Cognitive Diffusion Model: Facilitating EFL Learning in an Authentic Environment

Rustam Shadiev, Wu-Yuin Hwang, Yueh-Min Huang, and Tzu-Yu Liu

Abstract—For this study, we designed learning activities in which students applied newly acquired knowledge to solve meaningful daily life problems in their local community – a real, familiar, and relevant environment for students. For example, students learned about signs and rules in class and then applied this new knowledge to create their own rules for a location in their community (e.g., playground rules that tell visitors what is or is not allowed to do in a local playground) to make it more environmentally friendly. To facilitate this, we developed a mobile learning system equipped with a dictionary as well as textual annotation, recording, and sharing functions. This mobile learning system enables students to take pictures of objects, describe them verbally or in writing, and share their work with peers. Our goal was to study the effectiveness of learning activities supported by a mobile learning system on the cognitive learning process by examining the changes in students' cognitive processes and the distribution of students who reach a certain level of cognition before and after learning. Fifty-seven junior high school students participated in the research, and their views of the mobile learning system and interest in continuing use were also explored. Students were divided into one control $(n = 26)$ group and one experimental $(n = 31)$ group. The control group completed learning activities using a traditional approach while the experimental group used a learning system installed in tablet PCs. The effectiveness of the mobile PC system on students' cognitive processes was tested by comparing the control and experimental groups' pre-test and post-test outcomes. Changes in students' cognitive processes were measured by calculating the differences in student scores among three tasks. The distribution of students who reached a certain level of cognition was derived based on their learning performance. Students' perceptions were evaluated using a questionnaire survey. The mobile learning system kept records of how students used it. Our results show that the experimental students significantly outperformed the control students on test items related to high cognitive levels. Students made clear cognitive progress from the second topic to the third one. Most students rated the learning system highly and want to use it in the future. Finally, the results show that creating text annotations is the best indicator of learning. Based on these results, we recommend applying appropriate learning activities supported by a mobile learning system to facilitate students' cognitive processes when they are studying English as a foreign language in an authentic environment.

Index Terms— Learning technologies, learning environments, tablet PCs, devices for learning

1 Introduction

A cognitive process is defined as a mental process by which knowledge is acquired and understood through thinking, experience, and the senses. Anderson and Krathwohl [1] argued that a cognitive process is different in terms of its complexity, and, thus, can be categorized from simple to more sophisticated. For example, when learning, some of us only obtain, store, and memorize knowledge while others transform and use it outside of its original context [45]. Therefore, one important issue the research and teaching community should consider is how to ensure that students engage in more complex cognitive processes. According to [21], cognitive processes can be promoted from simple to complex if students learn and apply new knowledge in a familiar authentic environment because that is where the knowledge will be used later in real life. Authenticity emphasizes meaningful learning in contexts that involve real-world problems [4]. A familiar environment involves relevant and predictable situations from students' background as well as previous experiences [41]. A familiar authentic environment creates advantages related to comprehension and application of new knowledge. For example, existing background knowledge of a familiar authentic environment is activated when learning takes place; thus the information-processing load related to contextual knowledge is reduced.

Related literature suggests that students can be situated in an authentic environment and learn using mobile technology [18], [36], [40], [44]. For example, mobile multimedia tools (e.g., cameras, text editors, voice recorders, etc.) enable students to observe and capture real objects for learning from daily-life situations. Several recent studies have looked at facilitating learning by using such approaches [8], [11], [15], [17], [30]. However, our literature review reveals two failings in the previous research on this topic. First, studies of mobile-assisted learning have not paid much attention to cognitive processes. Particularly, little is known about how to cross the gap between simple and complex cognitive levels in a mobile-assisted learning environment. Although

- *R. Shadiev is with the School of Education Science, Nanjing Normal University, No. 122, Ninghai Road, Nanjing 210097, Jiangsu Province, China. E-mail: rustamsh@gmail.com.*
- *Y.M. Huang is with the Department of Engineering Science, National Cheng Kung University, No. 1, University Road, Tainan 70101, Taiwan. E-mail: huang@mail.ncku.edu.tw.*
- *W.Y. Hwang is with the Graduate Institute of Network Learning Technology, National Central University, No. 300, Jhongda Rd., Jhongli 32001, Taiwan. E-mail: wyhwang@cc.ncu.edu.tw.*
- *T.Y. Liu is with Bei-Zheng Junior High School, No. 14, Ln. 2, Sec. 3, ZhiNan Rd., Taipei 11605, Taiwan. E-mail: sixfish1018@googlemail.com.*

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[21] discussed crossing the gap between levels of cognitive mastery, they did not provide any empirical evidence. Second, familiar contexts in authentic environments have not been considered in most related studies. An authentic learning environment has been created in a classroom [11], [17], [30] or outside [8], [15]; however it was virtually authentic and not actually familiar to the participating students. In this study, we attempt to address these limitations. First, we designed learning activities that focus on both knowledge acquisition and its application in a familiar, authentic environment. Students learn in class and then apply their new knowledge outside of school to solve real-life problems. For example, after students covered a topic about signs and rules, they created rules for one place in their local community to make it more environmentally friendly. Second, a mobile learning system was developed to support learning activities. Students were required to take pictures of objects (e.g., a place that is not environmentally friendly) and describe them using text and audio annotations (e.g., why it is not environmentally friendly and what rules could be applied to make it so). We aimed to test the benefits of this approach for learning. Changes in students' cognitive processes and the distribution of students who reached a certain level of cognition with respect to different learning periods were also investigated.

2 Literature Review

2.1 Cognitive Process in Language Learning

Researchers have posited a variety of theories to explain how we learn language. For example, the *input hypothesis* [12], [31], [41] suggests that input from listening and reading plays an important role in second/foreign language acquisition. According to this hypothesis, language acquisition occurs when learners receive a sufficient amount of comprehensible input. However, in order to progress with their language development, this comprehensible input should be slightly more advanced than their current level, represented as "i + 1" ("i" is the current language ability and "+1" is the next level of acquisition). This hypothesis highlights the importance of exposing learners to as much of the target language as possible, from teachers, peers, etc. The *affective filter hypothesis* [31] attempts to explain why some learners are able to learn a second language while others are not. This hypothesis accounts for the influence of affective factors such as motivation, self-confidence, and anxiety when receiving input. That is, motivated, confident learners with low anxiety have low filters that enable input to reach the language acquisition part of the brain, thus enabling language acquisition to take place. On the other hand, unmotivated and non-confident learners with high anxiety have high filters that prevent the input from being absorbed and processed. Therefore, it is important that educators create stress-free and welcoming learning environments in which students feel comfortable making mistakes and taking risks. The *output hypothesis* [12], [41], [42] argues for the importance of language output, such as speaking and writing, in the learning process. [42] suggested three main functions of output: (1) *noticing function* - learners notice their errors and linguistic shortcomings while producing the target language, (2) *hypothesis-testing function* - when a learner produces output, he/she tries out the target language to test various hypotheses underlying this output and receives feedback that enables this learner to re-produce output and re-test a hypothesis, and (3) *metalinguistic function* - learners reflect upon their output (i.e., spoken or written), which is helpful for language development. According to [13], both language input and output are essential elements for foreign language acquisition, and a balance should be kept between them.

