knowledge through word association (67%), followed by multimedia association (27%), and concept mediation (7%) (see Fig. 4).

The massive application of word association reflects the general assumptions among vocabulary learners and instruction designers in China, in which a one-to-one connection exists between L1 translations and L2 lexicons. Learners could acquire target word knowledge based on their counterparts in L1 and use those words by translating L1 into L2. Moreover, EFL students might have preferred this cognitive access due to its high speed of delivering word knowledge, whereby "tracing the link between the corresponding L1 and L2 representations in the lexical store, bypassing conceptual memory" (Lotto & de Groot, 1998, p. 35). This approach may be particularly useful for low-proficiency learners who have much more difficulty understanding word concepts than word lexicons (Lotto & de Groot, 1998). However, it remains controversial as to

whether the L1 bypassing led to the correct destination. Some researchers believe that the gaps between different languages and cultures determine the unsolvable incompatibility between L1 and L2 lexicons of the same concepts, which may challenge the accuracy and reliability of word association as a cognitive approach to word teaching (Webb, 2007).
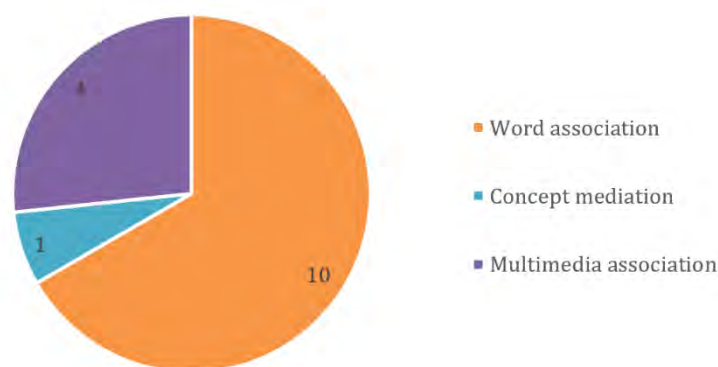

Fig. 4. Numbers of apps of three methods

Concept mediation was applied least, and only by Shanbay. When using this app, learners were first presented with an example sentence describing the context and definition/explanation of the target words in L2, helping students establish cognitive connections between target lexicons and corresponding word meanings. If students succeeded in retrieving the word concept from their memory based on the given cue, they were able to pass the learning of the word by pressing the upper one of the two buttons at the bottom of the interface; otherwise, learners could press the lower button and view the L1 translation of the words for better understanding and memorisation outcomes (see an example in Fig. 5). The L2-concept cognitive approach may be closer to people's development of L1 than the other approaches, and therefore word concepts achieved through this approach may be more accurate and applicable in real life (Yoshii, 2006). However, the L2-concept route was longer than the L1–L2 one, so this approach usually requires more effort and time from students for vocabulary learning (Lotto & de Groot, 1998), which explains why only one app applied this cognitive approach for word teaching. Moreover, compared to understanding the multimedia annotations and L1 translations of words, understanding L2 definitions/explanations usually requires higher levels of L2 proficiency of students, which may shrink the size of the target user groups. As such, the possibility of smaller user groups might have reduced app developers' willingness to apply the concept-mediation approach in their products.

Four apps enabled students to access word knowledge through multimedia association. The application of this cognitive approach was mainly based on the assumption that learners could decode the multimedia representations of word concepts and understand the underlying word meanings automatically. Accessing word knowledge through this approach involved an L2-multimedia cognitive routine that was "longer" than the L1–L2 one with multimedia representations as mediation between lexicons and concepts, which may reduce students' efficiency of processing information and understanding word meanings (Lotto & de Groot, 1998, p. 35). Nonetheless, some app

