QR Code and Augmented Reality-Supported Mobile English Learning System

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Abstract. Mobile learning highly prioritizes the successful acquisition of context-aware contents from a learning server. A variant of 2D barcodes, the quick response (QR) code, which can be rapidly read using a PDA equipped with a camera and QR code reading software, is considered promising for context-aware applications. This work presents a novel QR code and handheld augmented reality (AR) supported mobile learning (m-learning) system: the handheld English language learning organization (HELLO). In the proposed English learning system, the linked information between context-aware materials and learning zones is defined in the QR codes. Each student follows the guide map displayed on the phone screen to visit learning zones and decrypt QR codes. The detected information is then sent to the learning server to request and receive context-aware learning material wirelessly. Additionally, a 3D animated virtual learning partner is embedded in the learning device based on AR technology, enabling students to complete their context-aware immersive learning. A case study and a survey conducted in a university demonstrate the effectiveness of the proposed m-learning system.

Keywords: Augmented Reality, Handheld Device, Immersive Learning, Task-based Learning.

1 Introduction

Globalization is a major index of a country's competitiveness. Given the leading role of English as an international language, the Taiwanese government has mandated numerous programs to strengthen the English language skills of students. However, among the factors that have limited the success of such programs are limited practice time that students have outside the classroom, lack of motivation in English learning activities, and absence of learning opportunities in actual circumstances. Therefore, in recent years, there has been emphasis on the application of information technology to resolve the abovementioned problems in English learning.

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In [1], the authors indicated that the mobility, flexibility, and instant access of handheld devices enable students to actively engage in highly interactive learning activities without constraints in time or location. The role of m-learning in improving language learning has also received considerable attention. For instance, in [2], the authors developed an adaptive computer-assisted language learning software for mobile devices called Mobile Adaptive CALL (MAC). MAC helps Japanese speakers of English in perceptually distinguishing between the non-native /r/ vs. /l/ English phonemic contrast to improve their discriminative capability. By adopting mobile computing and information technologies in [3], the authors developed a mobile-based interactive learning environment (MOBILE) to facilitate elementary school English learning. Their results demonstrated the effectiveness of MOBILE in enhancing students' learning motivation and learning outcomes. Although the aforementioned studies have effectively developed mobile English learning environments and activities to aid learning, there are rare studies on investigating the use of context-aware learning strategies in English learning. Context-aware systems featuring contextual data retrieval, engaging learning experiences, and improved learning effects are described in [4]. Thus, it is worth investigating how a context-aware m-learning environment benefits English learning.

This work presents a context-aware m-learning environment called handheld English language learning organization (HELLO) that provides interesting learning activities to increase students' motivation in English learning. Students in this learning environment actively engage in English learning activities without constraints in time or location, thus upgrading their English language skills. Additionally, a case study conducted on a university campus demonstrates the effectiveness of the proposed English learning environment. This work has the following objectives:

- To develop a 2D barcode and an augmented reality-supported mobile English learning environment that enables situated and immersive learning;
- To develop collaborative, situated, immersive, and m-learning activities by applying the proposed learning environment in order to improve students' learning interest, motivation, and outcomes; and
- To understand how the proposed learning environment and its related learning model influence student attitudes toward learning as well as to assess the degree of system acceptance by administering a questionnaire survey.

2 Literature Review

Recent advances in wireless communication technologies have led to the evolution of an m-learning model. Mobile learning is superior to e-learning in terms of flexibility, cost, compactness, and user-friendliness [5]. With the assistance of wireless technologies and handheld devices, an m-learning environment can be easily created to facilitate the objectives of learning without time and location constraints as well as in various formats, which are impossible in traditional classroom learning.

