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# A context-aware ubiquitous learning environment for language listening and speaking

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**Abstract** This paper reported the results of a study that aimed to construct a sensor and handheld augmented reality (AR)-supported ubiquitous learning (u-learning) environment called the Handheld English Language Learning Organization (HELLO), which is geared towards enhancing students' language learning. The HELLO integrates sensors, AR, ubiquitous computing and information technologies. It is composed of two subsystems: an English learning management system and a u-learning tool. In order to evaluate the effects of the proposed learning environment on the learning performance of students, a case study on English learning was conducted on a school campus. The participants included high school teachers and students. A learning course entitled 'My Campus' was conducted in the class; it included three activities, namely 'Campus Environment', 'Campus Life' and 'Campus Story'. The evaluation results showed that the proposed HELLO and the learning activities could improve the students' English listening and speaking skills.

**Keywords** augmented reality, handheld device, immersive learning, task-based language learning, ubiquitous learning.

## Introduction

English is the most popular language in the world and has become the most important second language (L2) in many non-English-speaking countries. Unlike English learning in Singapore, English is learned as a foreign language (known as EFL) in Taiwan, Japan and Korea. The ways in which students' listening, speaking, reading and writing abilities can be improved are critical issues in non-English-speaking countries. However, promoting English learning in these countries involves the following difficulties. First, English teaching is not connected with real life; traditional English education tends to involve knowledge acquisition rather than life skills. The recitation of words, explanation of syntax and reading of papers cannot enhance students' learning motivation. Second, the frequency of English learning is too low; students learn English only in English classes in traditional classrooms, and they have few opportunities to practice English outside the classroom without time and space limitations. Thus, developing an effective language learning environment and learning activities that support English learning is an important topic in the computer-assisted language learning (CALL) field (Collins 2005; Shih 2005).

Mobile learning (m-learning) offers a new way to infuse learning into daily life. M-learning uses mobile computing technologies to enhance the learning experience; those technologies can be blended together to engage and motivate learners any time and anywhere. The disadvantages of m-learning compared with

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e-learning include a small screen size, a short battery life, no keyboard, the inconvenience of carrying an additional device and the difficulty of designing effective learning content. M-learning has many advantages over e-learning including flexibility, low cost, small size and user-friendliness (Jones & Jo, 2004). For this reason, many mobile-assisted language learning (MALL) environments and activities have been successfully implemented to aid English learning. The following can be cited as examples of such environments or activities: a mobile device-supported, peer-assisted learning system for collaborative early EFL reading (Lan *et al*. 2007), a personalized intelligent m-learning system for supporting effective English reading (Chen & Hsu 2008), a personalized mobile English vocabulary learning system for recommending appropriate English vocabulary materials to learners (Chen & Chung 2008), a Collaborative-Learning support-system with a Ubiquitous Environment (CLUE) system for providing knowledge-aware language learning information (Ogata & Yano 2004), a highly interactive learning activity to support reading for ESL (English as L2) learners (Chang *et al*. 2007) and a learning content with both written and pictorial annotation to help learners with higher verbal ability (Chen *et al*. 2008).

Moreover, many studies have developed mobile language learning environments to enchance vocabulary ability (Thornton & Houser 2005; Chen & Chung 2008), to improve reading comprehension ability (Lan *et al*. 2007; Chen & Hsu 2008), to enhance sentence-making ability (Morita 2003), to increase learning opportunities (Stockwell 2007), to eliminate learning time and space limitations (Rosell-Aguilar 2007), and develop a podcast environment for supporting English listening (Edirisingha *et al.* 2007).

Although numerous studies have been conducted in the field of mobile language learning, they cannot be applied widely to train students in listening to and speaking a language. Conventional desktop CALL listening and speaking training approaches have faced two main difficulties. First, students lack sufficient opportunities to practice conversation with their English teachers, classmates and native English speakers. Second, schools lack appropriate English learning environments (including software and hardware). Students rely on textbooks and audio CDs as their major learning materials and use paper tests to evaluate learning performance, leading to deficiencies in spoken English. Thus, using CALL technology to improve English speaking and listening become a challenge.

## Related works and our work

Kukulska-Hulme (2005) argued that MALL has excellent potential to provide students with rich, real time, convenient, collaborative, contextual and continuous learning experiences both inside and outside the classroom. Several studies have been conducted on the use of m-learning to improve English listening and speaking abilities. For example, Uther *et al*. (2005) developed an adaptive CALL software program for mobile devices called Mobile Adaptive CALL (MAC). MAC is aimed at helping Japanese–English speakers in perceptually distinguishing the non-native /r/ versus /l/ English phonemic contrast with the aim of improving their discriminative ability. Moreover, Yang *et al*. (2005) developed a system for a one-on-one English oral practice and assessment by using handheld devices in a classroom. Their findings showed that students increased their performance in oral practice and readily accepted the use of handheld devices for English learning.

