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The Impact of Supported and Annotated Mobile Learning on Achievement and Cognitive Load

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ABSTRACT

We designed activities for learning English as a foreign language in a mobile learning environment with familiar authentic support for this study. Students learned at school and then applied their newly gained knowledge to solve daily life problems by first using a tablet to take pictures of objects they wished to learn about, then describing them and sharing their homework with peers. For this study two experiments were carried out in which 59 junior high school students participated. A class of 28 students served as the control group in Experiment 1, and as the experimental group in Experiment 2; a second class of 31 students served as the experimental group in Experiment 1 and as the control group in Experiment 2. In the class serving as the control group, students studied and completed each learning activity using traditional textbooks while the experimental group studied using an electronic textbook and used a learning system installed on tablet PCs. This study investigates the effects of the mobile system on learning achievement and cognitive load. The research resulted in three main findings. First, the experimental students outperformed the control students on post-test items in both experiments. Second, learning activities using the tablet learning system caused less cognitive load for the students than when learning without technological support. Finally, this study found that creating text annotations is very important learning behavior and it predicts learning achievement. Based on these results, several implications along with conclusions and suggestions for future research are suggested at the end of this study.

Keywords

Mobile learning, Familiar authentic environment, Annotation, Learning achievement, Cognitive load

Introduction

The rapid advancement of information and communication technology has created new opportunities for curriculum design (Liang & Huang, 2014; Shadiev, Hwang, & Huang, 2015). For example, according to a growing number of studies, mobile technology provides advantages such as giving the ability to learn anywhere and at any time (Hwang, Chen, Shadiev, Huang, & Chen, 2014a). Chang, Tseng, and Tseng (2011), Chu (2014), and Hwang, Shih, Ma, Shadiev, and Chen (2015) suggest that mobile technology creates an authentic learning environment in a real-world context in which learners adapt learning content to the context they find themselves in. Furthermore, mobile technology can be used as a cognitive tool to aid learning by decreasing learners' cognitive load (Hwang, Wu, Zhuang, & Huang, 2013). Following these discoveries, mobile-assisted learning has been successfully implemented in a number of studies in various disciplines to manage cognitive load and facilitate learning; for example, in a social science course (Hwang et al., 2013; Chu, 2014) and in foreign language learning (Chen, Hsieh, & Kinshuk, 2008; Chang et al., 2011).

However, in spite of the potential advantages of this approach, the present study has also uncovered some potential issues that have not yet been addressed appropriately in related research. For example, previous studies have not dealt with developing speaking and writing skills or the ways in which knowledge is applied. In addition, most related studies have only focused on the effects of mobile learning on cognitive load in general; being in a familiar context in an authentic environment was not yet considered. Therefore, this study seeks to remedy these problems through the design of various speaking and writing learning activities to be carried out in a familiar authentic environment supported by mobile technology.

Literature review

Cognitive load

Mayer and Moreno (2003) and Plass, Chun, Mayer, and Leutner (2003) argue that taking cognitive load into consideration should be a central principle in the design of effective instruction because working memory limits learners' cognitive capacity to accommodate demands imposed by learning tasks. According to Mayer and Moreno (2003) and Plaas et al. (2003), learning performance can be negatively affected when cognitive load exceeds the limit of cognitive capacity. Thus the issue of how to reduce cognitive capacity overload while encouraging knowledge construction should be considered when attempting to improve instruction design.

Three types of cognitive load are distinguished in the literature: intrinsic, extraneous, and germane (Brunken et al., 2003; Sweller et al., 1998). Intrinsic load is determined by the inherent nature of the learning material, learners' expertise and an interaction between them; that is, the amount of information units that a learner needs to hold in working memory to comprehend the information. It is argued that intrinsic load is not affected by the instructional design but only by the learning material. Therefore, to avoid exceeding the appropriate intrinsic load, instructors need to adjust learning materials to meet the learners' expertise. The term "extraneous load" refers to the cognitive load caused by the format and the manner in which information is presented as well as by the working memory requirements required to perform the actual instructional activities. An extraneous load can be imposed by improper instructional design. Thus, to keep the extraneous load from becoming excessive, instructors need to organize, present and carry out learning information and activities appropriately. A germane load is determined by learners' efforts to process and comprehend the learning material. This load is also associated with motivation and interest. A germane load is induced by appropriate instructional design and can enhance learning.

Cognitive load in foreign language learning

Numerous studies on foreign language learning have investigated how to keep learners from being cognitively overloaded. Some information processes in foreign language learning are complex and impose a heavy cognitive load on working memory (Keysar, Hayakawa, & An, 2012). For example, applying learned vocabulary to new contexts involves high interactivity of elements, which causes a high intrinsic load (Plass et al., 2003). To reach the intermediate level of a foreign language, thousands of words need to be learned (Hulstijn & Laufer, 2001). When learners apply learned vocabulary to a new context, they have to focus on output (i.e., what to say/write and how to say/write it) which requires that several language forms (i.e., vocabulary and sentence patterns) be retrieved from long-term memory (Nation, 2003). Another example is when learners listen to a lecturer to comprehend instructional content; learners need to retain information in working memory integrate it with what follows, and all the while continually adjust understanding of incoming information with prior knowledge (Chen & Chang, 2009).

Several approaches have been proposed to develop instructional methods to teach learners how to efficiently apply what they have learned to new contexts using their limited working memory capacity. Of particular interest to this study are those approaches based on multimedia support. Cognitive theory of multimedia learning postulates that people learn more when information is presented through more than one media, e.g., words and pictures (Mayer, 2009). This is because learners process the information through multiple channels, e.g., auditory and visual; consequently, learning is deeper and information is retained in the memory longer. Acha (2009) and Plass et al. (2003) suggest that different presentation modes (i.e., visual and verbal) can ease the information processing load. Many tasks have visual and verbal representations; therefore, learners can easily access them, keep less learning information in working memory, and use more attentional resources elsewhere (Skehan, Willis, & Willis, 1996).

Children in a study performed by Acha (2009) read a short story in English on a computer screen and received verbal annotations (written translation). Acha (2009) found that verbal annotation affects vocabulary learning as children establish a direct connection between the verbal representation of the word in the native language and its foreign equivalent. English-speaking students of Plass et al. (2003) read a story in German on a computer and received verbal annotation, visual annotation, or neither. It was found that reading comprehension was worse with only the visual-annotations than with either no annotations or both verbal and visual annotations. Apparently the visual image annotation, when presented alone, introduce confusion, especially for words that are difficult to depict visually.