Features of contextual data retrieval, active engagement in learning, and enhanced learning outcomes that are characteristic of context-aware systems have been extensively adopted in various learning activities [4]. In [6], the authors coined the term "context-aware," in which context is regarded in terms of location, identities of nearby individuals and objects, and subsequent changes to those individuals and objects. In [7], the author defined "context" as contextual information that can characterize an entity that can be an individual, location, or physical object that is viewed as relevant to the interaction between a user and an application. Several studies have developed various context-aware learning systems to improve language learning. For instance, in [8], the authors developed a tag added learning objects (TANGO) system, capable of detecting objects around learners and providing learners with object-related language learning materials by radio-frequency identification (RFID) technology.

Augmented reality (AR) is highly promising for integration in an m-learning environment for improving learning outcome and learning experience by immersion. Immersive learning allows individuals to experience feelings and emotions as they do in the real world by interacting in a virtual environment. Many studies have developed AR-based learning systems to enhance immersive learning. For instance, in [9], the authors developed a wearable AR learning system, namely, MagicBook, in which a real book is used to seamlessly transport users between reality and virtuality. That work adopted a vision-based tracking method to overlay virtual models on real book pages, thereby creating an AR scene. Users seeing an AR scene and AR objects enjoy an immersive virtual reality (VR) world. Therefore, AR (or VR) is a valuable technology for students to acquire a richer learning experience and improve learning outcomes. Video cameras are normally embedded in mobile phones; thus, wireless local area networks (WLANs), Bluetooth, GSM (also known as Global System for Mobile Communication), and multimedia capabilities can assist students to learn without time and location constraints. To achieve the objectives of context-aware and immersive learning in English, this work presents a sensor technology and AR-supported context-aware m-learning environment with handheld phones for facilitating campus learning. In this environment, students are actively engaged in interesting English learning activities, thus enhancing their English language skills.

3 Implementation of a Mobile English Learning System

3.1 Implementation Issues

While context-aware m-learning provides a more situated and interactive learning experience than m-learning [10, 11], integrating situations into a context-aware m-learning environment poses a major challenge. Fortunately, advanced sensor technologies, including 2D barcode, Infrared Data Association (IrDA), global positioning system (GPS), Bluetooth, RFID, Zigbee, and WLAN can provide situated services. Table 1 compares various sensor technologies for positioning. Among these positioning technologies, 2D barcode technology is feasibly applied to mobile phones in context-aware m-learning.

Table 1. Comparison of positioning technologies

Characteristics	802.11	GPS	RFID	2D barcode
Positioning accuracy	Low	Low	High	High
Indoor	Yes	No	Yes	Yes
Context-awareness	Low	Low	High	Middle
Sensor technology	Auto	Auto	Auto	Passive
Cost	High	Low	High	Low
Cover Area	Micro	Wide	Micro	Micro
Practicability	Low	Low	High	High

2D barcode technology has many advantages, including a large storage capacity, high information density, strong encoding, strong error-correcting, high reliability, low cost, and ease of printing [12]. 2D barcode technology has thus become popular in various applications, including ticketing services, manufacturing, product identification, flow control, quality control, logistics management, interactive advertising, marketing, mobile commerce, business transactions, medical treatment, and location-based services.

2D barcode technology stores data along two dimensions, allowing it to contain a greater amount of information than a 1D barcode. Despite more than 200 2D barcode standards worldwide, only a few are widespread, including portable data file 417 (PDF417), data matrix, quick response (QR) code, and Magic Code. Of the 2D barcodes, QR code, as created by Denso-Wave in 1994, has become increasingly popular in Taiwan since QR code-decrypting software is embedded in many mobile phones. QR code requires only around 23 micro seconds for decoding; therefore, this work adopts it to assess user receptiveness to the proposed mobile learning system.

2D barcode software performs two basic functions of encoding and decoding. Table 2 lists established 2D barcode software providers. Developers can use these barcode toolkits to develop 2D barcode-based applications. Each product may only provide either a 2D barcode encoder or a decoder; alternatively, it either only supports Windows or Windows Mobile applications. A developer can use the software development kit (SDK) to develop diverse 2D barcode technology applications.