Several studies also developed MALL to improve contextual language learning experience. For example, Tan and Liu (2004) built an m-learning environment called MOBILE (MObile-Based Interactive Learning Environment) for assisting English learning for elementary schools. Several theme-based m-learning activities were conducted inside and outside of the classroom. Experimental results indicated that MOBILE can significantly increase students' interest in learning English compared with the traditional manner. Moreover, Cui and Bull (2005) developed a mobile intelligent tutoring system, the TenseITS, with learners' location awareness for supporting language learning, designed primarily for Chinese learners.

The rapid development of modern computer science and sensor technology has enabled many new ubiquitous computing applications. Ubiquitous computing refers to the use of computer systems in everyday environments that enable user interaction at any time (Weiser *et al*. 1999). In ubiquitous learning (u-learning), ubiquitous computing occurs all around the students, whether or not they are aware of it. Ogata *et al*. (2005) developed a ubiquitous computing environment called the TANGO (Tag Added learNinG

Table 1. Comparison of u-learning and m-learning.

| Characteristic | Ubiquitous learning | Mobile learning |
|---|---|---|
| Permanency | The learning process, learner behaviours and environmental situations are recorded in the learning system permanently. | Only the learning process is recorded in the learning system permanently. |
| Accessibility | Network is ready in the whole environment. The learners can access information from any location and at any time. | The learners must link with networks to access information. |
| Immediacy | The learners can immediately access useful information in real time and get an immediate response from the learning environment. | The learners must spend considerable time accessing learning contents. |
| Interactivity | The learners not only interact with teachers, peers, learning devices, digital content, real environment and virtual objects in real world, but also collaboratively complete a common task and share their experiences with each other. | The learners can only interact with teachers, peers, learning devices and digital content. |
| Situation | The learning environment understands the situation of the learners by detecting their status via the sensor network. The learners can gain authentic knowledge in real environment. | The learning environment can not understand the situation of the learners. |
| Calmness | The learning devices are quiet, invisible agents that recede into the background of the learning environment. | The learners get learning content by operating the learning devices. |
| Adaptability | The learners use any devices to learn in the changed learning environment. | The learners use specified devices to learn in the fixed learning environment. |
| Seamlessness | The learning process is not interrupted when the learner is moving. | The learning process is interrupted when the learner's position changes. |
| Immersion | The learners experience real feelings and emotions as they do in real world through interacting with the virtual objects and the environment. | The learner can only employ mobile devices to interact with the virtual objects and the environment. |

Objects) system, which detects objects around the learner using radio frequency identification and provides the learner with the right information for language learning. A comparison of u-learning and m-learning is given in Table 1 (Tan *et al*. 2007; Liu *et al*. 2009).

Context-aware systems featuring contextual data retrieval, engaging learning experiences and improved learning effects have been applied to various learning activities (Cooper 1993). Schilit *et al*. (1994) regarded context in terms of location, identities of nearby people and objects, and changes to those objects. Dey (2001) defined context as contextual information about an entity, which may be a person, a place or a physical object. This information is considered relevant to the interaction between a user and an application. U-learning provides context-aware information and self-learning opportunities for learners. Thus, u-learning not only enables students to achieve their learning goals anytime and anywhere, but it also cultivates their ability to explore new knowledge and solve problems (Tan *et al*. 2007; Liu *et al*. in press).

On the other hand, integrating virtual reality (VR) into a u-learning environment could increase learning by immersion as well as providing a richer learning experience. VR includes four types: VR, augmented virtuality (AV), augmented reality (AR) and reality (Milgram *et al*. 1994). In VR, the surrounding environments are completely digitalized. In AV, real objects are embedded into virtual ones. In AR, digital objects are embedded into the real environment. In immersive learning, learners experience real feelings and emotions as they do in a real world through interacting with the virtual environment. According to Whiteside (2002), an immersive learning environment is effective if it engages the learner holistically – cognitively, emotionally and even physically – using a combination of designed VR techniques. Various handheld, AR learn-

ing games have been devised to explore the effectiveness of these technologies for learning. For instance, Wagner and Barakonyi (2003) proposed a handheld AR educational application in which a virtual character teaches users about art history.

Although information technology can effectively support language learning, appropriate learning strategies and approaches can further enhance learning performance. Interaction and communication are key elements in language learning (Nunan 1989; Johnson & Johnson 1994; Ellis 2003). There are many approaches to communicative language learning. Communicative language teaching refers to language learning for the purpose of communication, task-based language learning (TBLL) focuses on asking students to finish meaningful tasks using the target language, competency-based language teaching focuses on measurable and useable knowledge, skills and abilities, and natural approach focuses on 'input' rather than practice. Among these studies, TBLL is claimed to be one of the most effective pedagogical approach.