Working more on the output hypothesis, [10] argued that communicative ability is an important factor in language acquisition and suggested that more focus should be given to it. This has led to new teaching methods being proposed, such as the communicative teaching method [7], which is based on the idea that learning a language successfully lies in knowing not only the structure and forms of a language, but also its function and purposes. This approach emphasizes meaning-based communication rather than the practice of isolated grammatical forms [32]. That is, when students are involved in real communication, their natural strategies for language acquisition will be used, and this allows them to learn how to use the language [7]. Therefore, to facilitate communicative abilities, [13] recommended that instructors design learning tasks in which students must use language as a vehicle for actual communication. Furthermore, the situation in which the language is used needs to be realistic. That is, all words and sentences must grow out of some real situation, and the meanings of words should be tied to the situations in which they are used. One important theory related to communication in second/foreign language is communicative competence. Hymes [23] defined *communicative competence* as the ability to convey and interpret messages and to negotiate meanings interpersonally within specific contexts. Canale [6] defined communicative competence in terms of four components: (1) grammatical competence – knowledge of lexical items and rules of morphology, syntax, sentence-grammar semantics, and phonology; (2) discourse competence - the ability to connect sentences of discourse, i.e., spoken conversation or written texts in which a meaningful whole is formed out of series of utterances, (3) sociolinguistic competence - knowledge of the sociocultural rules of language and discourse, and (4) strategic competence - the verbal and nonverbal communication strategies that may be called into action to compensate for breakdowns in communication due to performance variables or insufficient competence. Bachman [2] divided communicative competence into broad headings called "organizational competences," which include grammatical and discourse (or textual) competence, and "pragmatic competence," which includes sociolinguistic and illocutionary (i.e., pertaining to sending and receiving intended meanings) competence. Strategic competence was also included, but it was included as a completely separate construct.

Various explanations of cognitive processes can also be found in the literature. *Language comprehension* is the process of making sense of written or spoken information, i.e., understanding what others write and say [14], [41]. Language comprehension is a complex process because it involves a variety of different abilities, skills, processes, knowledge, and dispositions that are used to derive meaning from written or spoken information, for example, decoding skills (i.e., knowledge of the alphabet and its sounds), word knowledge (i.e., knowing the meaning of words), linguistic knowledge (i.e., the formal structures of a language), and so on. The combination of these allows making inferences about language and successfully comprehending it. The *production process* of spoken or written language is very complex because it involves different functions [27], [41]. For example, production starts with deciding what needs to be expressed, generating ideas, and organizing them in a coherent order. Then, appropriate words are selected and organized into relevant grammatical forms. After that, the resulting sounds are articulated into speech by the motor system using the vocal apparatus. Finally, produced language is analyzed against errors and corrected.

The abovementioned cognitive theories inform this study. That is, the learning activities we designed are based on these theories, and they are used to explain our research findings.

2.2 Practice in Authentic Environment

Hwang et al. [19] asserted that real-world and life-related scenarios are directly related to language acquisition. If they are correct, an authentic context is one important prerequisite for effective learning [29] due to the following critical characteristics [19]: (1) it provides contexts that reflect the way in which the knowledge will be used in real life; (2) it provides activities that have real-world relevance; (3) it creates an opportunity for learners to share learning experiences and enables learners with various levels of expertise to practice; (4) it promotes reflection, and (5) it offers authentic within-task learning assessment. When students learn in an authentic environment, they are more inclined to learn. Related studies suggest that a familiar, authentic environment is beneficial for learning [21]. This claim is based on cultural schema theory [34], which explains the familiar and pre-acquainted knowledge one uses when entering a familiar environment. According to this theory, all knowledge of past experiences is organized into schemata. Nishida [34] argued that when we acquire and retain information from our environment, cultural schemata are created and stored in our brain. The environment becomes familiar after we enter it many times. Stored schemata then guide our behavior and help us predict what is to be expected and looked for in a familiar environment.

Practice is one important component of learning; it involves using skills repeatedly and regularly in order to improve and master them. Thus, practice plays a vital role in enhancing learning performance [16] because it represents a necessary and productive stage in the transfer from classroom learning to the real world. One instructional approach that can potentially facilitate language practice is storytelling [33]. Guha et al. [26] defined storytelling as a highly-effective instructional method that surrounds students with the target language and enables them to communicate intentionally by using narrative sentences. Huffaker [16] and [26] claimed that storytelling promotes verbal skills and supports literacy development. Through storytelling, students interact, associate with each other in the target language, negotiate meanings, learn from each other, and share experiences. Various storytelling learning activities have been proposed in the English as a foreign language learning (EFL) literature. Of particular interest to this study are those in which students tell stories through introducing, describing, and explaining some particular objects. For example, in other related studies, students introduced a lunch menu from their school cafeteria [19] or described changes in their rooms before and after cleaning [39].

Related studies have informed the design of our learning activities. First, activities were carried out in an authentic environment. Second, students were given real-life-related tasks to introduce, describe, and explain some particular objects in their school community.

2.3 Mobile Assisted Language Learning

According to [8], mobile technology can offer a seamless language learning experience (i.e., anytime and anywhere). Huang et al. [15] and [43] suggested that mobile technology can aid learning both in and outside of the classroom. Therefore, through the use of this technology, access to learning activities and engagement in learning tasks is increased [37]. Mobile technology has a great potential to assist learning in an authentic environment. For example, the mobility of modern technology allows students to visit places with real objects and daily-life situations appropriate for learning.

Related studies have emphasized the idea of using mobile technology to situate students in authentic environments so that they can link newly acquired knowledge to daily life experiences [18], [36], [40], [44]. Hwang et al. [18] listed several potential criteria of mobile technology for learning in authentic contexts. For example, mobile technology is able to sense the learner's situation or the situation of the real-world environment in which the learner is located and to offer more adaptive and personalized support to the learners in the right way, in the right place, and at the right time based on the personal and environmental contexts, as well as the profile and learning portfolio of the learner. Mobile technology enables seamless learning; that is learning services will not be interrupted when the learner is moving from place to place, and the environment is changing. Ogata et al. [36] highlighted the main characteristics of mobile learning in authentic environments. They are permanency (all learning processes are recorded continuously), accessibility (learners have access to their materials from any location), immediacy (information can be obtained immediately), interactivity (learners can interact with experts, teachers or peers), and situating instructional activities (the learning is embedded in daily life). Wong and Looi [44] derived the following features that characterize mobile learning in authentic contexts: encompassing formal and informal learning; encompassing personalized and social learning; across time; across locations; ubiquitous knowledge access; encompassing physical and digital worlds; combined use of multiple device types; seamless switching between multiple learning tasks; knowledge synthesis; and encompassing multiple pedagogical or learning activity models.

Mobile multimedia tools such as cameras, text editors, or voice recorders are useful for learning in authentic contexts. For example, these tools enable students to observe and capture objects as well as to create related learning content, e.g., descriptions of objects [24]. By doing so, students are actually engaged in language learning. Interaction with real objects stimulates their imagination, helps to bring out meaningful output, and enables repeated and regular practice in the target language [5]. Hwang et al. [19] focused on improving elementary school students' EFL writing skills by having them take pictures of specific objects and describe them using a dictionary. Shadiev et al. [39] aimed at improving EFL students' learning achievement and reducing their cognitive load. Students in their study practiced EFL skills by reading their textbooks aloud, taking pictures of objects from daily life, and orally introducing them to their peers. In this project, students recorded all of their speeches. Shadiev et al. [39] claimed that sharing homework with peers allows deeper reflection, discussion and more collaboration. Therefore, students listened to recordings of their peers when studying. Hwang et al. [19] argued that authentic context decreases students' communication anxiety; students who learn in an authentic environment can give more detailed descriptions of objects using new vocabulary and sentences. According to [43], a mobile learning environment increases students' learning motivation while giving them more opportunities to communicate with each other and negotiate meaning in the target language.

Related studies have informed the design of our mobile learning system. That is, our system features a dictionary and such functions as textual annotation, recording, and sharing to facilitate language learning. Using our system, students are able to take pictures of objects and create both written and verbal content. In addition, students are able to share their created content with their peers.