developers applied this approach because multimedia representations may display word information more vividly and attractively, and therefore improve students' experience in app-assisted vocabulary learning (Zhang & Zou, 2020b) and elicit their long-term engagement therein (Çakmak & Erçetin, 2018). Furthermore, according to Mayer and Moreno's (2003) theory of mediation effect, multimedia presentations of word knowledge would activate auditory/verbal and visual/pictorial memory channels of students' cognitive systems, thereby leading to their higher learning efficiency, so long as neither of the channels are overloaded.
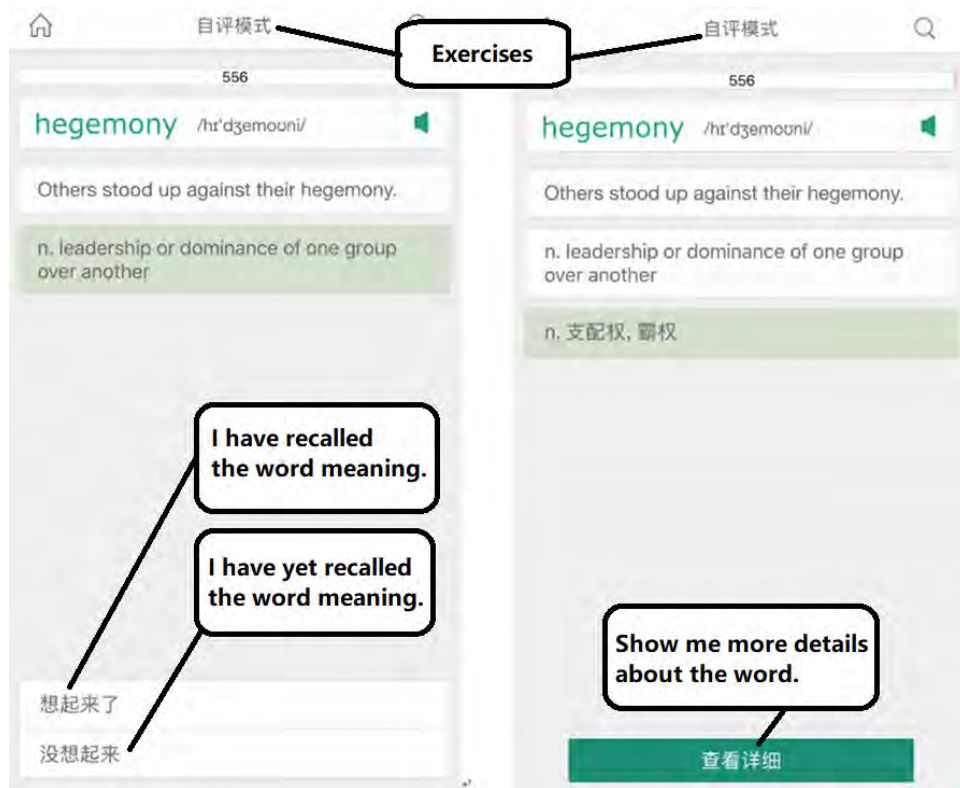
Fig. 5. Two steps of word teaching through the concept-mediation approach in Shanbay

Commercial vocabulary learning apps clearly apply diversified cognitive approaches to guiding students to access word knowledge, among which word association is applied most frequently. Word association enables learners to access more information within a minimal timeframe, leading to the highest efficiency of app-assisted vocabulary learning. The other approaches (i.e., concept mediation and multimedia association) require students – especially low-proficiency ones – to devote more time and effort to vocabulary learning, and as such, are less efficient than the word association approach. However, these two approaches may improve students' long-term vocabulary learning outcomes by supporting their comprehension, memorisation, and application of target word knowledge.

4.2. Multimedia input

Table 1 illustrates the application of multimedia input in the reviewed vocabulary learning apps. Apps which included that specific type of input are marked "✓"; otherwise, they are marked "✗". The table shows that all apps presented text input of word knowledge. In addition to the text input, most apps provided one or two types of multimedia input. None of the 15 reviewed apps took more than four types of input. In terms of the types of multimedia input provided by the apps, audio input was applied most, followed by image input. GIF input was used by none.

Table 1
Multimedia input of apps

Apps	Text	Image	GIF	Audio	Video
Shanbay	✓	✗	✗	✓	✗
Hujiang Cichang	✓	✓	✗	✓	✗
Maimemo	✓	✗	✗	✓	✗
Baicizhan	✓	✓	✗	✓	✓
Wordsend	✓	✗	✗	✓	✗
Youdao Recite	✓	✓	✗	✓	✗
IWordnet	✓	✗	✗	✗	✗
English Vocabulary Cards	✓	✓	✗	✓	✗
Drops	✓	✓	✗	✓	✗
Bbdc	✓	✗	✗	✓	✗
ILeci	✓	✗	✗	✓	✓
Roots & Affixes	✓	✗	✗	✓	✓
Kuaibei	✓	✗	✗	✓	✗
Super Word King	✓	✗	✗	✓	✗
Towords	✓	✗	✗	✓	✗

The cognitive theory of multimedia learning (Mayer, 2001) may explain the number of types of multimedia input applied in vocabulary learning apps. According to the theory, presenting knowledge through one or two types of multimedia input, in addition to text input, may result in high learning effectiveness. Thus, because the input activated both the auditory/verbal and visual/pictorial memory channels of the students' cognitive system, this helped students to establish cognitive connections between different representations of word concepts, thereby facilitating their memorisation of word knowledge (Mayer, 2001; Mayer & Moreno, 2003). However, it is worth noting that both the auditory/verbal and visual/pictorial channels were of limited capacity, and that too much multimedia input for vocabulary learning can clog students' cognitive channels and result in mental overload, distraction from the learning activity, and reduced learning efficiency (Chen et al., 2019). Thus, more than three types of multimedia input, in addition to textual input, should be avoided in vocabulary learning apps, as consistent with the Zhang et al. (2021).