Learning in authentic environment with multimedia support

Context plays an important role in learning (Hwang et al., 2014a; Shadiev et al., 2015). Therefore, when designing learning activities, educators have to ensure that the environment where the learning activity takes place is authentic, i.e., relevant to real-life situations. According to Hwang et al. (2014a), an authentic environment (1) provides contexts that reflect the way the knowledge will be used in real life, (2) provides authentic activities that have real-world relevance, and (3) creates an opportunity for learners to share their learning and accessing experiences with various levels of expertise.

According to Chang et al. (2011), Chu (2014), and Huang and Chiu (2014), mobile technology can be used in authentic contexts with rich resources for students to learn. Furthermore, mobile-assisted learning offers a seamless learning experience, i.e., it can be accessed at any time or place (Hwang et al., 2014a). The effectiveness of multimedia-based instruction has been emphasized in many previous studies. With mobile multimedia tools, students can create learning materials in an authentic environment (Huang, Huang, & Wu, 2014). Multimedia aids, such as pictures and audio, make learning more interactive and information rich (Huang et al., 2011). Moreover, multimedia objects in learning stimulate students' imagination and help bring out meaningful output (Caldwell, 1998). Students in the study of Hwang et al. (2014c) took pictures of learning objects in authentic contexts and then described them by using vocabulary and grammar learned in class. In the study of Hwang, Huang, Shadiev, Wu, and Chen (2014b), students practiced the target language by speaking out learning materials from the textbook, taking pictures of learning objects from daily life, and orally introducing them. Hwang, Shadiev, and Huang (2011) argue that, with multimedia aids, students can practice the target language repeatedly and regularly and expose themselves to diverse learning objects which increase the richness of their language experience. Harmer (2007) suggests that if students record their speech they (and the instructor) can listen to their own recordings, evaluate language performance, and see how much progress they have been making. Without multimedia support students need to hold a mental representation of the context in working memory over a period of time which is called "representational holding" (Mayer & Moreno, 2003). According to Mayer and Moreno (2003), when students attempt to engage in both information processing (i.e., selecting, organizing, and integrating learning material) and representational holding, cognitive overload occurs. Distributed cognition theory suggests that students' representational holdings can be transformed into artefacts (i.e., pictures and their descriptions in written or oral form) which may prevent students being cognitively overloaded (Hollan, Hutchins, & Kirsh, 2000). Hollan and his colleagues argue that knowledge and cognition are not confined to an individual but distributed by placing memories, facts, or knowledge of the objects, individuals, and tools in the learning environment as a set of representations.

Hwang et al. (2011) suggest that the learning material and relevant multimedia aids should be placed on the same screen. In this way, a connection can be built between learning materials and supporting multimedia that gives students a clear picture of the whole learning scenario. Mayer and Moreno (2003) call this form of presentation "integrated presentation." Using this approach, learners are more focused on essential information processing; that is, more cognitive capacity can be activated.

Huang et al. (2011) claim that multimedia supports students in their efforts to communicate in the target language with less anxiety about making mistakes. Chen et al. (2009) asserts that anxiety is a subjective feeling of worry, nervousness, or unease associated with arousal of the autonomic nervous system. Anxiety interferes with the cognitive ability to absorb, process, and produce a foreign language. Furthermore, it negatively affects cognitive load.

Hwang et al. (2011) claim that sharing homework with peers allows further reflection, discussion, and collaboration. In addition, sharing homework increases practice opportunities and helps students engage in English as Foreign Language (EFL) contexts. For example, students can listen to others' audio recordings in which they can hear a diversity of speeches (i.e., variations in accent, fluency, and level of learning performance). Students in the Hwang et al. study (2015) and Hwang et al. (2011) listened to recordings of peers and pre-recorded how the instructor reads the text in the book. Through sharing, students also exchanged meaningful comments (Hwang et al., 2015). For example, students gave reflective comments and suggestions to a peer who did not complete the homework correctly (Hwang et al., 2011). Comments given by peers were useful in revising and improving homework.

Managing cognitive load in an authentic learning environment

It has been suggested that learning activities which occur in an authentic environment are more likely to facilitate learners' cognitive activity and conceptual change. The reason is that an authentic environment simulates learners by causing them to interact with real world problems that they are confronted with. This provides learners with real life learning experience and stimulates them not only to develop knowledge but also to learn how to apply that knowledge to solve encountered problems. Brown, Collins and Duguid (1989) argue that knowledge is a part of the environment and specific to a particular situation. Moreover, knowledge manifests itself in everyday activities and is in part a product of the activity, context, and culture in which it is developed and used.

From a cognitive load perspective, authentic learning tasks are more complex and impose a high cognitive load on students, especially novices or inexperienced ones. Tasks in a rich real world context have many different solutions, are ecologically valid, and usually cannot be mastered in a single session (Van Merriënboer & Sweller, 2010). Therefore, authentic learning tasks are cognitively demanding and require high-element interactivity, i.e., learners have to deal with several elements simultaneously (Van Merriënboer, Kester, & Paas, 2006). Based on cognitive load theory, instructional design guidelines were proposed in related literature to balance cognitive load and to enhance learning in an authentic environment (Van Merriënboer, 1997; Van Merriënboer et al., 2006; Van Merriënboer & Sweller, 2010). For example, the guidelines suggest to assign learning tasks in simple-to-complex order (i.e., earlier tasks have lower element interactivity), to scaffold learners within a task, and to focus learners' attention on most important elements for learning. The guidelines also suggest to provide learners with supportive and procedural information (i.e., how a complex problem can be approached and what steps learners need to take) along with part-task practice (i.e., to develop knowledge elements that allow the learner to perform routine aspects at a high level of automaticity). In this way, extraneous load can be decreased, intrinsic load managed and germane load optimized.

In an authentic environment, cognitive tools, such as mobile multimedia applications, can aid learning by diminishing the chances of an excessive cognitive load. Hwang et al. (2013) introduced a mobile learning system to aid sixth grade students' local culture learning during a field trip taken as part of a social science course. Using the system, students accessed physical and virtual resources in an authentic environment; the system presented the learning tasks, guided students to explore the real-world learning targets, and provided them with supplementary materials via the mobile devices. The effects of this approach on students' cognitive load and learning achievements were investigated, and the results showed that students who learned with technological approach had better learning achievement and less cognitive load than those who learned using a traditional approach. Hwang et al. (2013) suggest that the mobile learning approach has positive effects on students' local culture learning.