2.4 EFL Learning with Tablet PCs

Mobile technology, such as tablet PCs, has been widely used in different EFL learning contexts. For example, [11] introduced traditional (i.e., paper-based) and technological (i.e., tablet PC-based) approaches during English reading class. The results indicated that students score similarly when using different approaches. Hung et al. [17] employed a mobile learning system to improve students' English proficiency. The results of their experiment showed that the system led to better interaction between students, and it also enhanced their learning achievement. Kim and Kim [30] applied a learning system for elementary school students to learn English vocabulary with visual aids and found that the system was effective for vocabulary acquisition: students who used it showed significant learning improvement. Students say the system helps them rapidly look up new vocabulary and reinforces known vocabulary. More recent studies have focused on employing tablet PCs both in the classroom and outside of the classroom. Hwang et al. [20] developed an electronic reader system to assist elementary school students' EFL reading comprehension. The study's results revealed that high-achieving students performed significantly better than those who were low-achieving. However, low-achieving students expressed their willingness to use the system in the future while high-achieving students did not. Huang et al. [15] created a mobile learning system for elementary school English learners. This system detects students' locations and provides appropriate English learning content (i.e., videos and audios) for contextual learning. Huang et al. [15] found the system to be beneficial and meaningful. Chen [8] carried out a study in which students use tablet PCs to learn English in informal settings. Their results showed that tablet PCs are ideal tools for creating an interactive, collaborative, and ubiquitous environment for language learning.

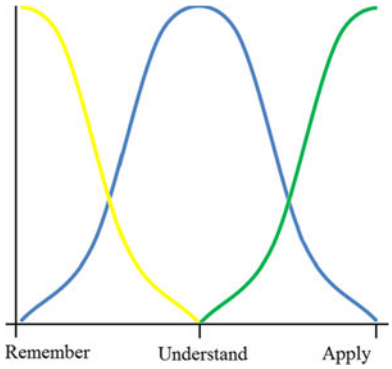

Fig. 1. Distribution of students who reached a certain level of cognition during different learning periods: pre-instruction (yellow curve), post-instruction (blue curve), and high cognitive process (green curve) [21].

Our literature review reveals that familiar contexts, which can be found in an authentic environment, have not been considered in most related studies. Authentic learning environments have been created in some classrooms [11], [17], [30] or outdoors [8], [15], however, they were merely "virtually" authentic and not really familiar to students.

3 Cognitive Diffusion Model

A taxonomy for learning, teaching, and assessing [1] is a revised version of Bloom's taxonomy [3]. Teachers who apply this taxonomy can monitor, assess, and understand students' cognitive processes. The taxonomy consists of six levels that increase in complexity as the learner moves through them [1]. The first three levels of the taxonomy are: (1) *Remember* – Retrieve relevant knowledge from long-term memory; (2) *Understand* – Construct meaning from instructional messages, including oral, written, and graphic communication; (3) *Apply* – Carry out or use a procedure in a given situation.

Hwang and Shadiev [21] proposed a Cognitive Diffusion Model. This model is shown in Fig. 1: the x-axis shows cognitive levels; the y-axis demonstrates a number of students who reach a certain level of cognition as the highest, and curves of different colors represent different learning periods (pre-instruction – yellow curve, post-instruction – blue curve, and high cognitive processes – green curve). Pre-instruction is a learning period before students are taught some knowledge at school; post-instruction refers to the period after students acquire some knowledge and then carry out related exercises at school. High cognitive process refers to a period when students acquire some knowledge and apply it to solve daily life problems. According to this model, some students are differently distributed into different levels, i.e., Remember, Understand, and Apply. The distribution changes as learning develops, such as before school (i.e., pre-instruction), after school (post-instruction), and when new knowledge is applied to solve daily life problems (i.e., high cognitive process period). The model defines the higher number of students to be those with a low level of cognition before instruction (i.e., pre-instruction). That is, most students have prior knowledge that some remember, and some do not, while only a small number of students can understand specific information. After students are taught something and then carry out related exercises (i.e., post-instruction), their cognitive process develops and becomes more complex. That is, after instruction, most students both remember knowledge taught at school and understand it. However, only a few students can apply learned knowledge in real-life situations. To better explain this model, [21] provided two examples related to EFL and math learning. With respect to EFL learning, they argued that upper grade elementary school students in Taiwan know English words, including their spelling and pronunciation; however, few are able to apply these words in real-life situations, such as in a conversation. Similarly, some students understand math and geometry concepts and operations and can use them to solve test problems; however, few can apply newly acquired knowledge to real-life situations.

According to this model, a chasm exists between the lowest (e.g., Understand) and the highest (i.e., at least Apply) cognitive levels. "Crossing the chasm" occurs when students' cognitive level is promoted from the lowest to the highest one. If the chasm is crossed, then students not only understand the knowledge but can apply it to daily life problems. It is very important for educators to help students cross this chasm. However, in traditional paper and pencil pedagogy, "crossing the chasm" is unlikely [21]. Therefore, curriculum design should be changed. First, the curriculum should not focus on exams, but rather on the practical application of knowledge. Second, students should also learn outside of school by applying new knowledge to meaningful, real-life problems.

Since this study focuses on EFL learning, we have attempted to match the cognitive levels of the revised taxonomy [1] with the cognitive processes of EFL learning. The "Remember" level is the lowest level and merely means what has been learned can be remembered and identified. The "Understand" level can be matched to "comprehension" while "Apply" can be matched to "production" of spoken or written language. In addition, we adopted Anderson and Krathwohl's taxonomy [1] for assessing students' cognitive levels.

After reviewing the related literature, we found that previous studies on mobile-assisted language learning have neglected the cognitive processes that occur during learning. Particularly, little is known about how to cross the gap between simple and complex cognitive levels. Although, [21] proposed the Cognitive Diffusion Model along with guidelines for the model, it has not been tested, and no empirical evidence was provided.

4 Research Questions

We have attempted to address the limitations in the above-mentioned studies. To this end, we designed learning activities that focus on knowledge acquisition and its application, developed a mobile learning system to assist students' EFL learning, and tested the feasibility of our programs. Changes in students' cognitive levels during learning activities and the distribution of students who reached a certain level of cognition with respect to different learning periods were also investigated. Finally, we evaluated students' attitudes toward the learning system and interest in using it in the future. The following research questions were addressed in this study: 1. Do students who participate in EFL learning activities supported by a mobile learning system perform significantly better than those who do these activities without technological support? 2. Are there any changes in students' cognitive processes with respect to different EFL learning topics? 3. What is the distribution of students who reached a certain level of cognition with respect to different EFL learning periods? 4. What are students' perceptions and behavioral intentions towards this mobile EFL learning system? 5. What learning behaviors occur during use of a mobile learning system, and what is their importance for learning?

5 Methods

A quasi-experimental design was applied in this study by adopting a nonequivalent control group method. The effectiveness of applying learning activities supported by a mobile learning system on students' cognitive processes was tested by comparing the pre-test and post-test outcomes of the control and experimental groups.

5.1 Participants and Experimental Procedure

A total of 57 junior high school students from northern Taiwan participated in this study. One class with 26 students served as the control group, and another class with 31 students served as the experimental group. Most students in both groups were thirteen years old with four to six years' experience with using computers (Table 1) and one to three years' experience with using tablet PCs. All of the students had had five years of EFL: three years in elementary school and two years in junior high school. Their previous EFL curriculum had emphasized communicative abilities in elementary school and reading, writing, and communicative abilities in junior high school.

The experimental procedure is presented in Fig. 2. We gave a pre-test on the first day of the experiment, after which both classes received the same number of hours of English instruction: one-hour lessons three times a week for seven weeks. After the lessons, students participated in learning activities. Both groups had the same curriculum and were given equal practice opportunities. Outside of school, however, we cannot say how much time the two groups spent on their work, as they had no time limits for completing their tasks. The key difference between the two groups is that the control group completed learning activities using a traditional approach while the experiment group used a mobile learning system installed in tablet PCs. Learning activities included three tasks to be completed within two weeks. At the beginning of the experiment, each experimental student received a tablet PC and was instructed how to use it. The post-test, questionnaire, and interview surveys took place during the last class.