Moreover, AR is a highly effective educational application owing to its ability to embed digital objects into a real environment [13]. Creating an AR application involves superimposing virtual image on a live video. The AR tool has the following operation procedures: tracking a marker via a camera and then taking a series of snapshots regarding this marker in real time; decoding the internal code of the marker (which refers to a virtual image); and overlaying the virtual image on a live video.

To create AR applications, ARToolKit is one of the most widely used tracking libraries with more than 160,000 downloads. Developed by Kato in 1999 and subsequently released by the Human Interface Technology (HIT) Lab of University of

Table 2. 2D barcode software provider list

Platform/codec Provider	SDK for Windows		SDK for Mobile		
	encoder	decoder	encoder	decoder	free
Denso-Wave					
TEC-IT		√			
Lead Technologies	√	√	√	√	
Neodynamic	√		√		
Inlite Research, Inc.	√				
PartiTek, Inc.	√	√	√	√	√
AIPSYS.com	√	√	√	√	√
PyQrCodec	√	√			
MW6	√		√		
SIA DTK Software			√	√	
IDAutomation	√	√	√	√	
SimpleAct, Inc.					
iconlab Co., LTD.					
Yusuke Yanbe	√	√	√	√	√

Washington in [14], ARToolKit is maintained as an open source project hosted on SourceForge (http://artoolkit.sourceforge.net/) with commercial licenses available from ARToolWorks in [15].

ARToolKitPlus was developed internally as an integral part of the Handheld AR project in [16], later released to the public domain. ARToolKitPlus is an extended version of ARToolKit in [17]. ARToolKitPlus was succeeded by Studierstube Tracker, i.e., a computer vision library for detection and estimation of 2D fiducial markers. Studierstube Tracker was written with high performance for personal computers and mobile phones in [18]. Although ARToolKitPlus is available in the public domain, Studierstube Tracker requires a subscription fee. Several AR tool kits listed in Table 3 can be adopted to develop handheld AR applications.

Table 3. Argumented reality toolkit list

Organization	Toolkit	Platform	OS	SDK Fee
HIT Lab, University of Washington	ARToolKit	PC, laptop	XP, Mac OS, Linux	Free
Christian Doppler Lab , Graz University of Technology	ARToolKitPlus	PDA	PocketPC 2003 SE	Free
Christian Doppler Lab , Graz University of Technology	Studierstube Tracker	PC, mobile phone, PDA	XP, WinCE, Windows Mobile, Linux, Symbian, MacOS, iPhone	Charge
Augmented Environments Laboratory, Georgia Institute of Technology	OSGART	PC, laptop	XP, Vista, Mac OS, Linux	Free
University College London	MRT	PC, laptop	XP	Free

3.2 System Design

Fig. 1 illustrates the architecture of the proposed 2D barcode and AR-supported m-learning environment. The proposed learning environment consists of two subsystems: a HELLO server and m-Tools (application software). While teachers access the HELLO server through personal computers via the Internet, students communicate with the HELLO server from their mobile phones via WLAN. The functionalities of the two subsystems are as follows.

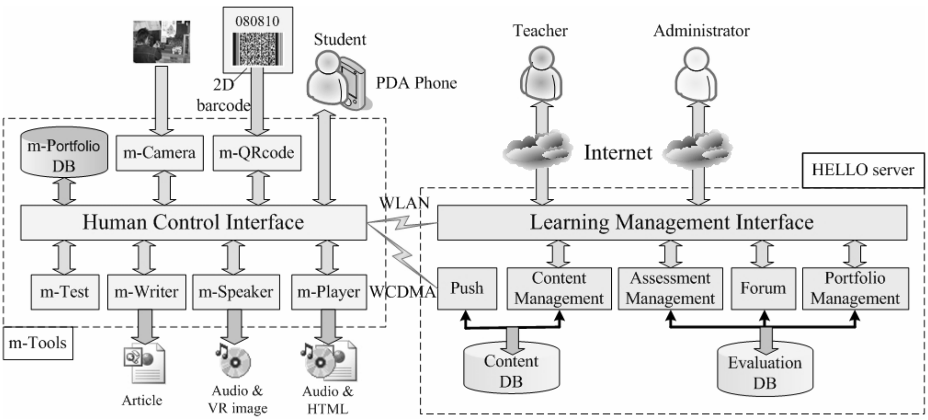

Fig. 1. Architecture of HELLO

The functionalities of the HELLO server are as follows:

- Content management unit (CMU): University administration assigns independent study courses and stores the learning materials in a content database (CDB).
- Assessment management unit (AMU): University instructors can give assessments to students to evaluate their learning outcome.
- Portfolio management unit (PMU): Students can upload their portfolios into an evaluation database (EDB) for review by instructor and grades evaluation via the PM unit.
- Forum unit: Through this unit, university instructors can instruct students to share their learning experiences with each other.
- Push unit (PU): Every day, this unit automatically delivers a sentence to students for daily practice.

A student with a PDA phone installed with m-Tools can learn English without location or time constraints. The functionalities of m-Tools are as follows:

- Listening and reading: The m-Player can download course materials and then students can read articles/news or listen to conversations from the HELLO server;

- Playing: The m-Player can play learning games or English songs;
- Speaking: To enhance speaking skills, students can use the m-Speaker. Students can practice speaking with the virtual learning tutor (VLT);
- Writing: Students can use the m-Writer to write an article or a diary entry in English;
- Context-awareness: When a student holds a PDA phone near the zone attached with 2D barcode technology, the m-Reader on that phone decrypts the internal code and sends it to the HELLO server. The HELLO server then downloads context-aware content to the PDA phone; and
- Evaluation: Students can use the m-Test to take tests and evaluate their learning achievements. Moreover, learning records can be stored in the m-Portfolio through the human control interface (HCI) after learning tasks are completed. Upon completion, the student learning portfolio can be uploaded into the EDB of the HELLO server for instructor review.

HELLO operates as follows. Teachers input materials and assessments into the CDB through the CMU, AMU, and PU. Teachers can review student portfolios and give grades through the PMU. The PU automatically delivers a daily English sentence to students' PDA phones via a wireless network, such as GSM and code division multiple access (CDMA), in order to enhance the listening skills of students.

Equipped with PDA phones to communicate with the HELLO server, students can access materials stored in a server via a WLAN. Students use m-Tools software to download articles, news, learning games, English comics, English songs, listening

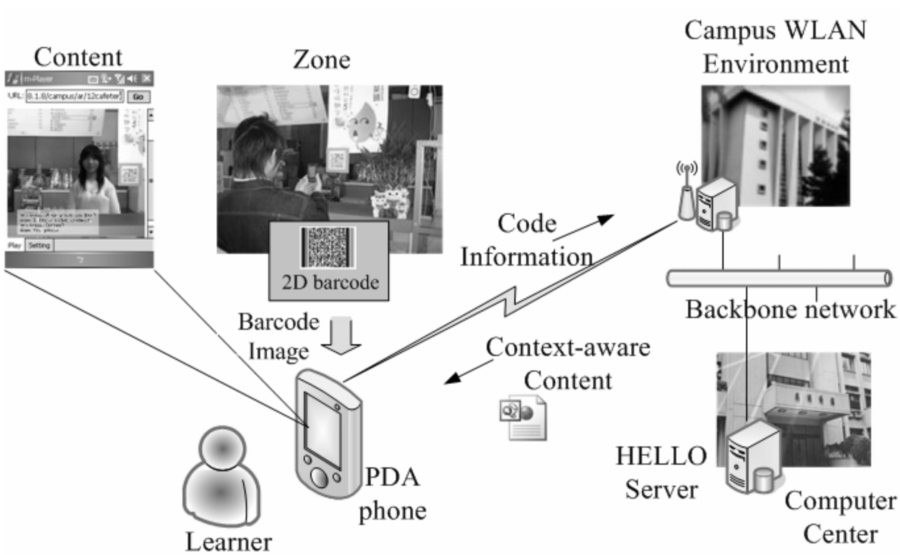

Fig. 2. Scenario of mobile English learning in the campus of the National Taipei University of Technology (NTUT)