Elementary school students in Chu's study (2014) explored an indigenous culture as a part of their social studies course by observing learning objects and completing the learning sheets. Students formed two groups, a control group and an experimental group. The control group participated in learning activities under the instructors' guidance while the experimental group was guided by a mobile learning system. Chu (2014) investigated the effects of mobile learning on learning achievement and cognitive load and found that learning achievement of the control group was much higher than that of the experimental group. The results also show that there was no difference in extraneous and germane cognitive loads between the two groups; however, the intrinsic load of the experimental group was higher than that of the control group. Chu (2014) concluded that the instructional variables had been well considered in her study, leading to a good balance between controlling the germane and extraneous cognitive loads. However, in an authentic learning environment, students not only need to interact with the real-world learning objects but also pay attention to the guidance and learning content provided by a mobile learning system at the same time. As a result, the learning process becomes more complex and the learning burden (including cognitive load) greater. This is particularly true when learners are under pressure caused by time limitations, the amount of learning content to be covered is large, the number of questions to be answered is considerable, and/or the students' do not have much experience in a mobile learning environment.

Chen et al. (2008) explored how short-term memory and content representation type affect language learning in a mobile learning environment. To accomplish this, EFL university students were divided into two groups, verbal and visual. They were all required to learn 24 English words (with written annotation and pictorial annotation) delivered by Short Message Service or Multimedia Message Service to their mobile devices. The researchers found that providing vocabulary with pictorial annotation is helpful for learners with lower verbal but higher visual ability as these learners find it easier to learn words presented in a visual rather than in a verbal form. However, providing vocabulary with both written and pictorial annotation can also help learners with both high verbal and high visual abilities. Chen et al. (2008) concluded that providing the basic learning material is more helpful to learners with low verbal and visual abilities, as too much information may produce a high cognitive load and shorten concentration time.

In a related experiment, Chang et al. (2011) examined how English proficiency (low vs. high) and material presentation mode (single channel vs. dual channel) affect English listening comprehension and cognitive load. In an experimental learning activity, university students studied animals in a zoo using a PDA. The system guided students to target specific animals and then displayed related material (i.e., text) and played an audio guide (spoken messages). Students in a single channel group learned through spoken messages only, whereas students in a dual channel group learned by text and spoken messages. Results of the study revealed that high and low English proficiency learners in the dual channel group had better English listening comprehension than learners in the single channel group. Low English proficiency learners in the dual channel group had a significantly lower extraneous load than those in the single channel group. Chang et al. (2011) concludes that dual channel presentation mode leads to an increased depth of information processing, with the different input modes reinforcing one another.

Research motivation

The literature review of this study evokes four important issues that have not yet been sufficiently addressed.

In many countries, English is now the language most widely taught as a foreign language, causing many students to experience cognitive overload. Therefore, how to reduce cognitive overload caused by English learning is an important question for instructors and researchers. Although, many studies have been carried out to address this question, most are limited to vocabulary learning, reading, and listening comprehension; for example, work done by Acha (2009), Chang et al. (2011), Chen et al. (2008), and Plass et al. (2003). Therefore, cognitive load associated with developing such important foreign language skills as speaking and writing has so far been overlooked.

Secondly, the ways in which being in a familiar context (i.e., familiar, relevant and predictable situations from learners' background and previous experiences) helps comprehension, recall and cognitive load in an authentic environment was not considered in most related studies. Other related studies have created an authentic learning environment by employing mobile technology for research purposes, for example, in a local temple (Hwang et al., 2013; Chu, 2014) or a zoo (Chang et al., 2011). Usually, students visit such places only a few times a year and therefore the learning context there is familiar to students at a certain level. The learning environment used in Chen et al. (2008), though, was only "virtually authentic," and so was not truly familiar to students.

Thirdly, the research to date has tended to focus on the effects of mobile learning on cognitive load in general rather than how specific mobile technological learning tools can help prevent students from being cognitively overloaded. For example, students unload some important information related to learning objects from everyday life when they use the annotation tool in their tablet PCs. This information would otherwise have had to be constantly held in working memory over a period of time. Later, annotations help students easily recall that important information and build a stronger connection between learning content and targeted objects, i.e., enhanced learning. That is, unloading cognitive work and making more "space" for new information in working memory is essential for keeping the cognitive load balanced, the condition which leads to the most effective learning. This is particularly important for situations in which students' learning burden can become excessive as they need to interact with real-world learning objects and simultaneously pay attention to learning content provided by mobile technology.

Finally, in previous studies, the ways in which knowledge is explored, verified and applied have received little attention. In most studies, a mobile learning system provides learning content, guides students to the learning targets and displays questions which students are then asked to answer (Hwang et al., 2013; Chang et al., 2011; Chen et al., 2008; Chu, 2014). Such learning processes do not facilitate high level cognitive processing, such as applying new knowledge learned in school to solve problems in daily life situations. Instead they focus on low level cognitive processes, such as recalling and remembering information.

This study strives to overcome these failings in previous research through the design of various learning activities supported by mobile technology. Guided by related literature, learning activities have been designed so students can learn in class and then freely apply the new knowledge to solve daily life problems in a familiar, authentic environment (e.g., their home or a local convenience store). To make sure that learners are not cognitively overloaded while learning and to enhance their comprehension, this study introduced mobile technology. In this study, non-native English speaking students take pictures of learning objects in a familiar authentic environment and use English to describe them in written and oral annotations by using mobile technology. This study aims to investigate how mobile learning affects learning achievement and cognitive load. The following research questions are addressed in this study.

- Do students who participate in learning activities supported by the system perform better than those without technological support?
- How different is the cognitive load of students during learning activities supported by the system from that of those without technological support?

Method

This study employs a quasi-experimental design by adopting a nonequivalent control group method. The effectiveness of applying learning activities supported by the system on learning achievement has been evaluated by comparing the differences in the pre and post-test outcomes of the control and experimental groups in Experiment 1 and 2. The difference in cognitive load on students in the two groups during their learning was also investigated in both experiments. In this study, two classes were selected for the two experiments: one class serves as the control group in Experiment 1 and then becomes the experimental group in Experiment 2; the other class is the exact opposite: it serves as the experimental group in experiment 1 and as the control group in Experiment 2. By assigning two classes, this study hopes to make our results more reliable and valid while investigating the change in learning effectiveness and cognitive load under different conditions.

Participants and experimental procedures

Two experiments were carried out in this study. A total of 59 junior high school students participated in the two experiments. One class with 28 students served as the control group in Experiment 1 and as the experimental group in Experiment 2. The other class, with 31 students, served as the experimental group in Experiment 1 and as the control group in Experiment 2. Table 1 presents participants' profile whereas Figure 1 shows experimental procedure. Most students in both groups were thirteen years old with four to six years' experience of using computers and less than one to three years' experience of using tablet PCs. All students had five years of foreign language learning experience prior to this study: three years from the elementary school and two years at the junior high school now. In the primary school, the English education curriculum places greater emphasis on students' communicative abilities while in the junior high school on developing the reading and writing language skills in addition to communicative abilities (Ministry of Education, 2000).