5.2 EFL Learning Activities

Learning activities were designed based on a task-based approach [29], [35]. This approach is student-centered and emphasizes using language for meaningful tasks. Learning activities were focused on 1) learning basic knowledge and concepts and 2) their application to solve real-life problems. Knowledge application was linked to situational and authentic environments outside of school.

Students in Taiwan typically learn English through memorization and paper-based exercises, not through "using" the language, which is what this experiment aims for: giving students a real opportunity to write and speak English.

TABLE 1
Participants' Profile

Category	Control group (n = 26)		Experimental group (n = 31)	
	Frequency	Percentage	Frequency	Percentage
Gender				
Male	15	57.69	17	54.84
F emale	11	42.31	14	45.16
Age (years)				
12	9	34.62	12	38.71
13	17	65.38	17	54.84
14	0	0	2	6.45
Experience to use computer (vears)				
1-3	1	3.85	4	12.90
4-6	18	69.23	20	64.52
7 and more	7	26.92	7	22.58
Experience to use tablet PC (years)				
less than 1	6	23.08	10	32.26
1 to 3	16	61.54	18	58.06
more than 3	4	15.38	3	9.68

Before the experiment, students may not have known how to apply what they have learned, but through the experiment, we expect they will learn to use the language and even extend their newly learned skills to other tasks.

Three topics from the textbook were chosen: 1) "Where Are You From?" 2) "Your School Is Very Big," and 3) "Be Quiet and Sit Down, Please." Three learning activities were organized, one around each of the three learning tasks.

Task 1: VIP in your heart. In this task, each student is asked to take a photo of a person who is very important in his/her life, such as a teacher or close friend. Students then were asked to introduce the person and tell why s/he means a lot to them, using 6-10 sentences.

Task 2: What does s/he look like? Each student is provided with a picture of a man and a woman whom they must describe using adjectives from their textbook. *What do your*

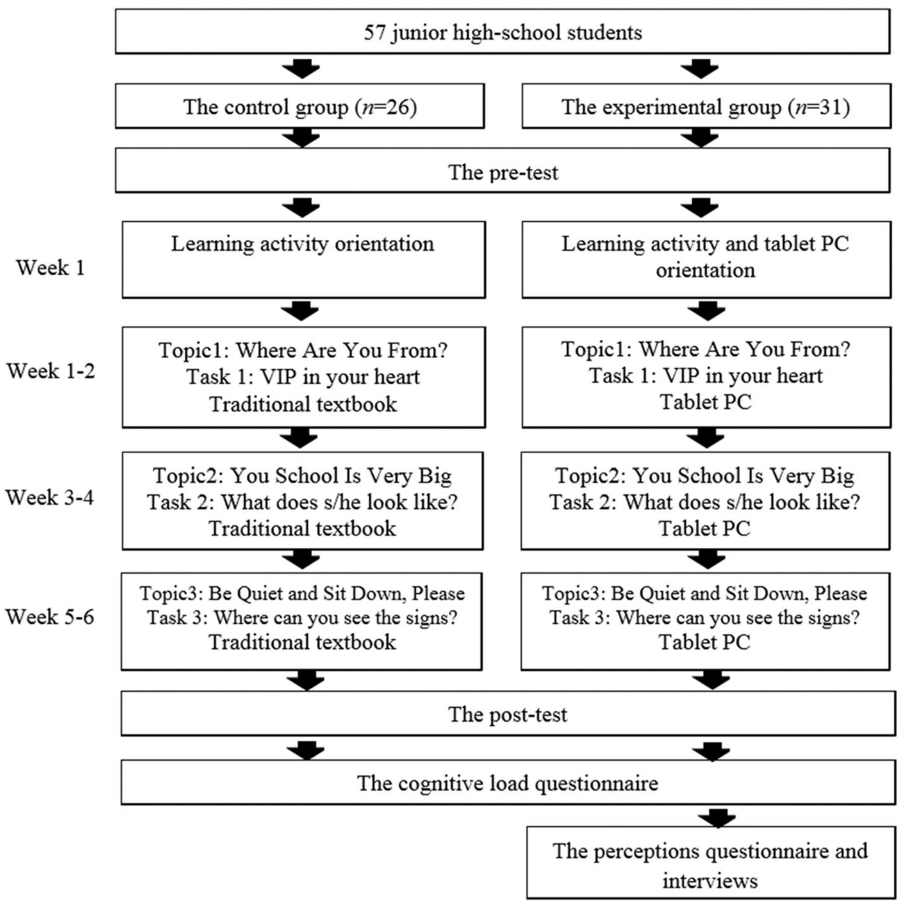

Fig. 2. Experimental procedure of the study.

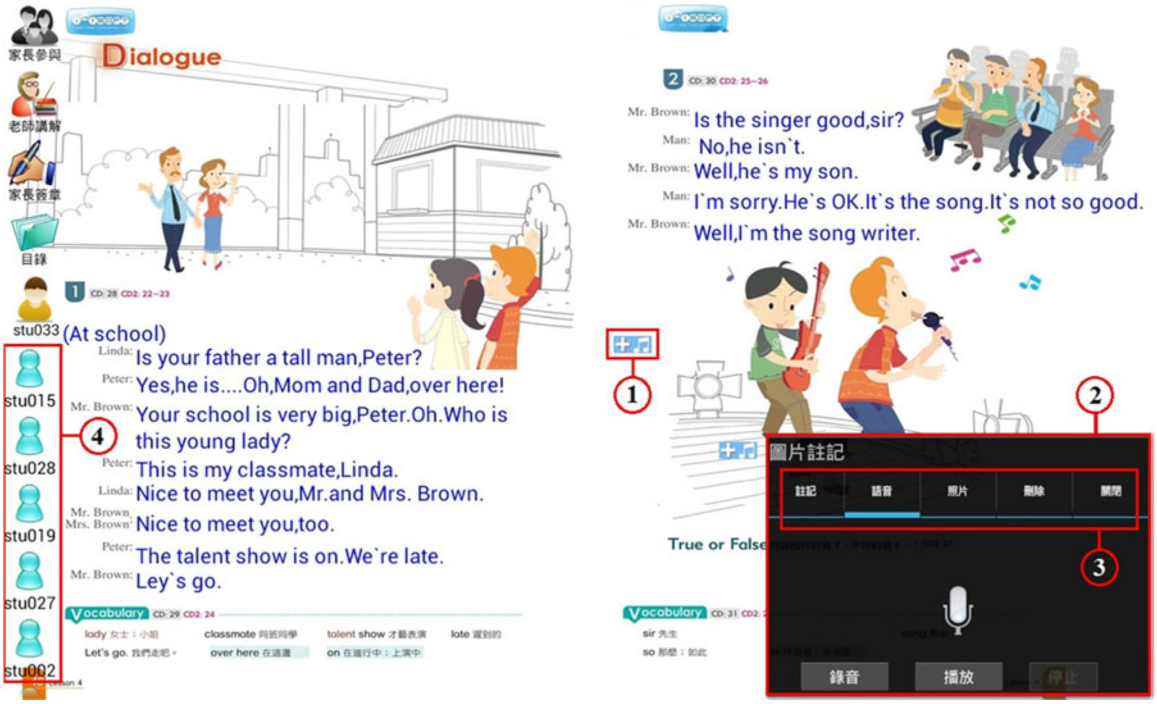

Fig. 3. The system interface: 1) An annotation with audio content. 2) Annotation tool. 3) Functions of annotation tool (from left to right): a. text annotation, b. voice recording, c. picture, d. delete, and e. exit. 4) Sharing function.

parents and siblings look like? In this task students use 6-10 sentences to describe a photo of their parents and siblings.

