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Development of a ubiquitous learning platform based on a real-time help-seeking mechanism

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Abstract

The popularity of mobile devices has encouraged the advance of ubiquitous learning, in which students are situated in a real-world learning environment with support from the digital world via the use of mobile, wireless communications, or even sensing technologies. Most of the ubiquitous learning systems are implemented with high-cost sensing devices for detecting the locations or behaviours of learners; moreover, these systems mainly focus on providing learning guidance or learning materials, while facilities for supporting mutual help among students are usually ignored. In this study, we propose a context-aware ubiquitous learning platform (CULP) which uses low-cost cell phones with embedded cameras and Internet service to support ubiquitous learning. CULP is able to provide instant support for learners in the ubiquitous learning activity; that is, learners can receive help from the right people via the hints given by the learning system when they encounter problems during their learning activities. The experimental results of a Personal Computer-Assembling course show that, with the assistance of the new learning platform, both the learning efficiency and the learning achievement of the students were significantly improved.

Background and motivation

In recent years, the learning environment has changed and shifted from traditional classrooms to online learning, mobile learning (m-learning) and even ubiquitous learning (u-learning) via employing various new learning devices and technologies (Ley, 2007; Chu, Hwang, Huang & Wu, 2008). For example, some existing ubiquitous learning environments have been implemented with sensing technology for detecting the locations of students by identifying signals from learning objects in real-world environments (Borriello, 2005; El-Bishouty, Ogata & Yano, 2008; Liu, Chu, Tan & Chang, 2007; Sakamura & Koshizuka, 2005), and personalised digital assistants (PDAs) with wireless networks to provide learning guidance and supplementary materials to the students (Chu, Hwang & Tsai, 2010; Hwang, Kuo, Yin & Chuang, 2010). Such a learning approach that employs mobile, wireless communication and sensing technologies has been called *context-aware ubiquitous learning* (Hwang, 2006; Hwang, Tsai & Yang, 2008).

Among the context-aware u-learning technologies, the technology for determining the geographical location of learners, called location-aware technology (LAT), has played an important role in enabling the provision of effective support by the learning system. LAT can either detect the learners' locations in order to provide relevant content at the right time, or to identify the learning objects that are close to the learners. In the past decades, most of the ubiquitous learning systems have been designed with radio frequency identification (RFID) or global positioning system (GPS) as the location-aware device (Chen, 2005; Chu *et al.*, 2010; Peng *et al.*, 2009; Yang, 2006).

Although researchers have demonstrated the benefits of context-aware ubiquitous learning, previous experiences relating to conducting relevant learning activities have also revealed some problems and barriers when applying this approach (Chen, Hwang, Yang, Chen & Huang, 2009). One of the problems is a lack of instant support when conducting collaborative learning (El-Bishouty *et al.*, 2008; Miyata & Kozuki, 2008); another problem concerns the cost of the sensing technologies and the mobile learning devices. Therefore, it is important to take the cost of the learning devices and the provision of collaborative functions into account when conducting context-aware ubiquitous learning activities (Hwang, Yang, Tsai & Yang, 2009).

In the meantime, researchers have emphasised the importance of conducting collaborative learning activities such that students can share knowledge, interact, collaborate and exchange individual experiences (El-Bishouty *et al.*, 2008; Roschelle, Rosas & Nussbaum, 2005). One of the main goals of ubiquitous learning is to deliver appropriate and timely information in the right place and at the right time; nevertheless, the information required to facilitate the collaboration of peers is usually not provided by the existing ubiquitous learning systems. If collaborative support can be instantly provided, the efficiency of ubiquitous learning could be significantly improved.

In terms of the cost issue, it is impractical to assume that the students will use high-cost devices or devices that are rarely used, such as PDAs and RFID readers. If the cost of mobile devices could be reduced, more students would be able to learn with this new approach. Therefore, it could be a good alternative to use cell-phones with QR-code technology as mobile learning devices, thus greatly reducing the barriers of promoting context-aware ubiquitous learning. A QR-code is a two-dimensional bar code proposed by Denso Wave (a Japanese company) in 1994. The term 'QR' represents 'Quick Response'. It is a matrix-like symbol that can be easily interpreted by scanner equipment, such as the digital camera, which is practically standard equipment for cellular phones. Therefore, using QR-code would significantly reduce the cost of context-aware ubiquitous learning since the mobile device (cellular phone) is popular and no extra cost is needed for the sensing or scanner equipment.