In addition to text input, the app developers frequently applied audio and image input for knowledge presentation because they are effective for vocabulary learning, and are easy and inexpensive to create. Audio and image input have been widely investigated in the field of vocabulary education and are reported to be effective overall (e.g., Bisson et al., 2015; Boers et al., 2017; Warren et al., 2018). Audio input was shown to be essential for learning word pronunciation (Celce-Murcia, Brinton, & Goodwin, 2010) and

improving learner motivation (Antes, 2014); while image input significantly facilitated students' comprehension of word knowledge and resulted in their deep knowledge processing (Zhang & Zou, 2020b). Text-plus-image-plus-audio may be even more effective for vocabulary learning, especially when the target knowledge points involve word form and form-meaning relation (Çakmak & Erçetin, 2018). According to cognitive theory, the combinations of these three types of input may help students establish cognitive connections among lexical, pictorial, and auditory representations of word knowledge, thereby facilitating their memorisation of target knowledge. Additionally, the creation of audio and image input may be easier, quicker, and cheaper than that of video and GIF input (Kjelldahl, 2012), making audio and image input more tempting choices for investors and designers when integrating multimedia technologies into vocabulary learning apps.

Video and GIF input were used far less frequently than the other types. This might be due to the higher overall cost and more time needed to create these two types of multimedia input (Kjelldahl, 2012). In addition, compared to text, image, and audio input, video and GIF input received relatively less academic attention in the field of vocabulary learning. As such, their effectiveness remains unclear (Zhang & Zou, 2020b). These factors might explain the low rate of application of these two types of multimedia input.

4.3. Learning materials

Table 2 illustrates the different types of learning materials provided in the reviewed vocabulary learning apps. Apps which included that specific type of material are marked with "✓"; otherwise, they are marked with "✗". The table shows that all apps presented text input of word knowledge. The review found that most apps provided three types of learning materials, followed by four types, and then five types. Example sentences were provided most frequently, followed by exercises, information about roots and affixes of vocabulary, and semantic mapping.

Table 2
Learning materials of apps

Apps	Example sentence	Exercise	Roots and Affixes	Semantic mapping	Others
Shanbay	✓	✗	✓	✓	✗
Hujiang Cichang	✓	✓	✗	✗	✗
Maimemo	✓	✗	✓	✓	phonogram
Baicizhan	✓	✓	✓	✗	pictographic word
Wordsend	✓	✗	✗	✗	synonym
Youdao Recite	✓	✗	✓	✓	phonogram
IWordnet	✓	✓	✓	✓	synonym
English Vocabulary Cards	✗	✓	✗	✗	✗
Drops	✗	✓	✗	✗	✗
Bbdc	✓	✓	✓	✗	✗
ILeci	✓	✗	✓	✓	✗
Roots & Affixes	✗	✗	✓	✓	✗
Kuaibei	✗	✓	✗	✗	✗
Super Word King	✗	✗	✗	✗	✗
Towords	✓	✓	✗	✗	✗

Most of the reviewed vocabulary learning apps provided example sentences. This type of learning materials gives students a simple yet lucid word contexts and thereby enhances their development of word meaning and word use (Nation, 2001; Yip & Kwan, 2006). The example sentences vividly displayed the word use and meaning in brief context, through which learners could achieve a comprehensive understanding of the target words and how to apply them in real-world settings. Moreover, many high-quality dictionaries provide example sentences that are extremely helpful for language learners (e.g., Longman Dictionary and Collins Dictionary), so app developers could access this type of learning materials easily.

Exercises have also frequently been provided in app-assisted vocabulary learning. Having been extensively investigated in previous research on vocabulary education (Goossens et al., 2014; Kang, Gollan, & Pashler, 2013), exercises are reported to be overall more effective in enhancing students' knowledge than restudying of the target knowledge or no re-exposure to the knowledge, termed "the testing effect" (Kang, Gollan, & Pashler, 2013). This study identified that all apps which provided exercises also presented learners with feedback on their performance, possibly reducing the risk of students' mistaking the wrong information as correct and enhancing vocabulary learning efficiency (Butler, Karpicke, & Roediger III, 2008).

Other types of learning materials may also enhance learners' word knowledge. Vocabulary information about roots and affixes can enhance students' knowledge of word form, especially form-meaning relationships and word spelling (Nation, 2001). Semantic mappings and synonyms of target words have been given to students to help them integrate new and existing knowledge, as well as understand it more efficiently. Phonograms of words provided in Maimemo and Youdao Recite enhanced learners' memorisation and application of knowledge about word pronunciation. Baicizhan innovatively created large numbers of pictographies of target words, thereby facilitating learners' word comprehension, promoting learning motivation, and enhancing vocabulary learning acquisition by converting the abstract into the vivid and the boring into the attractive. Since studies on pictographies for vocabulary learning remain sparse, research in EFL should focus on this in the future.

4.4. Game elements

This study identified the integration of game elements in 12 of the 15 apps. Table 3 shows the integration of game elements in the reviewed vocabulary learning apps. Apps which included that specific element are marked "✓"; otherwise, they are marked "✗". As can be seen in the results, Super Word King integrated the most game elements into vocabulary learning. Interactivity/Feedback was applied most frequently, followed by rewards, time limits, challenges/levels, and characters.