Task 3: Where can you see the signs? Each student is given four signs (e.g., "Don't swim here") and asked to explain where s/he might encounter them. *Find a place in the local community to set your own rules.* In this task, students take a photo of a place, including any signs that are there. Then, students are asked to create their own rules (at least five) for that place.

Students learned new vocabulary and grammar related to introducing someone (e.g., "year/s old..." or "where... from?") in Topic 1, describing a person (e.g., "young" or "tall") in Topic 2, and rules about what is or is not allowed to do (e.g., "trash" or "take it with you"), in Topic 3. The three tasks are aligned and integrated with three textbook topics. In addition, the tasks match the students' level of difficulty using overlapping vocabulary and sentence patterns.

We define familiar authentic learning in the context of this study as learning in a familiar authentic environment. Authenticity emphasizes meaningful learning in contexts that involve real-world problems, and a familiar environment involves relevant and predictable situations from students' background and previous experiences.

5.3 Mobile Learning System

A mobile learning system was developed using Apache, PHP, and MYSQL, and installed on Asus Transformer Pads. The client platform runs on Android and a Linux-based open source operating system, and the server platform runs on a Windows Server 2003. The system features the following four main functions (Fig. 3): (1) *textual annotation* – students can annotate important parts of learning material on tablet PCs with text; textual annotation also enables students to take pictures and add to their text annotations; (2) *recording* – students can record their own voices and listen to recorded audio afterwards; in addition, students can record lectures made by the teacher; (3) *dictionary* – students can get a list of words in alphabetical order with their meanings and translations; (4) *sharing* – students can share their own annotations and recorded audio with peers. For example, Fig. 3 shows dialogue related to Topic 2, which students read. Students recorded their voices while reading. Fig. 4 shows a screenshot of the third task (i.e., the first part). Students created textual annotations with their responses and recoded their oral responses as well. When a student clicks on a textual annotation, a window pops up showing content of a textual annotation.

Related studies suggest that completing learning tasks in a familiar authentic environment using technology is more complex and imposes a high cognitive load on students because (1) students need to simultaneously interact with the real-world learning objects, learning content, and technology, and (2) students have insufficient experience with using technology [9], [22], [39]. We considered these issues when designing our learning activities. First, students practiced knowledge application in the classroom before going to an authentic environment. Second, we ensured beforehand that all the students knew what they needed to do and how to do it during the learning activity; the instructor provided scaffolding and guidance to students when it was necessary. Finally, we taught students to use a tablet PC. This preparation helped students to have more meaningful learning in a familiar authentic context with and without technology.

The control group completed the same activities using textbooks. They took notes in their traditional notebooks and shared their notes with others. They were also invited to take pictures of objects and record their voices or the instructor's lectures.

Fig. 4. A screenshot of the third task: 1) A textual annotation. 2) An annotation with audio content. 3) Content of an textual annotation.

5.4 Research Tools

A pre-test was conducted to evaluate the students' prior cognitive levels and a post-test was conducted to measure their cognitive levels after the learning activities. The tests were designed by an experienced junior high school teacher based on the learning material covered in this study. Thirty items were included in both tests. The test items and related examples from the pre-test and post-test are presented in Table 2. The items for both tests were similar in structure but different in content. In addition, the items were of the same difficulty level. For example, students are asked to match "young" in the pre-test and "old" in the post-test with the correct Chinese meaning, or students were required to write down the Chinese meaning of "short" in the pre-test and "heavy" in the post-test. This study adopted Anderson and Krathwohl's taxonomy [1] for assessing students' cognitive levels, focusing on the first three levels, i.e., "Remember," "Understand," and "Apply." The "Remember" and "Understand" levels were divided into two sublevels based on item difficulty level in order to measure cognitive processes with better precision. Items 1-8 measured the "Remember1" level, and 9-14 measured the "Remember2" level. Students were asked to match English words with their correct meanings in Chinese in items 1-8 and to write down the Chinese meanings of English words in items 9-14. Therefore, the items for the "Remember1" level were easier than those for "Remember2." The same was true for the Understand level: items 15-24 measuring the "Understand1" level were easier than items 25-29 measuring the "Understand2" level. A correct answer to an item from 1 to 29 was scored as "1." The "Apply" level was measured by the last item (item 30). This item was an open ended question

TABLE 2
Test Items

#	Content	Level	Example Pre-test	Example Post-test	Max. score
1-8 (8 items)	Match English word with the correct Chinese meaning.	Remember	young - 年輕	old - 高的	8
9-14 (6 items)	Write down the Chinese meaning of English word.	Remember	short ___________ heavy ___________		6
15-24 (10 items)	Fill in the blank.	Understand	Is __________? A. that a boy tall B. that boy a tall C. that boy tall D. that tall a boy	Is Mr. Lin an ____? A. heavy box B. young lady C. old doctor D. ugly woman	10
25-29 (5 items)	Write down: a) a question based on a sentence; b) negative sentence from given one; c) translation of a sentence.	Understand	(a) My brother is ten years old. b) Please open your book. c) 那位可愛的男生是你的兒子嗎?	a) That tall and beautiful lady is my English teacher. (b) Let's go to the toy factory. (c) 人們來這裡是為了那有名的巧克力。	10
30 (1 item)	Describe your homeroom teacher.	Apply	Write down anything you know about your homeroom teacher.	Write down anything you know about your English teacher.	29

TABLE 3
Learning Behaviors to Use the System

Text annotation	Voice recording	Photo	Dictionary	Listen to recorded lectures	Recorded lectures	Review peers' text annotations	Listen to peers' recorded audios
874	283	198	217	55	69	N/A	N/A

with answers coded using a sentence as a coding unit and scored on a 29-point scale (with 29 as the highest score). The cognitive levels of the responses were also measured. For this, we collected students' completed tasks and then coded and scored them in the same way as their answers to item 30 of the test.

A questionnaire survey was conducted to evaluate students' perceptions and behavioral intentions towards the mobile learning system. The questionnaire survey was developed following general recommendations from related studies [19] and had four dimensions: *Perceived ease of the system use* (six items) - the degree to which a student believes that using the system would be free of physical and mental effort; *Perceived usefulness of the system during learning* (six items) - the degree to which a student believes that using the system for learning will enhance his or her learning performance; *Perceived satisfaction* (six items) – the degree to which a student is satisfied with the system for learning purpose; *Behavioral intention of using the system* (three items) – a major determinant of whether or not a student will continue to use the system.

One-on-one semi-structured interviews were conducted with ten students randomly selected from the experimental group. We aimed to explore participants' learning experiences with the system and gain insights into their perceptions toward its usefulness for learning. Each interview lasted for 20 minutes. Interviewees were asked the following open-ended questions: 1) "Please describe your learning experience with the system"; 2) "Was the system useful for learning? If yes, please explain why."

5.5 Data Analysis

Students' answers to the tests were scored by three raters. Notable differences in the assessment were resolved through raters' discussions until a consensus was achieved. The inter-rater reliability of the tests was evaluated by using Intra-class correlation coefficient (ICC). The average measured ICC was more than 0.900, indicating high reliability.

31 valid answer sheets to the questionnaire were obtained out of 31 experimental students. The students responded to the items using a five-point Likert scale, anchored by the end-points "strongly disagree" (1) and "strongly agree" (5). Cronbach's α values exceeded 0.80 in all dimensions, indicating the reliability of the questionnaire items.

With the students' permission, all interviews were audio-recorded and then fully transcribed for analysis. Three raters were involved in the interview data analysis. First, the raters examined the most distinctive responses and resolved big differences in the responses through discussion and by consensus. After that, the raters were engaged in the formal coding process. Raters coded the transcribed texts and categorized codes to produce a framework for reporting the research findings. The inter-rater reliability of interview data was evaluated using ICC; the average measured ICC was more than 0.900, indicating high reliability.