Nunan (1992) stated that TBLL increases student conversations, makes the classroom atmosphere relaxing and reinforces students' comprehensible input. Tasks refer to 'activities during which the target language is used by the learner for a communicative purpose in order to achieve an outcome' (Willis 1996, p. 23). Willis (1996) pointed out that in TBLL, students can learn by doing. The characteristics of TBLL are interaction, student-centred focus, meaningful materials, fluency language production, learning in the real world and clear learning goals (Willis 1996; Carless 2004). Several studies have focused on using task-based collaborative learning to help language learning. For instance, Kiernan and Aizawa (2004) used mobile phones as language learning tools for task-based learning in pairs and small groups and revealed that learning tasks encouraged L2 negotiation, which is composed of a key element of language acquisition. They argued that L2 acquisition is best promoted through task-based learning.

Although aforementioned studies have effectively developed mobile language learning environments and activities to aid listening and speaking, rare studies focus on investigating the use of context-aware ubiquitous and task-based collaborative learning strategies in improving the English speaking and listening skills of high school juniors in non-English-speaking countries. Omaggio (1986) suggested that effective language teaching should provide more practice opportunities in real situations and should guide students to complete a task collaboratively. Thus, it is worth investigating how a context-aware u-learning environment and effective learning activities benefit listening and speaking skills.

Although the handheld-supported learning environments described earlier have been successful in mobile language learning, many issues are worth exploring, specifically high school juniors who study English listening and speaking in non-English-speaking countries. The following issue arises: how does a context-aware u-learning environment improve language learning in class?

To address the aforementioned issue, this study integrates sensors, ubiquitous computing, handheld AR and information technologies to construct an English learning environment called the Handheld English Language Learning Organization (HELLO), which includes the following characteristics:

1. permanence: learning processes can be recorded in the learning system and stored permanently.
2. accessibility: learners can easily access audio and video learning materials anywhere.
3. immediacy: learners can immediately access audio and video learning materials at any time and can get an immediate response from the test tool.
4. interactivity: learners can operate learning objects and interact with peers.
5. situation: learners practice listening and speaking in real situations.
6. seamlessness: the learning process is not interrupted when the location of the learners changes.
7. immersion: learners can talk with virtual teachers in the real world.
8. context awareness: learners can hear context-aware audio language materials in specific zones.
9. social interactivity: learners can collaboratively complete a story.
10. individuality: learners can select proper learning materials according to personal ability, interest, requirement, objective and schedule.

## The HELLO

The HELLO is composed of two subsystems: the HELLO server, a learning server, and u-Tools, a soft-

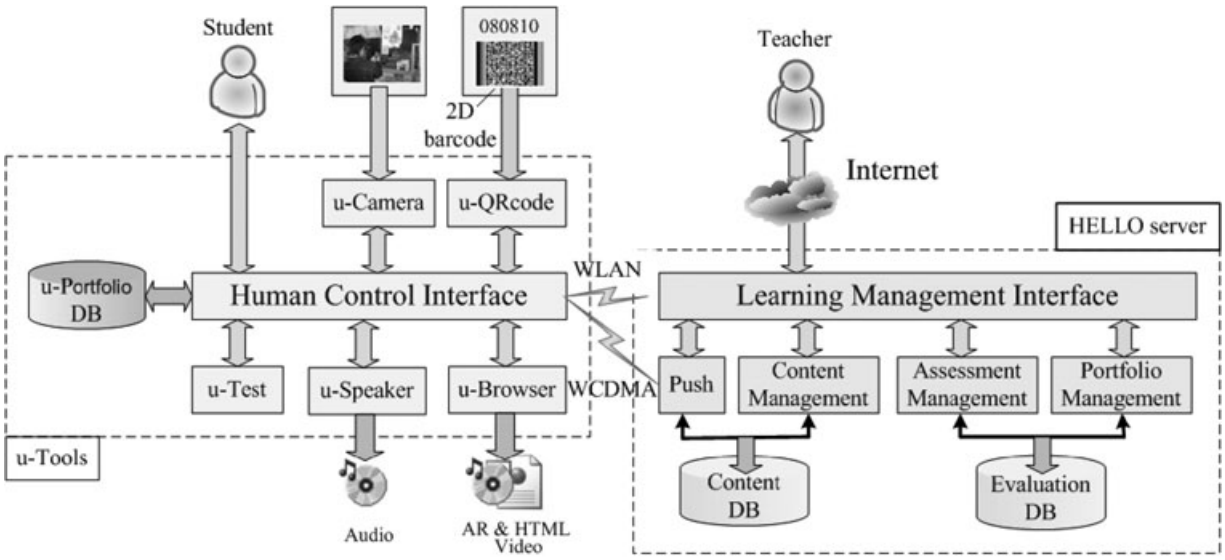


Fig 1 The architecture of HELLO.

ware application. Figure 1 illustrates the architecture of the HELLO. Teachers utilize a personal computer to connect with the HELLO server via the Internet. Teachers input materials and assessments into the Content Database through the Content Management Unit, Assessment Management Unit, and Push Unit (PU). Teachers can review students' portfolios and give grades through the Portfolio Management Unit. The PU automatically delivers a daily English sentence to students' personal digital assistant (PDA) phones via the Wideband Code Division Multiple Access (WCDMA) network in order to offer students practical conversation materials.