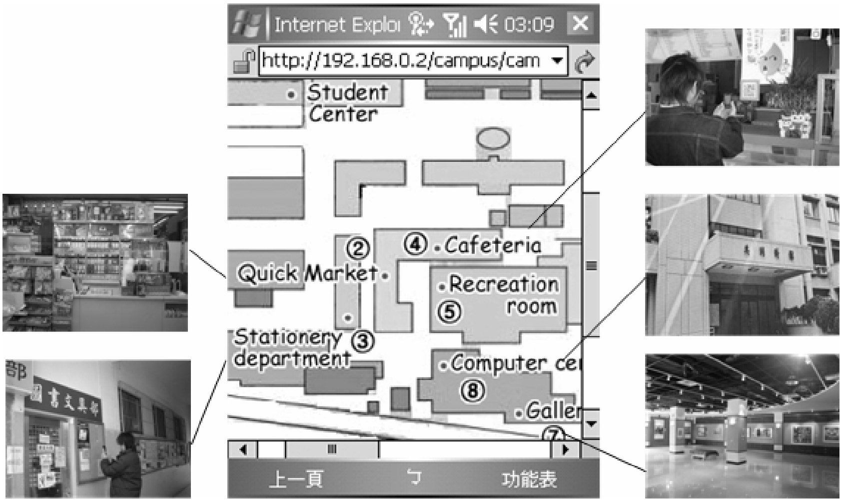

Fig. 3. Guide map of learning activity

materials, and conversational materials from the HELLO server, followed by use of the m-Player to play, listen to, and display learning materials. Additionally, each student holds a PDA phone near a zone that is attached to a 2D barcode. The student takes a photo of the QR code using the m-Camera, and the m-Reader on the PDA phone then decrypts the internal code; the QR code represents a Uniform Resource Locator (URL). Next, the PDA phone sends this URL to the HELLO server, subsequently downloading situated content to the PDA phone and displaying on the PDA screen. Fig. 2 illustrates a context-aware and immersive learning scenario based on 2D barcode, augmented reality, the Internet, mobile computing, and database technologies. Fig. 3 depicts a guide map of the learning activities. Fig. 4 presents an example of the learning activity. Students use the m-Speaker to talk to the virtual learning tutor (VLT) that appears on the PDA phone. The m-Speaker superimposes VLT on the learning zone image (captured from the m-Camera). VLT plays the role of speaker A, and the student plays the role of speaker B. VLT speaks the first sentence, and the student then speaks the next sentence following the prompt of conversation sentences in sequence. The conversation between VLT and the student can be stored into a PDA phone by an embedded software recorder and then uploaded into a server for instructors to grade. This features makes students feel as though they are talking to an actual person. Fig. 5 illustrates an example of AR learning material.

Additionally, students can use the m-Test tool to take tests and evaluate their learning performance. Learning records of students are then stored in the m-Portfolio after students complete their learning tasks. Upon completion, learning portfolios of students are uploaded into the EDB of the HELLO server for instructors to review.

Fig. 4. A scenario of learning activity: a student is talking with the virtual learning partner to practice conversation in a restaurant

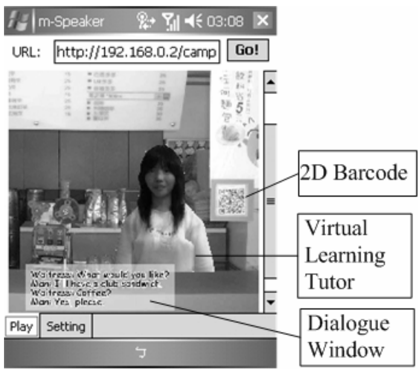

Fig. 5. An example of augmented reality learning material

4 Methodology, Course Design, and Experimental Procedure

A series of controlled experiments was performed with university students. Following completion of the experiments, a questionnaire was administered to students to evaluate the effectiveness of the HELLO in enhancing their learning motivation and learning outcomes.