The majority of vocabulary learning apps applied interactivity/feedback to enhance students' efficiency in exercises. Despite the overall positive effects of the exercise (Goossens et al., 2014; Kang, Gollan, & Pashler, 2013), students might not achieve satisfying learning outcomes using this type of material if they are not given any performance feedback (Roediger & Butler, 2011). Students may fail to retrieve the correct information from their memory, mistake the wrong information as correct, and end the test with learning errors if they receive no feedback about their problems, termed "the negative suggestion effect" (Butler, Karpicke, & Roediger III, 2008). Furthermore, without feedback, students might feel uncertain about their knowledge. Hence, to enhance effectiveness, most apps supported fast interactivity/feedback in vocabulary learning.

Table 3
Game elements of apps

Apps	Time limits	Rewards	Interactivity/ Feedback	Challenges/ Levels	Characters
Shanbay	✗	✗	✓	✗	✗
Hujiang Cichang	✗	✓	✓	✓	✗
Maimemo	✗	✗	✓	✗	✗
Baicizhan	✗	✗	✓	✗	✗
Wordsend	✗	✗	✗	✗	✗
Youdao Recite	✗	✗	✓	✗	✓
IWordnet	✗	✗	✓	✗	✗
English Vocabulary Cards	✗	✗	✗	✗	✗
Drops	✓	✓	✓	✓	✗
Bbdc	✗	✗	✓	✗	✗
ILeci	✗	✗	✓	✗	✗
Roots & Affixes	✗	✗	✗	✗	✗
Kuaibei	✗	✗	✓	✗	✗
Super Word King	✗	✓	✓	✓	✓
Towords	✓	✓	✓	✗	✗

Four apps supported a reward system (see Fig. 6 for an example interface). With the aid of the reward system, word learners could achieve scores or rewards based on their completion of, or performance in, various learning tasks. Previous research shows that students tend to be more motivated and engaged in learning and performing exercises if they are promised performance/completion-based rewards (Park et al., 2019; Ronimus et al., 2014). Since the achieved rewards or scores remain visible on the interfaces, students get a clear view of their progress throughout the entire learning process, which enhances their confidence, sense of achievement, and intrinsic motivation (Park et al., 2019; Ronimus et al., 2014). Such motivation drives students to make more of an effort in their vocabulary learning on the apps in the future.

The review found that three apps applied challenges/levels in word education. As shown in Fig. 6, some apps divided the total amount of vocabulary learning into multiple episodes depending on students' learning plans. This was likely done to reduce pressure and help learners fulfil their tasks on time. Additionally, maintaining a challenge and ability balance is essential for game-based learning. Otherwise, students might become frustrated and discouraged by over-difficult learning tasks, or become bored by over-easy tasks, both of which would result in students' reduced engagement, efficiency, and motivation in learning (Hsu, 2017; Perttula et al., 2017). Thus, some of the app developers in this study might have wanted to match the difficulty of learning tasks with their users' vocabulary knowledge and learning skills throughout the entire process, thereby reaching a good challenge and ability balance (Hsu, 2017; Perttula et al., 2017). Nevertheless, many apps did not apply this game element. One reason could be that the accumulation of word knowledge and vocabulary learning skills might be slow and unobvious, making it difficult for app developers to set challenges. Another reason could be that students might feel anxious and stressed when faced with challenges.
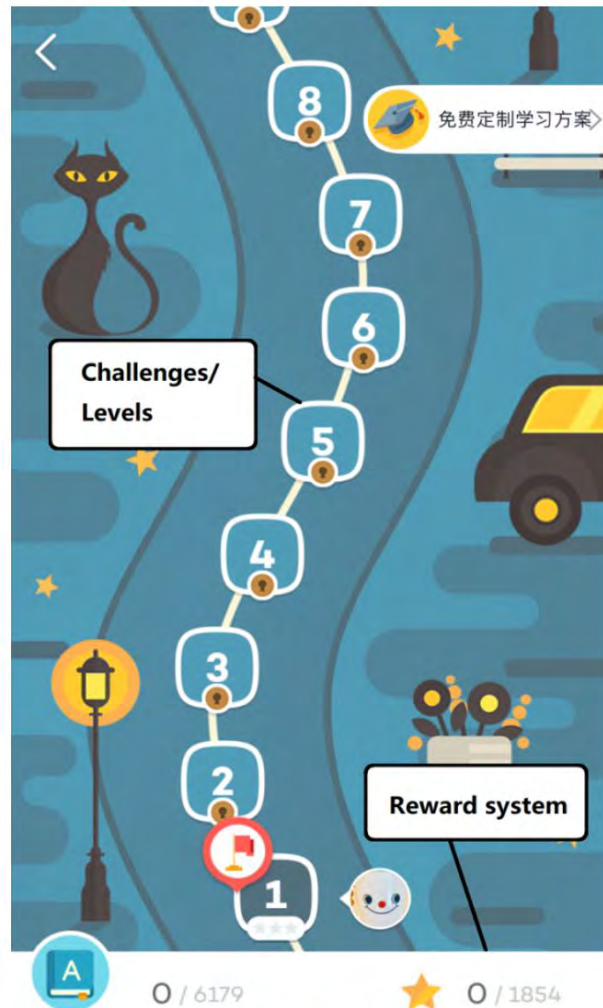
Fig. 6. Reward system and challenge/levels interface in Hujiang Cichang