Using the pre-test as a covariate, we employed an analysis of covariance to test differences in cognitive processes between the control and experimental students on the post-test. We used one-way repeated measures ANOVA with a Greenhouse-Geisser correction to investigate the progress of the experimental students' cognitive processes on the three tasks.

6 Results and Discussion

6.1 Learning Behaviors to Use the System

Table 3 presents an overview of how many times the students used the system functions. According to the table, the students used the text annotation function the most. The recording function ranked second, the dictionary ranked third, and the photo function ranked fourth. The system was not designed to record "review peers' text annotations" or "listen to peers' recorded audio" data, so this data was unavailable for our analysis. This limitation will be addressed in a future study. We used learning behavior data in a stepwise multiple regression analysis to predict the post-test scores. This approach provides objective evidence of the system's most educationally beneficial functions. In step one, text annotation was entered into the regression equation, and we found it to be significantly related to the post-test scores, $F(1, 29) = 7.926$, $p < 0.05$. The multiple correlation coefficient was 0.463, indicating that approximately 21.5 percent of the variance in the post-test scores could be accounted for by text annotation. Other variables were not entered into the equation at step 2. We ran a hierarchical multiple regression analysis 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 were added in a second. A hierarchical multiple regression analysis demonstrated similar results. That is, text annotation statistically and significantly predicted post-test scores perhaps because students put more effort into creating text annotations and because these annotations were easier to modify than other media. For example, the first step in the students' task was to write descriptions of objects. Students had to think thoroughly of how to describe the objects when drafting their ideas and then had to revise and improve drafts when they had a new idea or inspiration. When the text annotations were complete, students recorded their voice descriptions.

6.2 The Effectiveness of the Learning Activities on Cognitive Process

The mean and standard deviation pretest and post-test values are presented in Table 4. According to the results, the differences between the control and experimental groups on the

TABLE 4
Results of the Pre-Test and Post-Test and Analysis of Covariance

Cognitive level (the tests items)	Groups	The pretest		The posttest		F	Sig.	Partial eta squared
		M	SD	M	SD			
Remember 1 (items 1-8)	Control	7.96	0.20	8.00	0.00	N/A	N/A	N/A
	Experimental	7.74	1.12	8.00	0.00			
Remember 2 (items 9-14)	Control	3.19	1.96	3.64	2.14	0.433	0.514	0.008
	Experimental	5.65	0.56	5.58	1.06			
Understand 1 (items 15-24)	Control	6.00	2.10	6.10	2.28	0.849	0.361	0.015
	Experimental	8.15	1.40	8.55	1.71			
Understand 2 (items 25-29)	Control	6.08	2.48	3.50	2.67	39.997	0.000	0.426
	Experimental	5.97	3.23	6.55	2.50			
Apply (item 30)	Control	6.86	4.80	8.28	5.27	8.484	0.005	0.128
	Experimental	7.62	6.93	12.47	8.84			

post-test items were related to low cognitive levels, such as where "Remember 1," "Remember 2," and "Understand 1," were not significant. That is, regardless of which learning method was employed (traditional vs technological), students scored the same on these test items. However, the experimental group ($M = 6.55$, $SD = 2.50$) outperformed the control group ($M = 3.50, SD = 2.67$) on the post-test items related to "Understand 2," $F(1, 54) = 39.997, p < 0.05$, partial eta-squared $= 0.426$. Finally, a significant difference was revealed between the control ($M = 8.28, SD = 5.27$) and experimental ($M = 12.47, SD = 8.84$) groups on the post-test item related to "Apply", $F(1, 54) = 8.484, p < 0.05$, partial eta-squared $=$ 0.128. "Understand 2" and "Apply" relate to the learning activities in which students learned new vocabulary, adjectives, prepositions and grammar. The students' responses demonstrated that they understood new information and were able to apply it to solve a problem through EFL production. According to the results, the experimental students did better than the control students, suggesting that the learning activities supported by the system promoted the experimental students' cognitive processes. That is, the experimental students understood sentence structure and how to change statements into questions or negative forms better than the control students. The experimental group students also seemed to be better at applying new knowledge to solve daily life problems. These results are perhaps due to the fact that the experimental students had more practice with these types of problems during the learning activities. In terms of EFL learning theories, our results suggest that the experimental students had better EFL comprehension and production than the control students.

Ample support for our findings was obtained from the interviews. The students mentioned that the learning activities could be completed more efficiently using the system. Furthermore, according to the students, their EFL comprehension and production was enhanced due to the functions of the technology, i.e., textual annotation, recording, dictionary, and sharing. Using textual annotation and recording functions, students took pictures of objects, described them in textual annotations and then recorded their own voices. They preferred to review textual descriptions and to listen to their own recordings afterwards. One reason for this was to monitor their own performance; if created content was not satisfactory (e.g., mispronouncing words, incorrect grammar, etc.), the students were able to make improvements. According to the students, this led to more frequent language practice as well as to better quality of language output. In addition, the students admitted that the way they learned with the technology made them feel more comfortable about communicating in English and less anxious about making mistakes. The recording function was also useful to record lectures. If the students forgot something or wanted to check the teacher's pronunciation, they could replay the recorded lecture. This was particularly useful outside the classroom when they could not consult their teacher and ask questions. Using the sharing function, students shared created content with peers. This function enables students to learn from their peers or to get inspirational ideas to complete or improve their own assignments. The students also commented on each other's content and used suggestions from their peers to revise their work. Students thought highly of the sharing function. The dictionary helped the students translate unfamiliar vocabulary when they were working on tasks outside of school, introduced them to multiple meanings of words, and showed how they can be used in different contexts.

Our findings about the benefits of these learning activities and multimedia support match those reported in other related studies [8], [11], [15], [17], [28], [30]. However, in contrast to earlier studies, this research focuses on how the gap between low and high cognitive levels can be crossed. Our findings are also consistent with related cognitive theories of EFL learning. For example, in line with the output hypothesis [12], [41], [42], students who tried out the target language by producing output became aware of knowledge gaps and turned to a dictionary/asked peers, received feedback and re-produced output. Students' relative feeling of comfort when communicating in English using our system is in line with the affective filter theory [12], [31], [41].

Fig. 5 shows the distribution of students who reached different cognitive levels based on the pre-test and post-test scores. According to the figure, the number of students who reached each cognitive level was lower on the pre-test than the post-test (except for the control group on Understand 2_2 level). This finding suggests that learning took place, students acquired new knowledge, and they were able to answer more test items. In the case of the post-test, all or most control and experimental students reached the "Remember 1," "Remember 2_1," "Understand 1_1," "Understand 1_2," "Understand 2_1," and "Apply 1" levels.