4.1 Methodology

The questionnaire was administered to twenty students upon completion of the experiments (during the final class session) in order to determine the degree of perceived usefulness, user-friendliness, and attitudes toward the use of the HELLO server. A seven-point Likert scale was applied to all questions: 1 denoted strong disagreement, while 7 denoted strong agreement. The questionnaire results were analyzed using a one-sample t-test. The usefulness and user-friendliness of the system were evaluated using the technology acceptance model (TAM) [19, 20, 21]. TAM is an information system that creates models for how users accept and use a particular technology. TAM posits that two particular beliefs—perceived usefulness and perceived user-friendliness—are of priority concern. "Perceived usefulness" is defined as the subjective probability that the use of a given information system enhances a user's performance in an organizational context. "Perceived user-friendliness" refers to the degree to which the prospective user expects that using it is effortless. A user's "attitude toward using" is a function of the perceived usefulness and perceived user-friendliness that directly influences actual usage behavior [20, 22, 23, 24].

The internal consistency reliability of the questionnaire was evaluated using Cronbach's alpha coefficient. In [25], the author stated that 0.7 is an acceptable minimum reliability coefficient. Whether the two groups significantly differed from each other in terms of the pre-condition was determined using either an independent two-sample t-test or a pre-test.

4.2 Participants

Three instructors and twenty undergraduate freshmen selected from NTUT participated in the experiment. Two English instructors with teaching experience of more than a decade participated in the study. A computer science instructor with five years of teaching experience was responsible for installing, managing, and maintaining the computer system.

4.3 Course Design

Interaction and communication are essential to language learning [26, 27, 28]. Of the many communicative language learning approaches available, communicative language teaching (CLT) refers to language learning for the purpose of communicating. Additionally, task-based language learning (TBLL) focuses on asking students to complete meaningful tasks using the target language. Moreover, competency-based language teaching (CBLT) focuses on measurable and useable KSAs (knowledge, skills, and abilities). Furthermore, a natural approach (NA) focuses on "input" rather than practice. Among them, TBLL is the most effective pedagogical approach. In [29], the author stated that TBLL increases student conversations, relaxes the classroom atmosphere, and reinforces students' comprehensible input. Tasks refer to "activities where the target language is used by the learner for a communicative purpose in order to achieve an outcome" [30]. More than simply asking students to complete tasks sequentially, TBLL consists of three stages: pre-task, task cycle, and language focus [30]. Teachers discuss the topic with their classes, highlight useful words and phrases, help students understand task instructions, and prepare the pre-task stage. Each student group completes a common task collaboratively and then presents its findings to the class—or exchanges written reports—and compares the results during the task cycle stage. During the language focus stage, teachers help students practice new words, phrases, and patterns that occur in data either during or after the analysis. In [30], the author indicated that in TBLL, students can learn by doing. TBLL has the following characteristics: interactive, student-centered focused, meaningful materials, fluency language production, learning in the real world, and clear learning objectives [30, 31].

By helping students to collaborate with teachers and peers, a TBLL curriculum gradually helps students to use English meaningfully. By adopting the TBLL approach, this work designs a course entitled “My Student Life.” Course topics include classrooms, libraries, a language center, gymnasiums, restaurants, dormitories, stadiums, cafeterias, the gallery, and the computer center. Mobile gamed-based learning, immersive learning, and context-aware learning are the pedagogical strategies. This course has the following learning objectives: to nurture listening, speaking and reading skills; to increase learning motivation through a designed learning game; and to enable students to learn in a real environment. Context-aware learning is then achieved through 2D barcode technology.