One may argue that when two classes are recruited for the experiment, half of each class could also be randomly assigned to the experimental and control groups in order to control for potential differences between the classes. In this study, we have assigned one class as one particular group. There are several reasons for this. First, classroom management is an important issue. In junior high school, if some students in class are provided with the technology and some are not then classroom management will be compromised. That is, some students will feel that it is unfair that they have to learn under unequal conditions.

In addition, managing the learning process in a class with many students who use different learning tools will soon become a logistical nightmare for the instructor, who is likely to encounter difficulty controlling and disciplining the class. Second, because students of one class are not acquainted with students of the other, merging them together could hamper their likelihood to take advantage of the sharing functions of the system. That is, students would have no idea whose work is the best to consult in order to learn or to get some inspirational ideas, and they wouldn't exchange as much feedback as when they learn with peers from the same class due to anxiety to feedback on homework of someone they do not know well.

Table 1. Participants' profile

Category	Group 1 (*n* = 28)		Group 2 (*n* = 31)	
	Frequency	Percentage	Frequency	Percentage
Gender				
Male	15	53.57	17	54.84
Female	13	46.43	14	45.16
Age (years)				
13	26	92.86	29	93.55
14	2	7.14	2	6.45
Experience to use computer (years)				
1-3	1	3.57	4	12.90
4-6	16	57.15	20	64.52
7 and more	11	39.28	7	22.58
Experience to use tablet PC (years)				
less than 1	10	35.71	10	32.26
1 to 3	10	35.71	18	58.06
more than 3	8	28.57	3	9.68

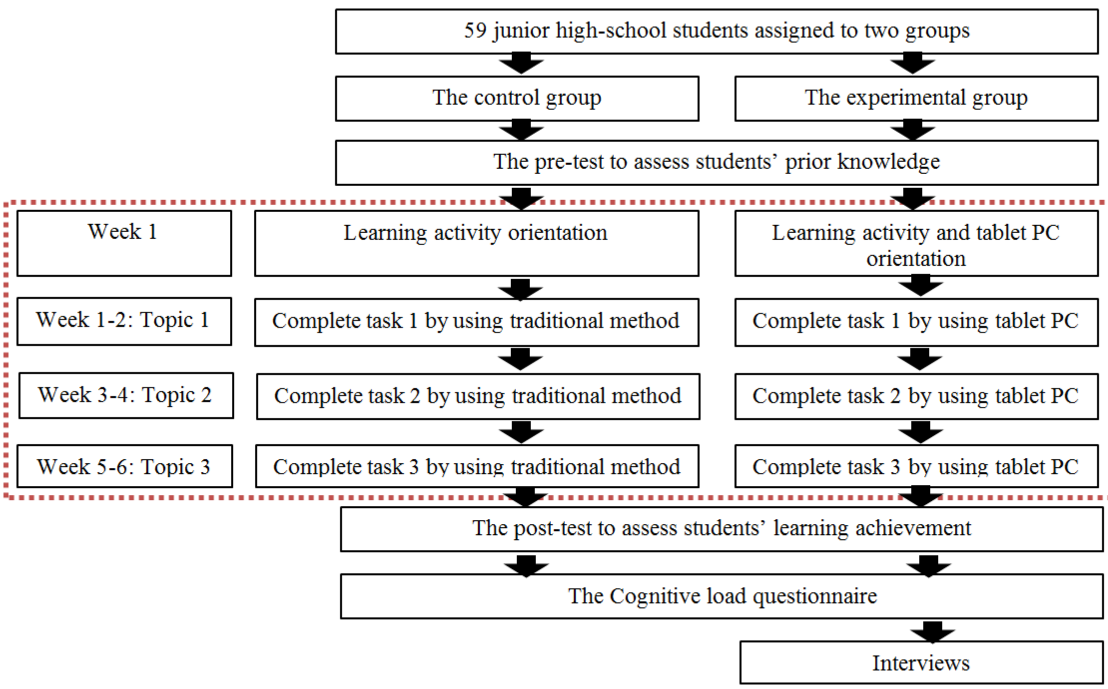

Figure 1. The experimental procedure

Learning activity design

This study designed learning activities that focus on learning at school and then applying that knowledge in an authentic environment outside of school, ideally in a wide range of daily life situations (e.g., at local convenience store or supermarket). Learning activities were built around three topics from the textbook: (1) "Where Are You From?" (2) "Your School Is Very Big," and (3) "Be Quiet and Sit Down, Please" for the first experiment and (1) "Which do you like – Healthy diet," (2) "How much / many do we need," and (3) "We were in different classes" for the second experiment. Learning activities include three tasks, and each corresponds to its topic. In each task, all students are asked to take a picture of a learning object (e.g., a sign for Topic 3 of the first experiment or a meal for Topic 1 of the second experiment) and then to introduce and describe it using a minimum of 6-10 sentences.

According to cognitive load theory, learning tasks that carried out in an authentic environment are more complex and impose a high cognitive load on students, especially novices or inexperienced ones. In the study of Chu (2014), students who learned in an authentic environment using mobile technology experienced low learning achievement but high cognitive load. We learned that the reason for such finding was due to (1) students' simultaneous interaction with the real-world learning objects, the guidance and learning content, (2) high pressure on students caused by time limitations, the large amount of learning content to be covered and the considerable number of questions to be answered, (3) students' insufficient experience in a mobile learning environment. Therefore, in this study, a learning activity supported by mobile technology was devised differently than that in Chu's (2014) study to ensure better learning achievement and a manageable cognitive load. Furthermore, learning tasks to be carried out in an authentic environment were designed following guidelines proposed by Van Merriënboer (1997), Van Merriënboer et al. (2006), and Van Merriënboer and Sweller (2010). First, students practiced how to apply learned knowledge in the classroom before going to authentic environment. Second, learning tasks were assigned to students in simple-to-complex order. Third, this study ensured beforehand that all the students knew what they needed to do and how to do it during the learning activity and that they had adequate skills to use a tablet PC, that is, that they were able to record their voice and write using the technology. Besides, students learned in familiar to them context and the instructor provided scaffolding and guidance to students when it was necessary. Forth, this study did not create and provide any learning content to students during the learning activity: students were asked to create their own content instead. Fifth, students in this study were asked to complete the required learning activity after school so that there would not be any pressure in terms of time limit or learning content. Finally, our students were not novices or inexperienced ones; instead, they already had five years of foreign language learning experience which included acquisition of communicative abilities as well as reading and writing skills.