Each student has a PDA phone with which he or she can communicate with the HELLO server. From these phones, students can access materials via a wireless local area network (WLAN) and/or the WCDMA. Students utilize a u-Browser tool to download papers, news, learning games, English comics, English songs, listening materials and conversational materials from the HELLO server. They then use the u-Browser tool to play, listen to and watch the learning materials. Each student was provided a PDA phone in the vicinity of a zone that was attached to a 2-D bar code. The u-QRcode tool on the PDA phone used the phone camera to photograph the bar code and interpret the image as data. The data were used to access learning material from the relevant server in the location and display it on the phone. Students utilize the u-Speaker to talk to the virtual learning tutor (VLT) that appears on the PDA phone. The u-Speaker tool superimposes the VLT on the learning zone image (captured from the u-Camera); this makes students feel as though they are talking to a person in the real world. For the bar code and VLT, it would be helpful to show a sequence of screenshots to illustrate the user interface and interactions. In addition, students can use the u-Test tool to take tests and evaluate their learning progress. Students' learning records can then be stored in the u-Portfolio after students finish their learning tasks. Upon completion, the students' learning portfolios can be uploaded into the Evaluation Database of the HELLO server, making them available for teachers to review.

## Methods

A series of controlled experiments was conducted with high school juniors. A formal assessment was performed in order to evaluate the students' learning progress at the end of each stage. After the experiments were completed, a questionnaire was given to the students; this helped evaluate the success of the HELLO in improving students' learning motivation and effectiveness.

### Participants

The participants included three teachers and 64 seventh grade students of 13 or 14 years of age from Taipei

Municipal Hongdao Junior High School. The students were split into groups of eight. Two of the teachers had taught English for more than 10 years at the junior high school. All three participating teachers had at least 2 years of experience in computer-assisted instruction. One teacher had taught computer classes for more than 5 years; he installed, managed and maintained the computer system for the study. In Taiwan, students begin to learn English in the first grade and begin to learn computer science in the third grade; therefore, from an early age, students acquire the basic skills needed to use information technology to assist with English learning.

### Equipment

The students used PDA phones to perform the outdoor learning activities. The HELLO server station was composed of a desktop computer equipped with Windows 2003, SQL server 2005 and an Internet connection. The PDA phone was a wireless enabled Dopod CHT 9100 PDA phone (High Tech Computer Corporation, Taiwan) with Windows Mobile 5, wireless LAN (IEEE 802.11B), Bluetooth, external camera and 1 G memory card. Additionally, many Quick Response (QR) code tags were attached on numerous information boards. Each board was placed on the walls of a specific learning zone such as a library. Each QR code tag was associated to a web link (such as http://www.hello.edu.tw/material/library/index.htm) that pointed to the location of the relevant learning material.

### Experimental design

This study adopted a quasi-experimental design for non-equivalent groups. The students were randomly assigned to either an experimental group or a control group; the experimental group used the HELLO, while the control group used traditional learning methods (using printed materials and CD players). The two groups used the same course content, although the interfaces they used during the classes were different. This study conducted a pre-test, three tests and a post-test for both groups for 8 weeks. The goal of the tests was to evaluate the students' skills in listening and speaking, with the base of necessary phonetics, large vocabulary and good grammar. Each specifically designed test had two sections: listening and speaking. The test score, ranging from 0 to 100, was given by each teacher.

This study adopted Cronbach's $\alpha$ coefficient in order to evaluate the internal consistency reliability of the assessments. Cronbach's $\alpha$ coefficient ranges between 0 and 1; Nunnaly (1978) stated that 0.7 is an acceptable minimum reliability coefficient. The internal consistency reliability of the pre-test, test no. 1, test no. 2, test no. 3 and the post-test were 0.78, 0.74, 0.82, 0.84 and 0.81, respectively, with 64 samples. All the Cronbach's $\alpha$ values of the tests exceeded 0.7, indicating the high reliability of the tests used in this study. An independent two-sample *t*-test was adopted in order to show whether or not the pre-condition of the two groups was significantly different. After the experiments were completed, analysis of covariance (ANCOVA) was used in the remaining activities to test the difference between the two groups in each test, with the previous test as a covariance.

### Course design

The curriculum included topics related to the classroom, gallery, library, gym, laboratory, cooperative (a shop), stationery store and health centre zone. An eight-week experiment was conducted during class time. The curriculum named 'My Campus' was designed in five phases as shown in Table 2. Context-aware, immersive and collaborative learning concepts were also adopted in designing the curriculum. The learning goals of this curriculum were as follows: to enhance English learning, to increase English learning interest and motivation through the designed learning games and to enable the students to learn in a real environment by using ubiquitous computing, sensor and AR technologies. The students were asked to learn conversations related to the zones. Table 3 represents a sample of dialogue.