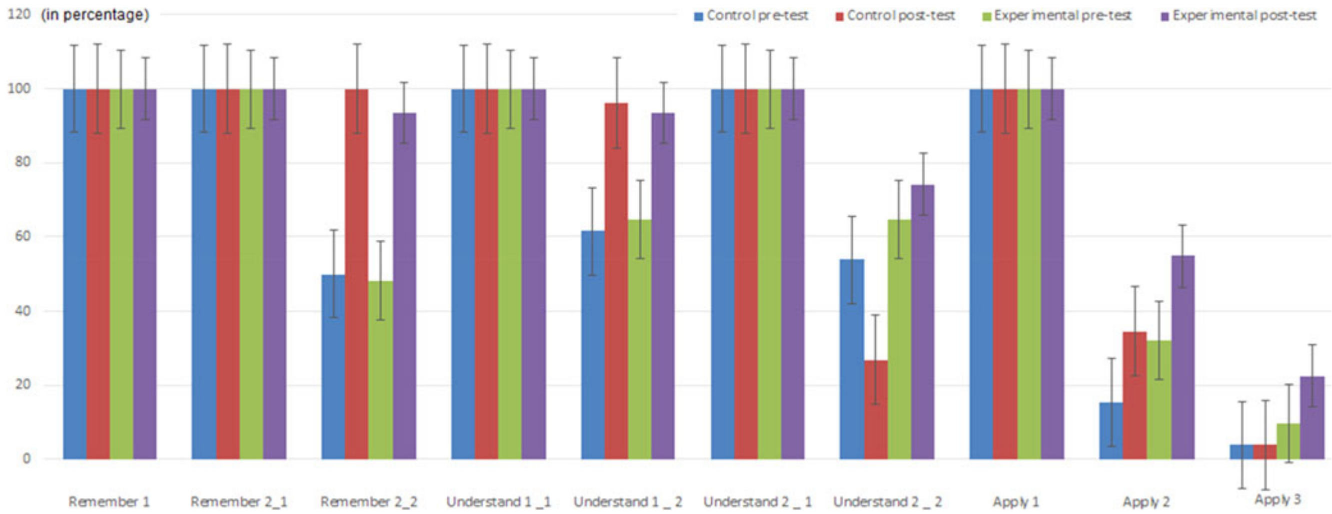

Fig. 5. Distribution of the control and experimental students who reached a certain level of cognition based on the pre-test and post-test results.[1]

Such a high number of students who reached these levels can be attributed to their learning. A quarter of the control (26.92 percent) and three-quarters of the experimental (74.19 percent) students reached Understand 2_2 level. In addition, 34.62 percent of the control students and 54.84 percent of the experimental students reached the Apply 2 level. Only 3.85 percent of the control and 22.58 percent of the experimental students reached the Apply 3 level. These results suggest that our approach facilitates students' cognitive processes. According to the figure, more of the experimental students reached "Apply2" and "Apply3" levels.

6.3 The Progress of Cognitive Processes During the Learning Activities

Fig. 6 shows the average scores of the experimental students on the three tasks. According to the figure, the students made progress on each topic: Topic 1 ($\mathrm{M} = 15.36, \mathrm{SD} = 5.37$), Topic 2 ($\mathrm{M} = 18.09, \mathrm{SD} = 4.64$), and Topic 3 ($\mathrm{M} = 24.27, \mathrm{SD} = 1.79$). The statistical results reveal a significant difference in the scores for the three tasks ($\mathrm{F}(1.593, 15.928) = 11.511, \mathrm{p} < 0.05$). Post hoc tests using the Bonferroni correction system reveal that the students' scores increased slightly from Topic 1 ($\mathrm{M} = 15.36, \mathrm{SD} = 5.37$) to Topic 2 ($\mathrm{M} = 18.09, \mathrm{SD} = 4.64$), which is not statistically significant ($\mathrm{p} > 0.05$). Perhaps it took time for the students to become familiar with the learning activities and technology, and this is why there was not significant progress from Topic 1 to Topic 2. However, the scores for Topic 3 increased ($\mathrm{M} = 24.27, \mathrm{SD} = 1.79$) and were higher than the scores for Topic 1 ($\mathrm{p} = 0.003$) and Topic 2 ($\mathrm{p} = 0.004$). Therefore, we conclude that applying the learning activities supported by the system enhanced the students' cognitive processes only from Topic 2 to Topic 3. Shadiev and Huang [38] suggested that educators and researchers design technology-based instruction in a way that guides and encourages students to use the technology regularly. Such an approach enables them to identify the strengths and limitations of the technology and then to fully utilize it for learning. In this study, students initially familiarized themselves with the learning system and tablet PCs, found their strengths and limitations, and then fully utilized them for learning. As a result, their progress significantly improved from Topic 2 to Topic 3.

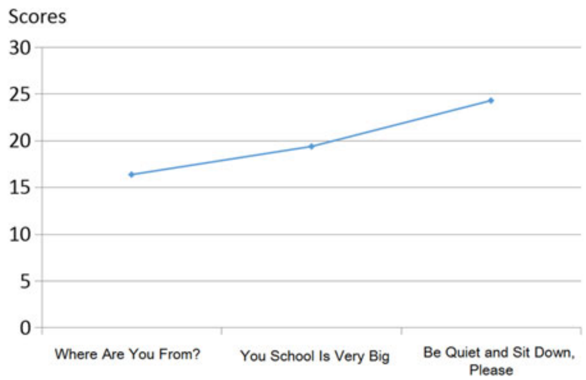

Fig. 6. The improvement progress of the experimental students' cognitive process.

6.4 The Distribution of Students Who Reached a Specific Level of Cognition with Respect to Different Learning Periods

Fig. 7 shows the number of students who reached the highest level of cognitive development on the pre-test and post-test. In order to reveal the distribution more precisely, its x-axis is labeled with six interval units with respect to different score ranges: (1) Scores: 1-4; (2) Scores: 5-9; (3) Scores: 10-14; (4) Scores: 15-19; (5) Scores: 20-24; and (6) Scores: 25-29. According to the figure, the distribution is different with respect to different learning periods (i.e., pre-instruction,

1. "Remember 1" is the distribution of scores to items 1-8 of the tests. "Remember 2" is the distribution of scores to items 9-14. "Remember 2" is divided into "Remember 2-1" and "Remember 2-2" because student may have different degree to remember knowledge. If students remember three out of six items, students' cognitive level relates to "Remember 2-1." If students remember more than three items, students' cognitive level relates to "Remember 2-2." "Understand 1" and "Understand 2" are the distributions of scores to items 15-24 and 25-29, respectively. "Understand 1" and "Understand 2," each was divided into "Understand 1-1" and "Understand 1-2," and "Understand 2-1" and "Understand 2-2" following the same principle as described for "Remember 2." "Apply" is the distribution of scores to item 30. This study assumes that students may demonstrate different degree in cognitive process to apply knowledge, i.e. to describe the teacher; therefore, "Apply" is divided into "Apply 1," "Apply 2" and "Apply 3".

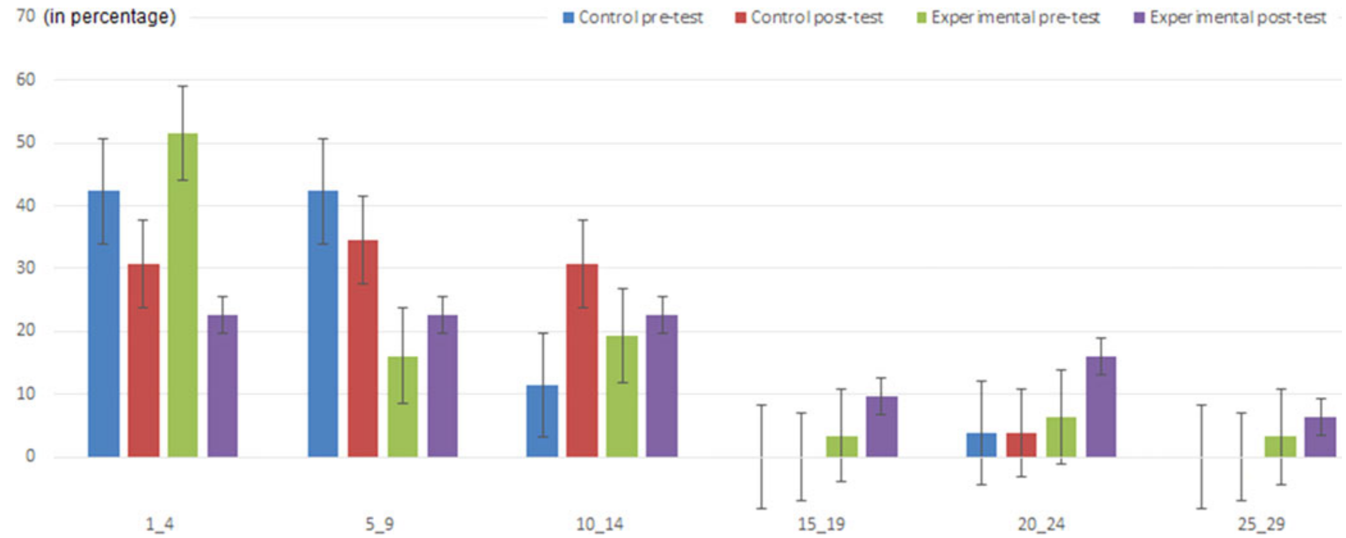

Fig. 7. Distribution of the control and experimental students who reached Apply level based on the pre-test and post-test results (in percentage).[2]