Time limits were applied in three of the vocabulary learning apps. As shown in Figs 7 and 8, the apps allowed learners to set time limits, then work on the learning and exercises in the allotted time shown on the interface. This game element could support vocabulary learning by engaging students in learning activities through a high level of motivation, concentration, and excitement (Lai et al., 2014; Zhang et al., 2021). Such an optimal experience, termed "a flow state", can result in very high learning efficiency, an enjoyable learning experience, and, consequently, enhanced learning effectiveness (Csikszentmihalyi, 1975; Perttula et al., 2017). Despite the positive effects of time limits, this element could also put pressure on students (Haynes, Mullins, & Stein, 2004). Some students might feel anxious about completing learning tasks within the time limits, which may negatively affect their learning experiences and outcomes. This might be one of the reasons why only three apps used time limits and rewards as part of word education.

Fig. 7. Time limit setting interface in Towords

Two apps applied characters as part of vocabulary learning. One was Youdao Recite, which used a cartoon image of bread as a computerised non-player character to interact with learners. The character reported students' performance in learning tasks, informed them of their progress, and encouraged them from time to time. Having a non-player character may help to overcome the lack of learning peers, alleviate the sense of loneliness, promote motivation in learning, and sustain learning engagement for an extended period of time (Annetta, 2010). The other app that applied characters as part of the process was Super Word King, which used a cartoon cat with whom learners, as the main character, played. In the app, learners were able to decide the name of the main character (see Fig. 8) and control their behaviour. During gaming, learners could control the main character to collect gold coins by overcoming a series of vocabulary learning challenges/levels (see Figs 9 and 10). Such a design could help to reduce students' self-awareness in the real world and enhance their presence in the virtual environment of vocabulary learning (Annetta, 2010). By allowing learners to have a sense of identity in game, it effectively focuses learners' concentration on the learning tasks at hand, helps them to ignore outside interference, and enables them to devote increased effort to vocabulary learning (Annetta, 2010). Nevertheless, despite the usefulness of characters in enhancing vocabulary learning efficiency, very few apps applied this game element. A probable reason was that characters could sometimes be distracting. Additionally, the design and creation of a dynamic character-based game may be time-consuming and

costly for the app developers. Since studies on character-based games for vocabulary learning are sparse, researchers might want to focus on this topic in future research.

Fig. 8. Time limits shown in the learning process in Towards

Fig. 9. Main character name decision interface in Super Word King

Fig. 10. Main functions and interface of Super Word King

5. Conclusion

The present study gives a systematic review of 15 EFL vocabulary learning apps used most frequently by Chinese students. The results show that most apps used word association to convey word knowledge to their users, mainly because of its learning speed advantages. Most apps applied one or two multimedia inputs, primarily audio and image input as well as text input, so that students could comprehend and memorise target word knowledge efficiently and without too much cognitive load (Mayer, 2001; Mayer & Moreno, 2003). The majority of the reviewed apps provided example sentences and exercises as vocabulary learning materials. Interactivity/feedback was the game element applied most frequently in vocabulary learning apps.

Based on the results of this study, we provide three recommendations for future app developers in the field of technology-enhanced EFL word education. First, developers may want to improve vocabulary learning apps by paying more attention to the efficiency of vocabulary learning rather than speed. This study identified an over-emphasis on the speed of app-based learning, which risks scarifying learners' in-depth comprehension and concrete memorisation of word knowledge. To reduce this risk, app developers are suggested to make better use of conceptual representatives. Second, developers may look to pay more attention to the video input of word knowledge, because previous research has widely acknowledged the overall effectiveness of video in promoting vocabulary learning efficiency (e.g., Aldera & Mohsen, 2013; Teng, 2019). Third, developers may want to apply more game elements in vocabulary learning, especially challenges/levels, time limits, and characters, since they are likely to improve students' learning experiences and learning efficiency.

Despite contributing comprehensively to the review of EFL vocabulary learning apps, this study has several limitations. First, this study only focused on apps that were downloaded most in the Chinese market, it did not examine app markets in other countries or regions. Future studies might consider conducting a more comprehensive investigation of commercial vocabulary learning apps on a global level. Second, this study did not investigate the effectiveness of the reviewed apps in experiments, leaving a question as to which app was the most effective in enhancing students' vocabulary learning. Future research may look to investigate the effectiveness of vocabulary learning apps by conducting empirical studies.

Author Statement

The authors declare that there is no conflict of interest.