The curriculum used tests to evaluate the students' learning achievement. The goal of the tests was to evaluate the students' English listening and speaking skills. Each test includes a listening and a speaking section. The listening section was composed of twenty questions. The students listened to the questions and then wrote down their answers by selecting from multiple choice options on the question papers or on a PDA phone. Table 4 demonstrates a sample question. The speaking section was composed of 10 questions. The students listened to the questions and recorded spoken answers on a voice recorder or PDA phone.

Table 2. The course design.

| Learning phase/group | Control group | Experimental group | Learning objective |
|---|---|---|---|
| Preparation phase (week 1) | The teachers explained the experimental objectives and evaluation methods. The teachers administered a pre-test. | The teachers explained the experimental objectives and evaluation methods. The teachers administered a pre-test. | Preparation task |
| Self-study phase (week 2–week 3) | The students used printed materials and audio CDs to learn. The teachers gave test no. 1. | The students employed the HELLO to play the game 'Campus Environment' in which they used PDA phones to listen to the audio materials. The teachers gave test no. 1. | Training listening ability |
| Context-aware immersive learning activity phase (week 4–week 5) | The students used printed materials and audio CDs to learn. The teachers administered test no. 2. | The students employed the HELLO to perform a context-aware immersive learning activity called 'Campus Life'. The teachers administered test no. 2. | Training listening and speaking ability |
| Task-based collaborative learning activity phase (week 6–week 7) | The students employed the digital voice recorder to perform a story relay race entitled 'Campus Story' in classroom. The teachers gave test no. 3. | The students employed the HELLO to perform a story relay race entitled 'Campus Story' in a real situation. The teachers gave test no. 3. | Training speaking and creation ability |
| Evaluation phase (week 8) | The teachers administered a post-test. | The teachers administered a post-test. | Evaluating outcome |

Table 3. Dialogue samples.

Zone: Gym
*Title: There's a big game in the gym today.*
*Learner: Wow! There are so many people in the gym.*
*Tutor: Yes, everybody knows it will be a great game.*
*Learner: Look at Tom. He's playing very well.*
*Tutor: Hey! He is trying to make a three-point shot.*
*Learner: Yeah! He made it. Cool!*
*Tutor: Will we win?*
*Learner: Of course, we will.*

Table 4. A sample question.

Zone: Cooperative
*Q: Can you smell that freshly baked bread?*
*(A) It's too early to take a break.*
*(B) Those fumes are going to kill you.*
*(C) Don't eat it if it's no fresh.*
*(D) It's making me hungry.*

## Procedure

During the preparation phase, the students were divided into control and experimental groups. The teachers administered a pre-test to the two groups in order to understand the prerequisite conditions of the students and explained the experimental purpose, goals, outlines and evaluation methods to the two groups. The teachers introduced the HELLO system and demonstrated how to use its learning tools.

During the self-study phase, the experimental group used the HELLO to execute self-learning. Each experimental group student had a PDA phone installed with u-Tools for English learning. The u-Tools included several tools that can be used to access self-study English songs, listening materials and conversational materials from the HELLO server via the WLAN. The self-study material was a learning game called 'Campus Environment'. A campus map appeared on the screen of each PDA phone after the students launched the game. The campus map contained numerous zones, each of which was clearly marked on the map. Figure 2 depicts a guide map for the 'Campus Environment' learning activity. The students clicked on the zone they desired, and the u-Browser then opened related materials. For instance, when a student selected the zone 'Library', a library appeared on the PDA phone. The student could then choose the multimedia room in order to hear an English conversation or watch an English movie clip. The key aspect of these options is that they enable students to learn without the constraints of time and place