4.4 Procedures

A four-week experiment was performed with twenty undergraduate students, as follows. During the independent study phase (first two weeks), teachers introduced the HELLO system and demonstrated how to use the learning tools. A mobile task-based pedagogical strategy was adopted in the self-learning process. Students used PDA phones installed with m-Tools. A campus map appeared on the screen after students launched the game “My Student Life” on their PDA phones. The campus map had many zones marked on the map. Students simply clicked the desired zone, with the m-Player subsequently making available materials related to that zone. For instance, when a student selected the zone “Library,” a library was displayed on the PDA phone. Students could also select the reading room to read an article, the newsroom to read news, or the multimedia room to watch a movie whenever desired. Importantly, students could learn without time or location constraints without going to an actual library.

During the context-aware learning phase (the other two weeks), students used the HELLO system to engage in the learning activity called “Campus Tour.” Each student used a PDA phone installed with m-Tools and followed the guide map that appeared on the screen to engage in context-aware learning activities. When approaching a zone, a student used the PDA phone to take a picture and decrypt the 2D barcode. The detected identification code of the 2D barcode was then sent to the HELLO server via a WLAN. The HELLO server located the students and sent the context-aware contents back to their PDA phones. The VLT was superimposed with the zone image on the PDA screen. Next, students practiced conversation with the VLTs, similar to how they would talk with actual partners in the real world. Students visited the next zone after completing a conversation with VLT at a particular zone, until they had visited all zones. Students accessed context-aware contents related to the location and engaged in context-aware learning. Finally, a survey for students was administered and subsequent interviews undertaken upon course completion.

5 Results and Discussion

Following completion of the experiment, a questionnaire survey was given to twenty students to understand their opinions. A seven-point Likert-scale was used for all questions: 1 denotes strong disagreement, while 7 denotes strong agreement, respectively. A total of twenty valid questionnaires were returned, a response rate of 100%. Additionally, statistical analysis was performed to determine the degree of perceived usefulness, ease of use, and attitudes toward the use of the HELLO system.

The responses to item A1 indicated that most students believed that the HELLO system is easily used (m = 6.10). Responses to item A2 (m = 5.80) indicated that the system functions were convenient and sufficient for learning. Students also commented that the tools had many functions with user-friendly interfaces that could assist them in completing the targeted learning activities.

Response results of item B1 (m = 6.05) indicated that the HELLO system can increase the motivation to learn. Many students commented that they were highly motivated to use modern devices such as PDAs. One student stated, "I used the m-Player to learn audio materials for actual circumstances. These interesting experiences could not possibly be learned in textbooks." Results of items B2, B3, and B4 (m = 6.20, 5.40, and 6.45, respectively) indicated that the HELLO system can enhance listening, speaking, and reading skills. Many students viewed the learning activities as engaging and interesting. One student said, "I could practice listening and speaking for actual circumstances. That was an interesting experience." Results of item B5 (m = 2.65) indicated that the HELLO system cannot improve writing skills. One student stated "Writing English on a keyboard-less PDA is inconvenient." Therefore, how to improve the writing skills of students is a major challenge of future studies.

The responses to item C1 (m = 6.20) indicated that most students liked using the HELLO system to learn after class. One student stated, "I could not only read web page-based English materials in campus, but could also listen to audio materials anywhere." Responses to item C2 (m = 6.15) indicated that most students would like to use the HELLO system in other courses.

Responses to item D1 (m = 5.90) indicated that the VLT appears to be part of the real world. Responses to items D2 and D3 (m = 6.10 and 6.15, respectively) indicated that the VLT is helpful and can enhance learning experiences. Many students commented that they enjoyed watching a virtual tutor on their PDAs. One student stated, "Through the m-Speaker function, I could see the virtual tutor and listen to English materials, which was a novel experience."