The learning system

A learning system was developed for this study which enables students to carry out the learning activity tasks. The interface of the system is shown in Figure 2. The following are the four main functions that the system can execute:

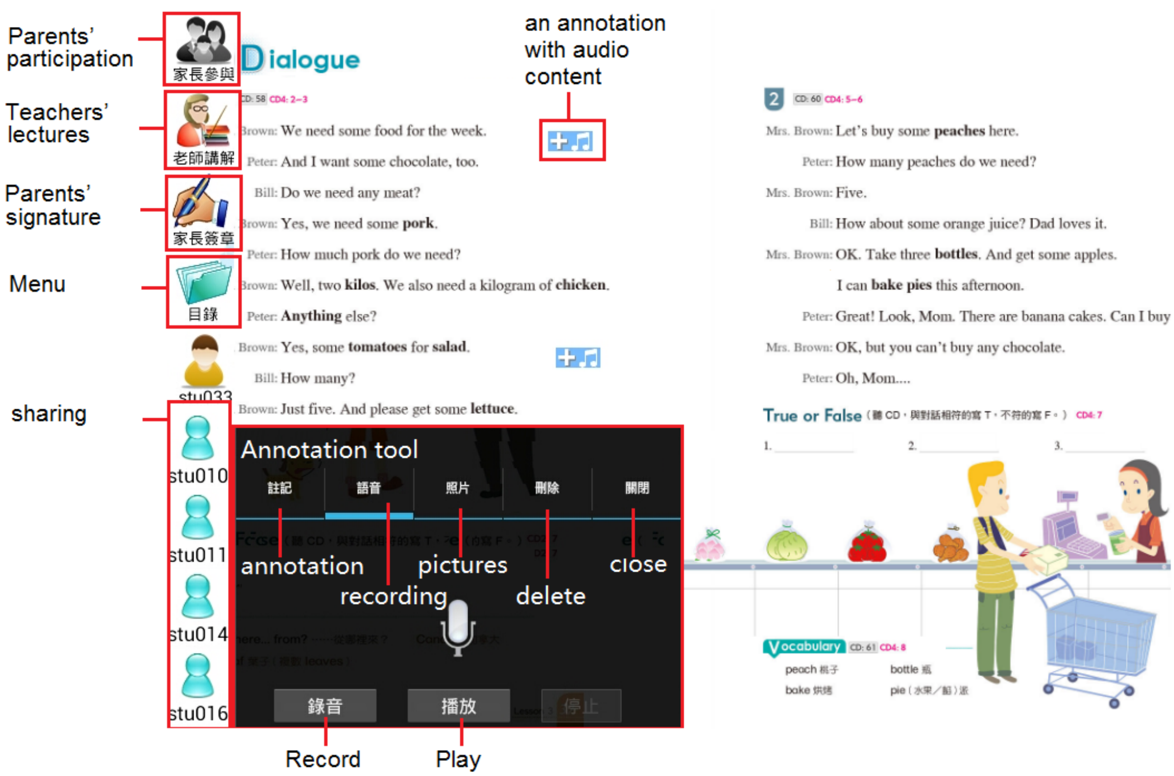

Figure 2. The system interface

Annotating. Students can annotate important parts of the learning material on their tablet PCs. For example, when using the electronic textbook, students can annotate important parts of the learning material, e.g., key concepts, by highlighting them or adding textual explanation to review them afterwards when doing homework or preparing for the exam. In addition, students were able to annotate unfamiliar vocabulary in the electronic textbook by adding textual annotations with translation and examples of how to use the new vocabulary in different contexts. When working on tasks, students could write a description of a learning object by creating a textual annotation. Students could also take photos of the learning objects in the familiar authentic environment and attach them to an annotation.

Recording. When students spoke out to describe a learning object, they could record their own voice and listen to it afterwards. In this way, the system enables students to find their own mistakes and improve the content of the recorded audio files. Students could also record the instructor's lectures and listen to them to review important concepts.

Assistance. Students were able to get assistance from the system, such as (1) reading a text aloud (Text-to-Speech Recognition), (2) translating unfamiliar vocabulary and sentences (Translation), and (3) listing of words in alphabetical order with their meaning and translation (Dictionary).

Sharing. Students were able to share their own annotations, photos, and recorded audio files with peers. This approach allows students to study peers' annotations so as to both enhance their own understanding of the learning material and improve their own annotations.

In this study, control students completed the same learning activity but by using traditional methods. That is, the control students studied the learning material by using traditional textbooks, took notes in their traditional notebooks and shared notes with others. Control students could also take pictures of learning objects; however, they could not record their voices or the instructor's lectures.

Instruments

Students' prior knowledge was evaluated through a pre-test and students' learning achievement was later measured using a post-test for both experiments. The test items were created by an experienced junior high school teacher based on the learning materials and activities of this study. The items of the pre-test and post-test for both experiments were similar in structure but different in content. Thirty items were included in each test. Test item examples are provided in Appendix 1. Students' answers to the tests were scored by three raters and notable differences in the assessment were resolved through raters' discussions until a consensus was achieved. Inter-rater reliability of the tests was evaluated by using Intra-class correlation coefficient (ICC). The average measure ICC was 0.971, indicating high reliability.

Several approaches have been proposed in related literature for measuring cognitive load. Paas, van Merriënboer and Adam (1994) introduced *a subjective, indirect measure of cognitive load* (a questionnaire survey). In this questionnaire students were asked to report the amount of mental effort they invested in understanding the learning material. Paas et al. (1994) argues that a low amount of invested effort could be a result of low-cognitive load. Kalyuga, Chandler, and Sweller (1999) proposed *a subjective, direct measure of cognitive load* (a survey that rates the difficulty of the materials). Brunken, Plass and Leutner (2003) recommend *an objective, indirect measure of cognitive load based on performance outcomes* (knowledge acquisition scores). We adopted a subjective measure of cognitive load for the present study. A cognitive load questionnaire was developed and its design follows the general recommendations from previous related studies (Chu, 2014; Huang et al., 2013; Hwang et al., 2013; Sweller et al., 1998). Four items (shown in Appendix 2) were included in the questionnaire: items 1 and 2 measure cognitive load and items 3 and 4 measure mental effort. All 59 students were asked to respond to the questionnaire, and 59 valid answer sheets were obtained. Responses to the items were scored using a five-point Likert scale, anchored by the end-points "strongly agree" (1) and "strongly disagree" (5). The internal consistency of the survey was tested by employing Cronbach α; the values exceeded 0.80, demonstrating satisfactory reliability of the items. This study has triangulated among different data sources to ground our findings related to cognitive load; that is questionnaire survey results were supported by interview results (Kalyuga et al., 1999) and performance outcomes (Brunken et al., 2003).