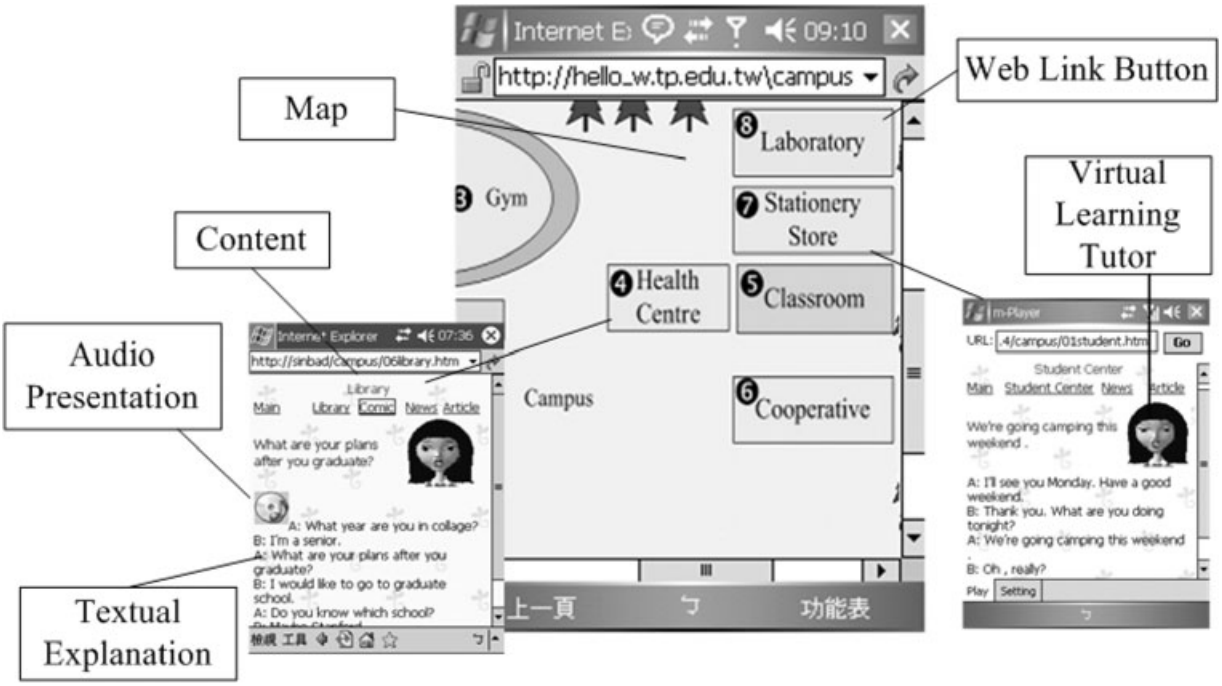


Fig 2 Map and learning materials for the 'My Campus' learning activity.

and without having to visit a real library. In contrast, the control group students learned zone-related audio conversations by using CD/MP3 players and printed materials in classroom. The teachers administered test no. 1 to both groups at the end of this phase.

During the context-aware immersive learning activity phase, the experimental group used the HELLO system to carry out a learning activity entitled 'Campus Life'. Figure 3 illustrates the context-aware u-learning scenario. Each student used a PDA phone installed with u-Tools and followed a guide map on the screen to perform learning activities. In order to approach the learning zones, each student followed the guide map on his or her PDA phone, which was equipped with a video camera and hooked up to the WLAN, in order to complete the learning process. For instance, when approaching the real 'Library' zone, a student could use his or her PDA phone to take a picture of the 2-D bar code beside the library and then decrypt the 2-D bar code. The detected identification of the bar code was then sent to the HELLO server, which located the student and returned a situation-related conversation material to his or her PDA phone. The VLT was then superimposed with the zone video on the PDA screen. The students then practiced a library-related conversation with the VLT, just as he or she would talk with a real person when practicing a conversation in the library. The students were thus able to access context-aware content related to locations, enabling context-aware immersive learning. Upon completing a conversation with the VLT in a particular zone, the student got a virtual golden coin and a hint related to the next zone, then proceeded to the next zone and continued until they had visited all the assigned zones. The student who got all the available virtual coins were eligible to receive a real gift as a reward. Meanwhile, the control group continued to use CD/MP3 players and printed materials to learn conversations in the classroom.

In contrast, the students in the control group listened to the zone-related audio conversations using CD/MP3 players and printed materials in the classroom similar to those used by the experimental group. The teachers administered test no. 2 to both groups at the end of this phase.

During the task-based collaborative learning activity phase, the designed task was a story relay race entitled 'Campus Story'. Each team had to select five zones on the map, then each member had to visit one zone and create a piece of a story about each zone. Each member orally recorded the piece of a story on the PDA phone.