post-instruction with traditional approach and after instruction with the technological approach). The distribution of students who reach the highest levels of cognition was low during the pre-instruction period but increased after instruction with both approaches although it was lower after instruction with the traditional approach. This finding may suggest that the learning activities supported by the system are beneficial for cognitive processes, making the level of cognition higher after instruction in a learning environment supported by technology. According to the Cognitive Diffusion Model [21], students' cognitive development is differently distributed into six levels, and the distribution of students who reach high levels of cognition increases due to different learning periods (i.e., pre-instruction, post-instruction, and crossing the chasm). The model defines students' cognitive processes at the lowest level of cognition before instruction, on a higher level after instruction, and even higher fallowing instruction supported by technology.

This study was an attempt to test the feasibility of the Cognitive Diffusion Model with regard to promoting student learning. The students were encouraged to use English in their everyday lives (e.g., visiting a convenient store to learn and practice English). The results showed that the experimental students' cognitive processes improved due to learning activities supported by the system, revealing a trend in cognitive development (Fig. 7), i.e., the left-right, up-down change from pre to post-instruction for the experimental students. However, we still need to carry out more experiments that last longer (e.g., one academic year or even longer), more well-rounded activity designs (e.g., introduce some learning strategies and scaffolding to learn with technological support), bigger sample size, and so on. Based on the experimental results and evidence, we modified the Cognitive Diffusion Model (see Fig. 7) in an attempt to make it better-rounded. That is, we suggest that the model starts at the top-left side of the diagram and moves left-right, top-down.

6.5 Students' Perceptions Toward the System

Results of the questionnaire analysis show that most items were ranked high: perceived ease of the system use ($\mathrm{M} = 4.03, \mathrm{SD} = 0.85$), perceived usefulness of the system during learning ($\mathrm{M} = 3.83, \mathrm{SD} = 0.80$), perceived satisfaction ($\mathrm{M} = 3.95, \mathrm{SD} = 0.84$), and behavioral intention of using the system ($\mathrm{M} = 3.82, \mathrm{SD} = 0.74$). These responses demonstrate that, in general, students find the system to be useful and easy to use for learning, and they are highly motivated to use it for learning in the future. During interviews, students mentioned that the multimedia tools were easy to use and did not require a lot of effort. Students also admitted that the tablet PC multimedia tools made their learning interesting and fun. Caldwell [5], [8], and [25] suggested that the utilization of multimedia aids, such as texts, picture, and audio can engage students in language learning, stimulate their imagination, and decrease anxiety while giving meaningful output. During interviews, most students agreed that creating and using multimedia content made language learning more interactive and engaging and also made learning information richer [28].

Both the students and the teacher claimed that the system was useful for learning. Interestingly, the teacher mentioned that the system was useful for monitoring students' learning progress. The teacher could find out who did not complete tasks and provide them with technical or pedagogical assistance. The students were also aware of being monitored and may have felt a greater degree of motivation to try to complete all of the assigned tasks. This finding is in line with other related studies. For example, [43] suggested that monitoring is useful to ensure the accountability of students. Monitoring also enables the instructor to keep track of students' learning processes easily and without too much delay and to provide guidance to students when necessary.

2. According to the pre-test and post-test results, all students reached "Apply" level of cognition. Therefore, this figure shows the distribution of students who reached Apply level of cognition. However, cognitive process degree related to "Apply" level varies among students. For example, one student described his homeroom teacher poorly using one or two sentences only in the test whereas the other one did that very well using more than 10 sentences. Thus, in order to demonstrate the distribution in more details, the figure demonstrates students' cognitive process in "Apply" level on a twenty-nine point scale from 1 (the lowest) to 29 (the highest) with six scales, i.e. 1_4 (from 1 to 4), 5_9 (from 5 to 9) and so on.

7 Conclusions

This study has several key findings. First, the experimental students significantly outperformed control students on the items related to "Understand 2" and "Apply" levels. Second, the experimental students made evident progress in cognitive processes after Topic 2. Third, the Cognitive Diffusion Model was tested and modified based on the experimental results and evidence. Most students positively perceived our learning system and are highly motivated to use it for learning in the future. Finally, we learned that creating text annotations is the most important learning behavior since it predicts learning achievement.

Based on these results, we can make several recommendations for the teaching and research community. First, we suggest that designing and implementing appropriate learning activities supported by technology can help students to cross the gap between understanding new information and applying it in new context. In particular, we would like to emphasize the importance of creating and sharing multimedia learning content during learning activities to enhance cognitive development during EFL learning. Second, we suggest that it is feasible to extend this proposed approach by applying it to other domains, such as natural science. That is, through this approach, students may acquire conceptual knowledge in class and then apply it outside of school in an authentic learning environment with a familiar context. Third, we suggest extending learning from the individual level to the collaborative level. It is not easy for students to apply new knowledge to solve real-life problems because most of them have no such skills or experience. Therefore, the instructor may form a small group of students with no prior knowledge or skills and assign a student-expert to a group who can demonstrate to other students how to use mobile technology and then guide them in applying new knowledge to solve real-life problems. The instructor could also design collaborative tasks that require students to complete them through cooperation. In this way, students' cognitive development can be promoted effectively. We further suggest that EFL educators give students sufficient time to get better acquainted with the technology being provided and encourage them to use it regularly. In this way, students will be able to identify the strengths and limitations of the technology and fully utilize it for learning. We suggest that the educators should encourage student participation, teach them useful strategies related to how to learn in a technologically supported environment, and also should scaffold and guide students' language learning so that their actions and progress can be recorded for further teaching designs. Finally, we suggest that students be encouraged to use textual annotations for learning more frequently since this type of annotation is important for learning.

There are some limitations to this study. First, due to a relatively small sample size, the findings cannot be broadly generalized. Second, such short-term exposure to the technology may have little relevance to findings in other research with long-term exposure. Furthermore, we could not control for time during which learning occurred since the students completed tasks after school in different places near their homes. In addition, we did not interview the students in the control situation to understand their learning experience without technology and to determine what parts of the traditional learning experience were useful. A future study will address these issues. Future studies might also investigate higher levels of cognition, e.g., "Analyze," by introducing other learning strategies and scaffolding mechanisms into learning activities.

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Rustam Shadiev is a professor in the School of Education Science, Nanjing Normal University, China. His research interests include learning and instruction in online synchronous learning environment, human-computer interaction for collaboration, and speech to text recognition technology for learning.

Wu-Yuin Hwang is a distinguished professor in the Graduate Institute of Network Learning Technology, National Central University, Taiwan. His research interests include computer assisted language learning, HCI, and knowledge construction.

Yueh-Min Huang is a distinguished professor in the Department of Engineering Science, National Cheng Kung University, Taiwan. His research interests focus on e-Learning, multimedia communications, artificial intelligence, and embedded systems.

Tzu-Yu Liu is a teacher at Bei-Zheng Junior High School, Taiwan. Her research interests include computer assisted language learning and e-Learning.