One-on-one semi-structured interviews were also conducted with ten students randomly selected from each experiment. Interviews aimed to explore students' learning experiences with the system and gain insights from their perceptions of the cognitive load they were under. Each interview lasted for 20 minutes and students were asked the following questions: (1) Please describe your learning experience with the system; (2) Was the system useful for learning? If yes, please explain why. All interviews were audio-recorded after receiving the students' permission, and were then fully transcribed for analysis. The text segments that met the criteria of providing the best research information were highlighted and coded. The codes were then sorted into categories; codes with similar meanings were aggregated together. Established categories produced a framework to report findings pertinent to the research questions.

Results and discussion

The effectiveness of applying learning activities supported by the system on learning achievement and cognitive load was evaluated by comparing the differences in the pre-test, post-test and questionnaire survey outcomes of the control and experimental groups. This study set a priori alpha-level (i.e., level of significance) at 0.05 since an alpha level of less than .05 is accepted in most educational research as statistically significant.

The effectiveness of mobile learning with authentic support on learning achievement

The difference between the pre-test scores of the experimental and control students was measured and then compared by employing an independent samples test. The means and standard deviations of the students' pretest and post-test scores are shown in Table 2. According to the table, students in the control (*M* = 47.19, *SD* = 14.71) and experimental (*M* = 48.64, *SD* = 20.81) groups had equal prior knowledge before the Experiment 1, $t = -0.299$, $p = 0.766$. The table also shows that prior knowledge of the students in the control (M=49.03, SD=20.55) and experimental (*M* = 45.46, *SD* = 22.13) groups was not different before the Experiment 2, $t = 0.637$, $p = 0.527$.

Table 2. Results of analysis of covariance with pre-test as covariate

	The control group		The experimental group		*F*	Sig. 2-tailed	Partial eta squared
	M	*SD*	*M*	*SD*			
Experiment 1							
Pretest	47.19	14.71	48.64	20.81			
Posttest	53.50	13.21	65.45	18.59	16.709	0.000	0.236
Experiment 2							
Pretest	49.03	20.55	45.46	22.13			
Posttest	58.30	22.67	70.32	17.01	20.345	0.000	0.270

This study used covariance to measure the differences in the learning achievement of students in the control and experimental groups on the post-test, with the pre-test serving as covariate. Results are reported in Table 2. In Experiment 1, a significant difference was observed between the control (*M* = 53.50, *SD* = 13.21) and experimental group (*M* = 65.45, *SD* = 18.59) on the post-test, $F(1,56) = 16.709$, $p = 0.000$, partial eta-squared = 0.236. In Experiment 2, the experimental group (*M* = 70.32, *SD* = 17.01) outperformed the control group (*M* = 58.30, *SD* = 22.67) on the post-test, $F(1, 56) = 20.345$, $p = 0.000$, partial eta-squared = 0.270.

We interviewed a number of students to provide subjective evidence that may support the empirical test results. In the interviews, students indicated that learning activities could be completed more efficiently using the system instead of the traditional approach. Furthermore, the system enabled more effective practice of EFL skills. First, students took pictures of learning objects and created text annotations and recorded their own voice when describing the learning objects. It seems that students enjoyed reviewing the pictures and text annotations and listening to their own recorded files. If the content quality of photos, annotations and recorded files was not satisfactory (e.g., mistakes in pronouncing some words), students wanted to improve it. According to students, such learning behavior led to more frequent language practice as well as to better quality of language output. Similar reasons for using multimedia tools for language practice have been reported in other research (Harmer, 2007; Hwang et al., 2011; Hwang & Shadiev, 2014). For example, students in Hwang et al. (2015) and Hwang et al. (2011) took advantage of the technology to practice the target language repeatedly and regularly. Harmer (2007) found that after students recorded their speeches, they listened to the recordings, evaluated their own language performance, and monitored how much progress they made. However, in contrast to other related research, this study did not only focus on learning the basic knowledge at school, but also on how students applied the learned knowledge to solve a wide range of real life problems in a familiar authentic environment.

Second, students shared their text annotations and recorded files with peers. In this way, students could read peers annotations and listen to peers' recorded files (i.e., usually to those who study hard and perform well) to get inspirational ideas to complete their own assignments or to learn how peers accomplished assignments so as to improve their own homework. Students could exchange meaningful comments through sharing. That is, some students gave reflective comments and suggestions to a peer who had not completed the homework correctly. Students' comments were reported to be useful for revising and improving homework. Students thought highly of the sharing mechanism of the system, as they were able to learn from others and use their new knowledge to locate and revise their own homework mistakes. Hwang et al. (2015) and Hwang et al. (2011) argue that, with multimedia aids, students access more diverse learning objects and this may increase the richness of their language experience. They further suggest that sharing multimedia learning content with others not only increases practice opportunities but engages students in EFL contexts and allows them to reflect more deeply on the learning content as well as enter into discussion and collaboration.

Third, students recorded instructor's lectures. If students forgot some particular parts of a lecture or they needed to listen to the instructor's pronunciation of the learning material, they could play and listen to the recorded lecture. This was particularly useful outside of the classroom when students could not consult their instructor and ask questions (Hwang et al., 2015).

Finally, students stated that the built-in dictionary was very handy when they needed to translate some unfamiliar vocabulary words when completing assignments outside of school or at home. In this case, a dictionary could help to translate these words. Moreover, with a dictionary, students could find multiple meaning of a word and see how it could be used in different contexts. Hulstijn and Laufer (2001) argue that the use of a dictionary positively affects vocabulary learning. Students look up target words in the dictionary during the reading session in order to find word meanings and to understand the main idea of the target texts. According to Hulstijn and Laufer (2001), students who read foreign language texts and use a dictionary understand the texts better and remember more word meanings.

In this study, students were asked to introduce and describe some learning objects (e.g., signs and rules in the convenience store of their local community) during the learning activity. The students in the experimental group in both experiments completed the assigned tasks better than those in the control group, suggesting that learning activities supported by the system facilitate students learning.

System usage

This section reports how many times experimental students used certain features provided by the learning system in the two experiments. The results are reported in Table 3. According to the table, students in both experiments used text annotation the most. Recorded audio is second, taking photos is third, listening to recorded lecture is fourth and recording lectures is the last in students' preference list of the system usage. Unfortunately, the system was not designed to record the number of students' reviews of peers' text annotations and their listening to peers' recorded audio. Therefore, the data related to reviewing peers' text annotations and listening to peers' recorded audio was not available for analysis. This limitation will be addressed in a future study.