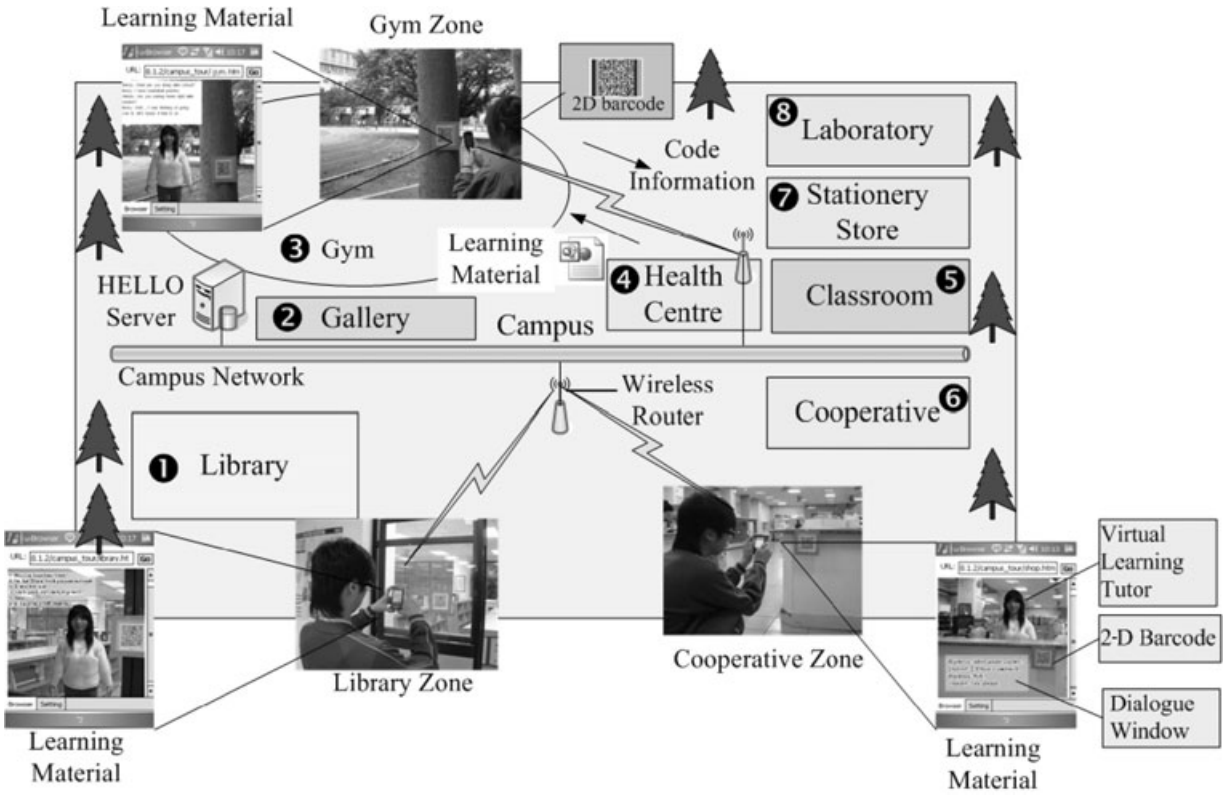


Fig 3 The scenario of the context-aware ubiquitous learning activity: students practice conversation with the virtual learning tutor at the learning zones.

Table 5. An example of a campus story.

| | |
|---|---|
| *Student 1. One morning, I heard a meow when I bought a pen in stationery store. I found a black cat crouching in the corner.* | *Student 4. One day, I saw 'Siao-Hei' appearing in front of the health centre. The cat took some bread and ran away.* |
| *Student 2. Next day, I saw the same black cat in my classroom. It looked very hungry, so I opened my lunch box and gave the cat a fish. I called it 'Siao-Hei'.* | *Student 5. I followed 'Siao-Hei' then entered into the cooperative. I found that 'Siao-Hei' was feeding her two little kittens. I gave the bread I had in my hand to 'Siao-Hei'. I hope her kittens can grow up soon.* |
| *Student 3. Several days away, my classmate said that he saw a dead cat under a tree beside the gym. When I went there, I noticed that dead cat was not 'Siao-Hei'. I was hoping that 'Siao-Hei' is still alive.* | |

Upon successfully completing a piece of a story in a given zone, each member handed off his or her baton (PDA phone) to the next member, who listened to the previous story and walked to the next zone, continuing in this manner until the team members had passed through their five selected zones. In contrast, the control group students completed stories by using digital voice recorders in the classroom. The teachers assigned a grade to each team depending on the creativity and quality of their story. Table 5 represents the best campus story created by the experimental group team no. 3.

During the evaluation phase, the teachers gave a listening and speaking test as a post-test to the students in order to evaluate the outcome of their learning. In order to understand the students' perception, interviews were conducted after the tests were completed.

## Results and discussion

An independent two-sample *t*-test was adopted to analyze both groups' pre-tests. The difference in average grades between the two groups in the pre-test ($t = -0.526$, $P = 0.601$) is non-significant, indicating that the prerequisites of the two groups of students were similar. In order to reduce the influence of the student prerequisites on the experiments, this study treated the pre-test as a control variable and omitted it. The result (significance > 0.05) of Levene's test for equality of variances, which indicates that the assumption of the homogeneity of variances in the groups is met. In addition, the test results (significance > 0.05) of between-subjects effects, which indicates the assumption of homogeneity of regression coefficients for the two groups, is satisfied for the rest of the tests. With this in hand, an ANCOVA analysis was performed using the pre-test as a covariate. Table 6 presents the mean grades and standard deviation of evaluations for each test. An effect size was adopted in order to measure the significance of the difference between the two groups' evaluation results. Cohen's *d* (Cohen 1992) is an appropriate effect size measure to use in the *F*-test. The values 0.2, 0.5 and 0.8 represent small, medium and large effect sizes, respectively (Thalheimer & Cook 2002).

In phase 1, the preparation phase, the teachers distributed a pre-test to both groups of students. In phase 2, the self-study phase, the ANCOVA result of test no. 1 ($F = 13.07$, $P < 0.05$, $d = 0.92$) indicated that the average grades of the experimental group exceeded those of the control group by about six points; this difference was significant because it demonstrated the effectiveness of the HELLO in improving learning. According to the interviews, this improvement occurred because the HELLO provides many interesting learning materials.

In phase 3, the context-aware immersive learning activity, the ANCOVA result of test no. 2 ($F = 20.17$, $P < 0.05$, $d = 1.14$) indicated that the average grade of the experimental group significantly exceeded (by 8.5 points) that of the control group. According to the interviews, this occurred because the HELLO provides an interesting context-aware immersive activity that can improve learning experience in listening and speaking, further increasing the students' results.