Acknowledgements

ORCID

Fu Lee Wang https://orcid.org/0000-0002-3976-0053

Ruofei Zhang https://orcid.org/0000-0001-5215-3306

Di Zou 🔘 https://orcid.org/0000-0001-8435-9739

Oliver Tat Sheung Au 🔘 https://orcid.org/0000-0002-9539-0229

Haoran Xie 🔘 https://orcid.org/0000-0003-0965-3617

Leung Pun Wong 🔘 https://orcid.org/0000-0002-5445-8768

References

Aldera, A. S., & Mohsen, M. A. (2013). Annotations in captioned animation: Effects on vocabulary learning and listening skills. *Computers & Education, 68*, 60–75.

Annetta, L. A. (2010). The "I's" have it: A framework for serious educational game design. *Review of General Psychology, 14*(2), 105–113.

Antes, T. A. (2014). Audio glossing during information-gap activities: The effect on learner output. *System, 45*, 163–174.

Bisson, M. J., van Heuven, W. J. B., Conklin, K., & Tunney, R. J. (2015). The role of verbal and pictorial information in multimodal incidental acquisition of foreign language vocabulary. *Quarterly Journal of Experimental Psychology, 68*(7), 1306–1326.

Boers, F., Warren, P., He, L., & Deconinck, J. (2017). Does adding images to glosses enhance vocabulary uptake from reading? *System, 66*, 113–129.

Butler, A. C., Karpicke, J. D., & Roediger III, H. L. (2008). Correcting a metacognitive error: Feedback increases retention of low-confidence correct responses. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(4), 918–928.

Çakmak, F., & Erçetin, G. (2018). Effects of gloss type on text recall and incidental vocabulary learning in mobile-assisted L2 listening. *ReCALL, 30*(1), 24–47.

Celce-Murcia, M., Brinton, D. M., & Goodwin, J. M. (2010). *Teaching pronunciation hardback with audio CDs (2): A course book and reference guide*. Cambridge University Press.

Chen, M.-P., Wang, L.-C., Zou, D., Lin, S.-Y., & Xie, H. (2019). Effects of caption and gender on junior high students' EFL learning from iMap-enhanced contextualised learning. *Computers & Education, 140*: 103602.

Chen, X., Zou, D., Cheng, G., & Xie, H. (2020). Detecting latent topics and trends in educational technologies over four decades using structural topic modeling: A retrospective of all volumes of Computer & Education. *Computer & Education, 151*: 103855.

Chen, X., Zou, D., & Xie, H. (2020). Fifty years of British Journal of Educational Technology: A topic modelling based bibliometric perspective. *British Journal of Educational Technology, 51*(3), 692–708.

Csikszentmihalyi, M. (1975). Play and intrinsic rewards. *Journal of Humanistic Psychology, 15*(3), 41–63.

Danowska-Florczyk, E., & Mostowski, P. (2012). Gamification as a new direction in teaching Polish as a foreign language. In *Proceedings of the 5th International Conference on ICT for Language Learning*. Florence, Italy: Libreriauniversitaria.

Gangaiamaran, R., & Pasupathi, M. (2017). Review on use of mobile apps for language learning. *International Journal of Applied Engineering Research, 12*(21), 11242–11251.

Godwin-Jones, R. (2011). Mobile apps for language learning. *Language Learning & Technology, 15*(2), 2–11.

Goossens, N. A. M. C., Camp, G., Verkoeijen, P. J. L., & Tabbers, H. K. (2014). The effect of retrieval practice in primary school vocabulary learning. *Applied Cognitive*

Psychology, 28(1), 135–142.

Haynes, A. F., Mullins, A. G., & Stein, B. S. (2004). Differential models for math anxiety in male and female college students. *Sociological Spectrum, 24*(3), 295–318.

Hsu, T.-C. (2017). Learning English with augmented reality: Do learning styles matter? *Computers & Education, 106*, 137–149.

Huang, C. S. J., Yang, S. J. H., Chiang, T. H. C., & Su, A. Y. S. (2016). Effects of situated mobile learning approach on learning motivation and performance of EFL students. *Educational Technology & Society, 19*(1), 263–276

Johnson, D. D., Pittelman, S. D., & Heimlich, J. E. (1986). Semantic mapping. *The Reading Teacher, 39*(8), 778–783

Kang, S. H. K., Gollan, T. H., & Pashler, H. (2013). Don't just repeat after me: Retrieval practice is better than imitation for foreign vocabulary learning. *Psychonomic Bulletin & Review, 20*(6), 1259–1265.

Kim, H., & Kwon, Y. (2012). Exploring smartphone applications for effective mobile-assisted language learning. *Multimedia-Assisted Language Learning, 15*(1), 31–57.

Kjelldahl, L. (2012). *Multimedia: Systems, interaction, and applications*. Springer Science & Business Media.

Kohnke, L, Zhang, R., & Zou, D. (2019). Using mobile vocabulary learning Apps as aids to knowledge retention: Business vocabulary acquisition. *The Journal of Asia TEFL, 16*(2), 683–690.