In this study, a context-aware ubiquitous learning platform (CULP) is proposed to support collaborative ubiquitous learning via the provision of an instant help-seeking function. A context-aware ubiquitous collaborative learning environment has been developed by employing low-cost mobile devices and sensing technology (ie, cellular phones and QR-code) based on CULP. Moreover, an experiment has been conducted to evaluate the performance of this innovative approach.

Relevant works

In the past decades, various issues concerning ubiquitous learning have attracted the attention of researchers from both the fields of computer science and education. In the following, we shall briefly introduce several well-known mobile and ubiquitous learning systems and compare their functions and characteristics, including

1. TANGO (Tag Added learNinG Objects): A ubiquitous learning system proposed for tackling the issues of learning at the right time and in the right place within a ubiquitous environment (Ogata & Yano, 2004). It provides a bulletin board system and a real-time chat tool.

Table 1: Comparison of the technologies used in various context-aware u-learning systems

	TANGO	*Musex*	*PERKAM*	*PPM*	*MoULe*	*PMDS*
Learning device	PDA	PDA	PDA	PDA	Smart phone	Mobile phone
Location-aware technology	RFID	RFID	RFID	RFID &GPS	GPS	QR-code
Availability	Low	Low	Low	Low	Medium	High
Cost	High	High	High	High	medium	low
Communication device	PDA	Transceiver	PDA	PDA	Smart phone	No
Instant help	Yes	Yes	No	Yes	Yes	No

PDA, personalised digital assistant; RFID, radio frequency identification; GPS, global positioning system; QR, quick response.

2. Musex: A collaborative learning system for supporting children in learning and exploring collaboratively in a museum with two PDAs (Yatani, Onuma, Sugimoto & Kusunoki, 2004). Children are usually divided into pairs or teams while learning with this system. The objective is to visit the points marked on the map as quickly as possible. At each point, children are given a task such as answering a question or playing a game. Musex also provides visualisation of the user's status on the PDA to support awareness and interaction between users. However, the instant help with oral messages can only be provided between group partners, and it requires two PDAs and transceivers for system operation.
3. PERKAM (PERsonalized Knowledge Awareness Map): A learning system proposed to tackle the issues of seeking knowledge in a ubiquitous environment (El-Bishouty, Ogata & Yano, 2006). It allows the learners to seek knowledge, to share knowledge, and to exchange individual experiences among peers. Moreover, a personalised knowledge awareness map is created according to each learner's interest and location. The learners specify their requests with keywords, and the system will recommend some appropriate educational materials and helpers nearby. However, in this system, the users need PDAs to access the system; moreover, no support is provided for instant online help.
4. PPM: A ubiquitous learning platform that supports learning indoors with RFID readers and outdoors with GPS, personal annotation management, and real-time group discussion (Yang, 2006). However, there is the added cost of the RFID readers and GPS for the learners to use this system.
5. MoULe: A mobile and ubiquitous Learning project for supporting students in collaborative knowledge construction via context-aware handheld devices. It supports collaborative knowledge construction with conceptual maps and collaborative creation of hypertext documents via instant messaging and chat rooms. However, this system requires smart-phones with GPS to access the system. Thus, there are extra costs for the learners.
6. PMDS: The picture mail database system (PMDS) for improving the quality of university lectures, especially communication between the teacher and students during mass lectures (Miyata & Kozuki, 2008). It allows students to submit, search for, extract and view pictures using mobile phones during lectures. Moreover, students can share knowledge via pictures and text. The students can conveniently use learning devices to submit data via QR-code. However, this system does not provide an instant help mechanism.