Table 3. Usage of the system features in the experiments 1 and 2

#	Text annotation	Students recorded audio	Photo	Dictionary	Listen to recorded lecture	Recorded lecture	Review peers' text annotations	Listen to peers' recorded audios
Experiment 1	874	283	198	217	55	69	N/A	N/A
Experiment 2	552	259	294	154	89	34	N/A	N/A
Total	1426	542	492	371	144	103	N/A	N/A

This study used the data from Table 3 in a stepwise multiple regression analysis to predict post-test scores. This approach provides objective evidence of the system's functions that are most beneficial for learning achievement.

From Experiment 1 data analysis it was found that at step 1 of the analysis, text annotation was entered into the regression equation, and was significantly related to the post-test scores, $F(1, 29) = 7.926$, $p = 0.009$. The multiple correlation coefficient was 0.463, indicating approximately 21.5 percent of the variance of the post-test scores can be accounted for by text annotation. Experiment 2's data analysis shows similar results; at step 1 of the analysis, text annotation was entered into the regression equation and was found to be significantly related to the post-test scores, $F(1, 26) = 7.762$, $p = 0.009$. The multiple correlation coefficient was 0.460, indicating approximately 21.1 percent of the variance of post-test scores can be accounted for by text annotation. Other variables did not enter into the equation at step 2 of either experiments' data analysis. A hierarchical multiple regression analysis was run to determine the incremental predictive value of text annotation. In this analysis, students' prior knowledge was added in a first step and the system usage variables in a second. A hierarchical multiple regression analysis demonstrated similar results. That is, text annotation statistically significantly predicted post-test scores in both experiments.

The reason that text annotation was found to be a strong predictive variable may be because students put more effort into creating text annotations and these annotations are easier to modify than other media. For example, the first thing students have to do to complete their tasks is to draft their descriptions of learning objects in text annotations. Students must think thoroughly of how to describe learning objects when drafting their ideas in text annotations, then revise when they get new ideas or inspiration and use these to improve their annotation. Finally, when text annotations are complete, students record their descriptions. Similar finding was reported in other related studies. For example, Hwang et al. (2011) found that only text annotations can significantly predict students learning achievement in Mathematics because text annotations play more important role to learning achievement than any other types of annotations.

The difference of cognitive load

This study also examined how the designed learning activities supported by the technology system affects cognitive overload during student learning. To accomplish this, the cognitive load of the experimental and control students was measured and then compared by employing an independent samples test. The means and standard deviation from the assessment with respect to seven items on the questionnaire and the results of the *t*-test are presented in Table 4. According to the results recorded in the table, the control group students had a higher cognitive load than the experimental group students.

Table 4. Results of cognitive load assessment and t-test for the experiment 1 and experiment 2

#	Control		Experimental		*t*	Sig. 2-tailed	*MD*
Experiment 1	2.05	0.85	1.56	0.44	2.807	0.008	0.495
Experiment 2	2.27	0.83	1.62	0.64	3.325	0.002	0.651

This study also explores the changes in the cognitive load of the two groups of students when engaged in different pedagogical approaches (learning activities both with and without technological support). For example, group A was the control group in Experiment 1 and used traditional methods to complete the tasks; then, it became the experimental group in Experiment 2 and used technological support to complete the tasks. In contrast, group B was the experimental group in experiment 1 and the control group in Experiment 2. So this study investigated how students' cognitive load changes when the language engagement method is changed. A dependent samples test was employed for this analysis. The means and standard deviation from the assessment and results of the analysis are presented in Table 5. The results show significant differences in students' cognitive load when engaged in the two different approaches. Compared to the control students, those who were in the experimental groups had lower cognitive load.

One reason that may explain these two findings is the nature of the learning materials and activities for the two groups. In this study, the learning materials and activities of the control and experimental students were identical apart from that the learning materials for the experimental students were in electronic form, enabling them to take advantage of the system's functions, (1) Annotating, (2) Recording, (3) Assistance, and (4) Sharing, to complete learning tasks.

Table 5. Results of cognitive load assessment and t-test for the group 1 and group 2 in the experiment #1 and #2

#	Control		Experimental		*t*	Sig. 2-tailed	MD
	M	SD	M	SD			
Group A*	2.02	0.85	1.62	0.64	3.167	0.004	0.402
Group B**	2.27	0.83	1.57	0.44	5.390	0.000	0.700

Note. *this group was the control group in the Experiment 1 and it was the experimental group in the Experiment 2; **this group was the control group in the Experiment 2 and it was the experimental group in the Experiment 1.

Related literature suggests that the intrinsic load lies in the nature of the learning material, learners' expertise and an interaction between them (Brunken et al., 2003; Sweller et al., 1998). It has been argued that intrinsic load represents the amount of different types of information that students need to consider in the process of acquiring new knowledge, i.e., how much information the working memory needs to deal with at the same time (Mayer & Moreno, 2003; Plaas et al., 2003). Hwang et al. (2013) argues that intrinsic cognitive load can be affected by the instructional or learning material. He also suggests that students will be cognitively overloaded if the materials are poorly structured, difficult to read, or too complex. In interviews, students in the experimental group mentioned that the system functions seemed to keep the intrinsic load from becoming too heavy when learning with the electronic textbook. Students could annotate important parts of the learning material (e.g., key concepts) by adding textual and multimedia explanation (e.g., a concept meaning and examples of its application in various contexts). Afterwards, these annotations helped students to find important concepts easily, to recall them, and to complete homework or to prepare for exams. It is important to note that the learning material and relevant annotations (i.e., text, photo, and audio) were presented on the same screen. Students anchored their annotations to learning materials which built a connection between them and gave students a clear picture of the whole learning scenario with an appropriate explanation of it. Mayer and Moreno (2003) call this form of presentation an integrated presentation, one which enables learners to focus more on essential information processing. Apart from learning from the electronic textbooks, students can also learn from peers' annotations. Studying shared annotations, including photos, texts, and audio, helps students to enhance their understanding of the learning material, gives students new ideas and inspiration, and improves their own homework. Students can also get assistance from the system using the Dictionary to find the definition and learn the correct pronunciation of unfamiliar vocabulary. If students need to recall some important concepts taught by the instructor in previous classes, they can listen to recorded lectures.