Kohnke, L., Zou, D., & Zhang, R. (2020). Exploring discipline-specific vocabulary retention in L2 through app design: Implications for higher education students. *RELC Journal*. doi: 10.1177/0033688219899740

Lai, C.-H., Lin, Y.-C., Jong, B.-S., & Hsia, Y.-T. (2014). Adding social elements to game-based learning. *International Journal of Emerging Technologies in Learning (iJET), 9*(3), 12–15.

Laufer, B., & Rozovski-Roitblat, B. (2011). Incidental vocabulary acquisition: The effects of task type, word occurrence, and their combination. *Language Teaching Research, 15*(4), 391–411.

Liu, Y. C., Wang, W.-T., & Lee, T.-L. (2021). An integrated view of information feedback, game quality, and autonomous motivation for evaluating game-based learning effectiveness. *Journal of Educational Computing Research, 59*(1), 3–40.

Lotto, L., & de Groot, A. M. B. (1998). Effects of learning method and word type on acquiring vocabulary in an unfamiliar language. *Language Learning, 48*(1), 31–69.

Ma, Q., & Kelly, P. (2006). Computer-assisted vocabulary learning: Design and evaluation. *Computer Assisted Language Learning, 19*(1), 15–45.

Mayer, R. E. (2001). *Multimedia learning*. New York, NY: Cambridge University Press.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 43–52.

Nami, F. (2020). Educational smartphone apps for language learning in higher education: Students' choices and perceptions. *Australasian Journal of Educational Technology, 36*(4), 82–95.

Nation, I. S. P. (2001). *Learning vocabulary in another language*. Cambridge, UK: Cambridge University Press.

Park, J., Kim, S., Kim, A., & Mun, Y. Y. (2019). Learning to be better at the game: Performance vs. completion contingent reward for game-based learning. *Computers & Education, 139*, 1–15.

Perttula, A., Kiili, K., Lindstedt, A., & Tuomi, P. (2017). Flow experience in game-based learning - A systematic literature review. *International Journal of Serious Games, 4*(1), 57–72.

Ponce, H. R., Mayer, R. E., Figueroa, V. A., & López, M. J. (2018). Interactive

highlighting for just-in-time formative assessment during whole-class instruction: Effects on vocabulary learning and reading comprehension. *Interactive Learning Environments, 26*(1), 42–60.

Rezaei, A., Mai, N., & Pesaranghader, A. (2014). The effect of mobile applications on English vocabulary acquisition. *Jurnal Teknologi, 68*(2), doi: 10.11113/jt.v68.2912

Roediger III, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15*(1), 20–27.

Ronimus, M., Kujala, J., Tolvanen, A., & Lyytinen, H. (2014). Children's engagement during digital game-based learning of reading: The effects of time, rewards, and challenge. *Computers & Education, 71*, 237–246.

Schmitt, N. (2008). Instructed second language vocabulary learning. *Language Teaching Research, 12*(3), 329–363.

Schmitt, N., & Schmitt, D. (2020). *Vocabulary in language teaching*. Cambridge, UK: Cambridge University Press.

Scott, C. M., & Windsor, J. (2000). General language performance measures in spoken and written narrative and expository discourse of school-age children with language learning disabilities. *Journal of Speech, Language, and Hearing Research, 43*(2), 324–339.

Shadiev, R., & Yang, M. (2020). Review of studies on technology-enhanced language learning and teaching. *Sustainability, 12*(2): 524.

Subramanya, S. R. (2014). Mobile apps as supplementary educational resources. *International Journal of Advances in Management, Technology & Engineering Sciences, 9*(2), 38–43.

Teng, F. (2019). Incidental vocabulary learning for primary school students: The effects of L2 caption type and word exposure frequency. *The Australian Educational Researcher, 46*(1), 113–136.

Tu, Y., Zou, D., & Zhang, R. (2020). A comprehensive framework for designing and evaluating vocabulary learning apps from multiple perspectives. *International Journal of Mobile Learning and Organisation, 14*(3), 370–397.

Walter-Laager, C., Brandenberg, K., Tinguely, L., Schwarz, J., Pfiffner, M. R., & Moschner, B. (2017). Media-assisted language learning for young children: Effects of a word-learning app on the vocabulary acquisition of two-year-olds. *British Journal of Educational Technology, 48*(4), 1062–1072.

Wang, H., Liu, Z., Liang, J., Vallina-Rodriguez, N., Guo, Y., Li, L., Tapiador, J., Cao, J., & Xu, G. (2018, October). Beyond Google play: A large-scale comparative study of Chinese android app markets. In *Proceedings of the Internet Measurement Conference* (pp. 293–307).

Warren, P., Boers, F., Grimshaw, G., & Siyanova-Chanturia, A. (2018). The effect of gloss type on learners' intake of new words during reading: Evidence from eye-tracking. *Studies in Second Language Acquisition, 40*(4), 883–906.