In Table 1, these previous studies are summarised and compared based on six dimensions, that is, learning device, location-aware technology (LAT), availability, cost, communication device and instant help. From Table 1, it can be seen that the approach used in PMDS could be a better choice

Table 2: Relationships between modules

Module name	*Input operation*	*Output operation*
QR-code module	Read a QR-code	Obtain a URL + parameter
Reading material module	Obtain the URL parameter	Display relevant content
Experienced peer selection module	Receive requests for seeing helpers	Store this request in the database.
Discussion module	Receive requests for help	Store discussion messages in the database
Message informing module	Retrieve query information from the database	Send out messages to the helpers
Request responding module	Receive requests for help	Select a requester
ASOS module	Read information about the helper	Inform the requester
Content management module	Get the content from teachers	Store the content in the learning content database
Learning activities recording module	Get learners' learning activity records	Store the records in the learning portfolio database
User profile management module	Get user's profile	Store the profile in the database

ASOS, Answer the System Online Support request; QR, quick response; URL, Uniform Resource Locator.

from both aspects of high availability and low cost; however, it does not provide collaborative support via instant help. To cope with this problem, in this study, we propose a CULP which provides collaborative support via instant help with high availability and low cost.

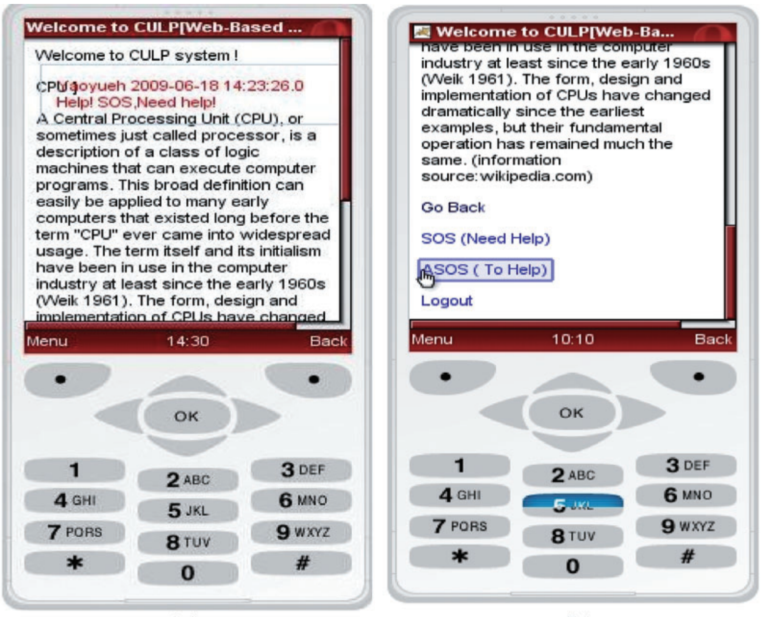
The ubiquitous learning platform with help-seeking mechanism

In this study, a CULP is proposed to provide instant help to the students when they participate in context-aware u-learning activities. Moreover, mobile phones with built-in camera and QR-code reader are used as the learning devices. That is, no extra cost is needed for learning ubiquitously. CULP is developed with Java Servlet API (Sun Microsystems, 4150 Network Circle, Santa Clara, CA 95054 U.S.A.). Moreover, AJAX (Asynchronous JavaScript and XML) technologies are used for processing online help (SOS, System Online Support) instantly. The database is developed using Microsoft SQL 2000. Table 2 summarises the functional modules and the corresponding input/output operations in CULP.

After logging into the system, learners are asked to complete the learning task, that is, 'the assembly of a computer'. When encountering problems during the learning activity, the learners can request real-time help from experienced peers. Via the assistance of CULP, the information of the potential helpers who have sufficient experience and ability to give help is shown in Figure 1a. The potential helpers who receive the request can show their willingness to provide assistance to the learner by pressing the ASOS (Answer the System Online Support request) button, as shown in Figure 1b. Usually, those learners who are experienced with the learning content and are located near the help-seeker will be recommended first, so that assistance can be provided either online or face to face.