It has been suggested that extraneous load can be caused by improper instructional design. Thus, in order to reduce extraneous load, instructors need to organize, present and carry out learning information and activities appropriately. In this study, functions of the system helped to reduce the extraneous load when students participated in learning activities. Experimental group students claimed during interviews that when they exposed themselves to the authentic learning environment outside of the school, taking pictures of learning objects and describing them with text or voice annotations, helped them gather their thoughts and then transform them into artefacts, i.e., distributing cognition (Hollan et al., 2000). Lu, Lai, and Law (2010) argue that technology plays an important role in handling intellectual tasks by easing the individual's cognitive load. Later, when students are at home, they will be in a more tranquil environment in which to study created artefacts (i.e., pictures and their textual and audio descriptions). These artefacts help students to easily recall details of the learning objects from the authentic learning environment, to find out what they missed while completing the tasks, and what else can be improved in their homework. Without this system, students would need to hold a mental representation of the context in working memory over a period of time, which is called "representational holding" (Mayer & Moreno, 2003). In the interviews, experimental group students also claimed that, compared to traditional method, it is easier to participate in learning activities with electronic textbooks and using the system. Students also state that a familiar authentic environment helps them recall vocabulary; the context is related to students' background and previous experiences and is also highly relevant to learning tasks.

Related literature suggests that the germane load is determined by appropriate instructional design and can enhance learning. With the system's support, this study has attempted to direct students' attention to cognitive processes that are directly relevant to the target learning material and tasks. In interviews, experimental group students mentioned that the system functions enabled them to take pictures of learning objects in a familiar authentic environment and then describe them with textual and voice annotations. Students could review their textual descriptions or listen to the audio recorded files afterwards. Students state that completing the tasks in this way facilitated their learning and made it more interesting. Furthermore, students claim that learning in authentic familiar context and creating their own learning materials related to everyday life inspired them to become more engaged with the materials and inspired them to try to produce more meaningful output. Huang et al. (2011) recommends increasing students' interest in learning and engaging them in learning activities and tasks more by utilizing multimedia aids (e.g., pictures and audio). Similarly, Caldwell (1998) argues that multimedia objects in learning stimulate students' imagination and help them produce meaningful output. Some students, particularly those with lower ability, admit that in the way they learn with the system, they can communicate in the target language with less anxiety about making mistakes. In contrast to traditional learning, students using the experimental system learned with more confidence and their learning was more creative and enjoyable. In interviews, students confirmed that learning content and activities in the electronic textbook with a familiar authentic context were more interesting, fun, and engaging than when using the traditional method.

Based on the above-mentioned results and considering that students in both groups learned with the same learning materials and tasks, this study suggests that learning activities supported by the system enable students to have less cognitive load compared to traditional learning setting.

Conclusion

To address limitations of previous studies in this field, and to facilitate learning and manage cognitive load, learning activities in familiar authentic environment supported by a mobile learning technology were designed, after which two experiments were carried out to investigate how mobile technology support influences learning achievement and cognitive load. During this process, three main findings were made. First, the students using the experimental system outperformed the control students on post-test items in both experiments. Second, learning activities in a familiar authentic environment supported by the system enabled students to have a lower cognitive load compared to the learners without technological support. In addition, according to experimental group students' reports, multimedia tools helped them to utilize a familiar authentic context better. For example, students could unload some important information from familiar authentic context related to learning objects by using annotating and recording functions of the system. This important information did not necessarily need to be held in working memory over a period of time; it could be easily recalled later and help to build a stronger connection between learning content and targeted objects in familiar authentic context. As a result, the experimental group students' performance was better and their cognitive load lower. Finally, this study found that creating text annotations is very important learning behavior which predicts learning achievement.

Based on these findings, the authors recommend that educators employ appropriate learning activity designs and use a system which facilitates students' learning achievement and their cognitive load management. In designing learning activities, the instructor needs to consider how to make the best of the system to develop students' productive skills and manage their cognitive load. For example, in this study, students took photos of learning objects and described them orally and in writing. Photos and textual and audio descriptions were shared among students so that they could learn from each other and get some new ideas to improve their own homework. The system provided multiple channels for students to present their language output (i.e., taking pictures of learning objects and then describing them in written and oral ways) and gave students more opportunity to use the target language. Thus, instructors can organize learning activities in a way similar to the design used in this study. Furthermore, the instructor needs to encourage students to use the functions of the system, such as annotating, recording, assistance, and sharing, to reduce their cognitive load. In this way, students can efficiently study appropriate learning materials, complete the tasks, and enjoy the learning process at the same time. For example, students can take advantage of annotating to reflect on learning material and review reflections afterwards for better understanding of new concepts or for exam preparation. Students can also distribute their cognition to artifacts created in an authentic environment within a familiar context. Furthermore, the learning environment created by the system can reduce students' anxiety and help in giving meaningful output, especially for lower ability students. Finally, it is suggested that text annotations are beneficial for learning and therefore students should be encouraged to use them for learning more frequently. For example, if students use text annotations in a familiar authentic context to draft their descriptions of learning objects and later improve them before orally describing them, their performance can be positively affected.

There are several limitations in this study that need to be considered. The first limitation concerns the relatively small sample size. The second limitation relates to short-term exposure of the technology to aid learning. For this reason, these findings cannot be generalized to a broader community based on this study alone or they have limited relevance to learning scenarios in which the technology is used over a longer term when exposed in "real-world" conditions. These limitations will be addressed in a future study. In the future, our approach can be applied to other domains (e.g., Mathematics or Biology), and cognitive load can be measured objectively by observations of behavior or physiological conditions. A future study will also focus on how a familiar authentic context without mobile learning assistance can decrease cognitive load of students by comparing cognitive load of the control and experimental groups.

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Appendix 1

Test items examples

#	Content	Example	Max. score
8 items	Match English word with the correct Chinese meaning.	large 大的 fruit 水果 pork 豬肉	8
6 items	Write down the Chinese meaning of English word.	tomato ________________ bottle ________________ junk food ________________	12
10 items	Fill in the blank.	Tom: _____________ do you want, papaya or apple? Sandy: I want apple. (A.) What (B.) Where (C.) Which (D.) Why	20
5 items	Write down: a) a question based on a sentence; b) negative sentence from given one; c) translation of a sentence.	a) I want two bags of flour. (用 How much 改成問句) b) I'm heavy now. (用 before 代替 now 改寫) c) 昨□電影院有很多人，但今天沒有.	20
1 item	Write down.	Write here about yourself when you were at the first grade of the elementary school. Write here about yourself at the moment. Compare and write here the difference between when you were at elementary school and now.	40

Appendix 2

Cognitive load questionnaire

1. Learning these materials was easy.
2. Completing learning activities was easy.
3. Learning these materials did not require a lot of mental effort.
4. Completing learning activities did not require a lot of mental effort.