In phase 4, the task-based collaborative learning activity (a story relay race), the ANCOVA result of test no. 3 ($F = 11.68$, $P < 0.05$, $d = 0.87$) indicated that the average grade of the experimental group exceeded (by eight points) that of the control group. According to the interviews, this occurred because the experimental group students practised their speaking in real situations, collaborated on their tasks in real conditions and completed their creation in actual situations.

In phase 5, the evaluation phase, the ANCOVA result ($F = 15.56$, $P < 0.05$, $d = 1.00$) indicated that the average grade of the experimental group significantly exceeded (by eight points) that of the control group in the post-test.

Figure 4 plots the error bar chart of the grades of the two groups. The bar chart of the experimental group shows that the average grade gradually increases and is higher than the control group's average grade, further indicating that the learning of the experimental group is better than that of the control group. This also indicates that the HELLO substantially improves the effects of all learning activities.

Table 6. Mean grades and SD of evaluations for each test ($N = 64$), $F_{0.95}(1,61) = 4.00$.

| Item | Experimental group | | | Control group | | | *F* | Effect size |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | SE | Mean | SD | SE | | |
| Pre-test | 74.06 | 11.32 | 2.00 | 75.47 | 10.03 | 1.77 | | |
| Test 1 | 82.03 | 5.37 | 0.95 | 76.66 | 6.35 | 1.12 | 13.07* | 0.92 |
| Test 2 | 86.88 | 7.04 | 1.24 | 78.44 | 7.77 | 1.37 | 20.17* | 1.14 |
| Test 3 | 85.63 | 9.57 | 1.69 | 77.53 | 9.76 | 1.72 | 11.68* | 0.87 |
| Post-test | 89.44 | 7.45 | 1.32 | 81.25 | 9.59 | 1.70 | 15.56* | 1.00 |

*$P < 0.05$.

SD, standard deviation; SE, standard error.

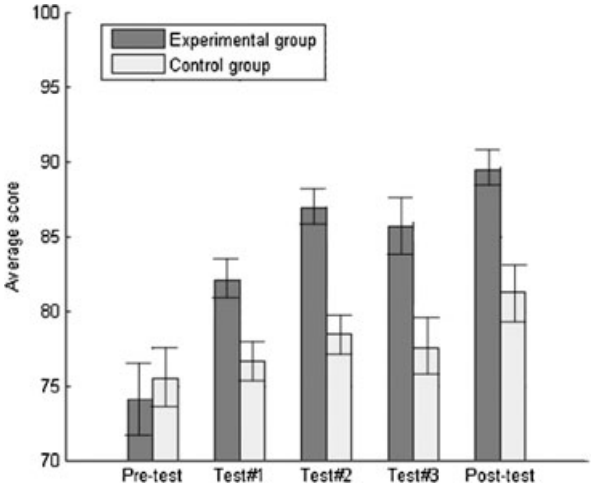


Fig 4 Error bar chart of the two groups' average grades.

## Conclusions

This study has constructed a sensor and handheld augmented reality (AR)-supported English learning environment called the HELLO, which provides effective learning resources and functions that assistance with the learning of English listening and speaking. A case study was performed with the participation of three high school teachers and 64 high school juniors from the Taipei Municipal Hongdao Junior High School. The learning activities occurred at the junior high school campus. Context-aware ubiquitous pedagogic strategies were adopted; a self-study learning game called 'Campus Environment', a context-aware learning game called 'Campus Life', a story relay race named 'Campus Story' and a series of formative tests were used during the eight-week course.

The experimental results show that the average grade on assessments of the experimental group exceeded that of the control group in test nos. 1, 2 and 3, and the post-test. The measured effect size reveals that the tests taken by the experimental group in all the learning activities were significantly better than those of the control group. According to the interviews, most of the experimental group students thought that practicing English in a real-life situation could not only improve their learning but also encourage their creative abilities, further demonstrating the HELLO's effectiveness in language learning. In summary, using the HELLO to conduct context-aware immersive u-learning can provide enjoyable and effective English learning experiences. Moreover, this work demonstrates that sensor, AR and ubiquitous technologies are useful in providing context-aware immersive u-learning experiences in English-learning activities.

Nevertheless, we also discovered some constraints with the HELLO when applied as a support for outdoor learning. These constraints include an insufficient size of memory, an insufficient computing efficiency, a small screen size, an unclear display under strong sunlight and a short battery life. This learning process was not long, but the students' precious experience with using technology to support their learning will definitely affect their learning in the future. This is another reason for which we applied context-aware ubiquitous computing to support language learning.

In future research, we will continuously work with high school English teachers to conduct full-scale studies and to investigate the practicality of the HELLO in effective learning activities, and adjust the HELLO to adapt to the individual student's needs, interests, styles and learning capacities.

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