Experiment design

In order to evaluate the performance of CULP, a learning activity was conducted; in addition, a questionnaire was administered to collect feedback from the participants. The learning activity is concerned with PC-DIY (Personal Computer- Do It by Yourself, the assembly of personal computers). The students need to identify each part of a personal computer (such as central processing unit, random-access memory, hard disk drive, compact disc read-only-memory, floppy disk,



(a) (b)

Figure 1: Interface for seeking help requests and responding to the requests

recovery card, power supply, monitor, keyboard and mouse) and assemble those parts into a workable computer.

The learners were 58 freshmen from a university in Taiwan. The students were 18 years old, on average, and were taught by the same teacher. They were randomly divided into two groups: the control group and the experimental group. Each group had 29 students. In order to implement the experiment, we also designed a questionnaire to collect feedback from the experimental group students. The questionnaire includes six dimensions, that is, 'Usefulness of CULP functions', 'Ease of use of the CULP user interface', 'Usefulness of the supplementary materials provided by CULP', 'Perceptions of the CULP system performance', 'Attitudes toward the use of CULP' and 'Overall Perceptions'. Each questionnaire item is presented by a five-point Likert scale, where '5' represents 'strongly agree' and '1' represents 'strongly disagree'. The Cronbach's alpha values for these dimensions are 0.876, 0.935, 0.951, 0.942, 0.893 and 0.91, respectively, and that of the questionnaire overall is 0.959. In addition, the midterm test conducted before the experiment was adopted as the pretest, and a posttest was conducted after the experiment for evaluating the learning achievement of the students.

Before the experiment, a training course regarding students' Internet service ability and QR-code reader installation in their mobile phones was held. Before the training course, some QR-code reader software was downloaded and stored on a web site, making it easy to install the QR-code readers.

The students in the control group were asked to learn with the traditional instructions of the PC-DIY lab-lecture. Basically, a teaching assistant (TA) explained the safety precautions and introduced PC knowledge, and then showed how to assemble and disassemble a PC. Later on, the students were asked to do it by themselves. If they had any questions, they were allowed to ask the TA. On the other hand, the students in the experimental group had the same PC-DIY lab-lecture but with CULP system assistance. As with the control group, a TA explained the

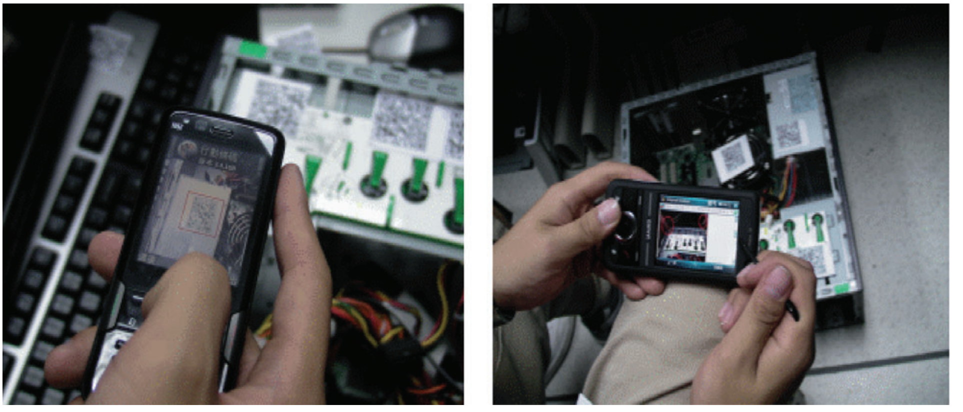


Figure 2: Learning scenarios of the PC-DIY (Personal Computer- Do It by Yourself) ubiquitous learning activity

Table 3: t-test results of learning efficiency for the experimental group and control group

Group	*n*	*M*	*SD*	*t*
Experimental group	29	42.41	11.160	−6.328***
Control group	29	62.52	12.969	

***$p < 0.001$.
SD, standard deviation.

safety precautions, introduced PC knowledge, and showed how to assemble and disassemble a PC. Later on, the students were asked to do it by themselves. In contrast with the control group, however, they were allowed to ask for help either from the TAs or via CULP when encountering any problems during the learning activities.

Figure 2 shows the learning scenarios of the context-aware u-learning activity. In the next section, we present the quantitative and qualitative analysis of the experimental results.