This study evaluated the internal consistency reliability of the questionnaire by using Cronbach's alpha coefficient. Table 4 reveals that all Cronbach's alphas of group A (0.76), B (0.75), C (0.76), and D (0.73) in this experiment exceeded 0.7, indicating the high reliability of the administered questionnaire.

Table 4. Summary of survey results from twenty students (7-point Likert scale)

Group	Item	Mean	SD
A. Easiness	A1. The user interface of u-Tools is friendly.	6.10	0.72
	A2. The functions of the m-Tools are sufficient.	5.80	0.77
B. Usefulness	B1. Applying the task-based HELLO to assist English learning can increase my learning interest and motivation.	6.05	0.76
	B2. Applying the HELLO to assist English learning can increase my listening ability.	6.20	0.70
	B3. Applying the HELLO to assist English learning can increase my speaking ability.	5.40	0.68
	B4. Applying the HELLO to assist English learning can increase my reading ability.	6.45	0.60
	B5.Applying the HELLO to assist English learning can increase my writing ability.	2.65	0.93
C. Attitude	C1. I like to use the HELLO to assist English learning after class.	6.20	0.61
	C2. I hope other courses can also use the HELLO to assist learning.	6.15	0.75
D. Usefulness of VLT	D1. The VLP seems to be part of the real world.	5.90	0.64
	D2. The VLP is helpful for completing the learning activity.	6.10	0.79
	D3.The VLP is helpful for learning.	6.15	0.67

d.f. (degree of freedom) = 19.

To include virtual images and actual scenes on the PDA screens, we recommend using a proper 2D barcode tag size to increase the effectiveness of the HELLO system. When a smaller 2D barcode tag is used, the distance between the tag and phone must be shortened, subsequently making the scene small and unclear. In our experience, proper length of a 2D barcode ranges between 8 and 12 cm, while the proper distance between the tag and phone is 40 to 50 cm. The appropriate angle between normal vector of wall and camera ranges from 0 to 30 degrees. With respect to system constraints, the PDA phone has a small screen size and unclear display under strong sunlight in an outdoor environment.

6 Conclusions

This work has developed a 2D barcode, handheld, augmented reality (AR)-supported English learning environment, called handheld English language learning organization

(HELLO), which provides valuable learning resources and functions to facilitate English language learning. HELLO consists of two subsystems: the HELLO server, and m-Tools. Teachers connect with the HELLO server using their personal computers via the Internet. Students communicate with the HELLO server using their mobile phones via WLAN. A pilot study was performed with the participation of three instructors and twenty undergraduate students from the National Taipei University of Technology (NTUT). Learning activities were conducted in the university. Mobile context-aware and task-based learning pedagogical strategies were adopted. An independent study activity entitled "My Student Life" and a context-aware learning activity called "Campus Tour" were undertaken in a four-week course. "My Student Life" is a learning game. The campus map had many zones marked on the map. The students simply clicked the desired zone and, then, automatically opened materials related to that zone. "Campus Tour" is an augmented reality game. When approaching a zone, a student used the PDA phone to decrypt the 2D barcode and then obtained context-aware contents from server. The students then practiced conversation with the virtual learning partners (tutors).

A questionnaire was administered to the students upon conclusion of learning activities. Based on those results, most students found the course interesting. Responses indicate that most students found HELLO easy to use and useful for assisting learning; they thus endorsed the use of HELLO in future learning. Analysis results also indicate that HELLO not only increased students' motivation to learn, but also enhanced their learning outcomes. This study further demonstrates that 2D barcodes and handheld AR technologies are useful in providing context-aware, immersive experiences in English-learning activities.

Future studies should strive to enhance new sensor networks, physical interaction, and ubiquitous AR technologies. We will continuously work with university English instructors to conduct full-scale studies and to investigate the feasibility of HELLO in various campus contexts and adapt HELLO to individual students' needs, interests, styles, and learning capacity.

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