Webb, S. (2007). Learning word pairs and glossed sentences: The effects of a single context on vocabulary knowledge. *Language Teaching Research, 11*(1), 63–81.

Xu, Z., Chen, Z., Eutsler, L., Geng, Z., & Kogut, A. (2019). A scoping review of digital game-based technology on English language learning. *Educational Technology Research and Development, 68*(3), 877–904.

Yang, Q.-F., Chang, S.-C., Hwang, G.-J., & Zou, D. (2020). Balancing cognitive complexity and gaming level: Effects of a cognitive complexity-based competition game on EFL students' English vocabulary learning performance, anxiety, and behaviors. *Computers & Education, 148*: 103808.

Yip, F. W. M., & Kwan, A. C. M. (2006). Online vocabulary games as a tool for teaching and learning English vocabulary. *Educational Media International, 43*(3), 233–249.

Yoshii, M. (2006). L1 and L2 glosses: Their effects on incidental vocabulary learning.

Language Learning & Technology, 10(3), 85–101.

Yu, Z. (2018). Differences in serious game-aided and traditional English vocabulary acquisition. *Computers & Education, 127*, 214–232.

Zhang, R., & Zou, D. (2020a). Types, purposes, and effectiveness of state-of-the-art technologies for second and foreign language learning. *Computer Assisted Language Learning*. doi: 10.1080/09588221.2020.1744666

Zhang, R., & Zou, D. (2020b). Influential factors of working adults' perceptions of mobile-assisted vocabulary learning with multimedia annotations. *International Journal of Mobile Learning and Organisation, 14*(4), 533–548.

Zhang, R., Zou, D., & Xie, R. (2021). Spaced repetition for authentic app-assisted word learning: nature, learner perceptions, and factors leading to positive perceptions. *Computer Assisted Language Learning*. doi: 10.1080/09588221.2021.1888752

Zhang, R., Zou, D., Xie, R., Au, O. T. S., & Wang, F. L. (2020). A systematic review of research on e-book-based language learning. *Knowledge Management & E-Learning (KM&EL), 12*(1), 106–128.

Zou, D. (2020). Gamified flipped EFL classroom for primary education: Student and teacher perceptions. *Journal of Computers in Education, 7*(2), 213–228.

Zou, D., Huang, Y., & Xie, H. (2021). Digital game-based vocabulary learning: Where are we and where are we going? *Computer Assisted Language Learning, 34*(1/2), 751–777.

Zou, D., & Xie, H. (2018). Personalised word-learning based on technique feature analysis and learning analytics. *Educational Technology & Society, 21*(2), 233–244.

Zou, D., Xie, H., & Wang, F. L. (2018). Future trends and research issues of technology-enhanced language learning: A technological perspective. *Knowledge Management & E-Learning, 10*(4), 426–440.

Appendix I

Reviewed apps

Apps	Links
Shanbay	https://www.shanbay.com/m/intro/?app=words
Hujiang Cichang	https://www.hujiang.com/app/?ch_campaign=tool12945&ch_source =itool_kxcc_0_xmdbtt#cichang
Maimemo	https://www.maimemo.com
Wordsend	http://www.ejetsoft.com/wordsend.html
Youdao Recite	https://recite.youdao.com/
English Vocabulary Cards	https://apps.apple.com/us/app/%E8%8B%B1%E8%AF%AD%E5% 8D%95%E8%AF%8D%E5%8D%A1- %E5%AD%A6%E4%B9%A0%E8%8B%B1%E8%AF%AD%E6% AF%8F%E6%97%A5%E5%B8%B8%E7%94%A8%E5%9F%BA %E7%A1%80%E8%AF%8D%E6%B1%87/id1443988726
iWordnet	http://iwordnet.com/
Bbdc	https://bbdc.cn/
Roots & Affixes	https://apps.apple.com/us/app/%E8%AF%8D%E6%A0%B9%E8% AF%8D%E7%BC%80%E5%AD%97%E5%85%B8- %E6%89%B9%E9%87%8F%E8%83%8C%E5%8D%95%E8%AF %8D/id528178365
Kuaibei	https://apps.apple.com/us/app/%E5%BF%AB%E8%83%8C%E5%8 D%95%E8%AF%8D- %E5%90%84%E7%B1%BB%E8%8B%B1%E8%AF%AD%E8%8 0%83%E8%AF%95%E5%BF%85%E5%A4%87- %E4%B8%8A%E7%8F%AD%E6%97%8F%E8%83%8C%E5%8D %95%E8%AF%8D%E7%9A%84%E5%88%A9%E5%99%A8- %E7%9F%AD%E6%9C%9F%E5%86%85%E6%8F%90%E5%8D %87%E8%AF%8D%E6%B1%87%E9%87%8F%E7%9A%84%E6 %B3%95%E5%AE%9D/id888604858
iLeci	https://www.ileci.com/staticView/index
Towords	https://www.towords.com/
Super Word King	https://superwordking.wixsite.com/home
Baicizhan	https://www.baicizhan.com/