Experimental results

To evaluate the performance of our approach, we analyse the experimental results both quantitatively and qualitatively.

Learning efficiency

According to our records, the finish time for these groups was counted and compared. The finish time is the period of time taken from students starting to disassemble their PC, through reassembly and TA's verification. The experiment took place on 3 December 2008 for the control group and on 4 December 2008 for the 29 students in the experimental group.

Table 3 shows the *t*-test result of the finish time for both groups. The finish time is used as an indicator for evaluating learning efficiency. The smaller value a group gains, the better learning efficiency it represents. Thus, the analysis of the result suggests that the difference in the time needed to learn the subject materials between the two groups is significant ($t = -6.328$, $p < 0.001$). That is, the students in the experimental group achieved better leaning efficiency by learning with CULP assistance; the experimental group finished the assembly task in nearly 30% less time than the students in the control group.

Table 4: Descriptive data and analysis of covariance of the posttest results

Variable	Group	n	M	SD	Adjusted mean	SE	F
Posttest	Experimental group	29	75.45	19.95	80.377	2.386	14.859***
	Control group	29	73.10	27.11	67.175	2.386	

***$p < 0.001$.
SD, standard deviation; SE, standard error.

To sum up, the *t*-test results for the learning efficiency of the experimental and control groups show a significant difference. Hence, we suggest that a learning environment with CULP is helpful to students' learning.

Learning achievement

To better gauge the effectiveness of CULP, the learning achievement of the students was evaluated. The midterm test of the computer course was taken as the pretest of the experiment. It consisted of 20 multiple-choice questions and five short-answer questions to test the students' basic knowledge about the computer components and their usage. The *t*-test was performed on the pretest scores to compare the computer knowledge of the students. It was found that there was no significant difference in the computer knowledge of the two groups of students before participating in the learning activity ($t = -1.856$, $p > 0.05$).

After conducting the learning activity, a posttest was performed to evaluate the learning achievement of the students. It consisted of 25 multiple-choice questions and 10 short-answer questions about computer architecture and the function of each computer component. An analysis of covariance (ANCOVA) was performed on the posttest scores, in which the pretest was the covariance, the posttest scores were the dependent variable and the 'different learning strategies (two groups)' were the fixed factor, to test the relationships between the posttest scores of the two groups. The ANCOVA results in Table 4 showed that the learning achievements of the experimental group students were significantly better than those of the students in the control group. Therefore, it was concluded that CULP was helpful to the students in improving their learning achievement in comparison with the traditional learning approach.

Questionnaire survey

In order to evaluate CULP, we designed a questionnaire for the experimental group. The students filled out this survey after finishing their PC-DIY lab-lecture. Table 5 shows the descriptive statistics of the questionnaire items. It can be seen that the students gave positive feedback for all dimensions.

For the 'Usefulness of CULP functions' dimension, the item P1-1 'Browsing materials function for the PC-DIY practice' function gets the highest rating (3.89), while P1-2 'SOS help function for the PC-DIY practice' function gets the lowest rating (3.68), implying that the students prefer to get help from the learning system instead of from their peers. Therefore, it is worth developing a frequently asked questions (FAQ) database to give more support to the students.

For the 'Ease of use of the CULP user interface' dimension, the items P2-3 'The SOS function is easy to use' and P2-4 'The answering SOS function is easy to use' get the lowest ratings (3.71 and 3.64), which can help explain why the students hesitate to get help from their peers. That is, the SOS and the ASOS interfaces need to be improved in order to encourage the students to collaborate with their peers. In the meantime, it is found that the acceptance degree of the low-cost sensing technology (ie, QR-code) is high (3.86), although the response time for such technology

Table 5: Questionnaire for CULP learners

Question	n	M	SD
Part 1. Usefulness of CULP functions		3.79	0.539
P1-1: The browsing materials function is helpful for the PC-DIY practice	28	3.89	0.497
P1-2: The SOS help function is helpful for the PC-DIY practice	28	3.68	0.548
P1-3: The answering SOS help function is helpful for the PC-DIY practice	28	3.82	0.612
P1-4: Overall, the CULP System is helpful for the PC-DIY practice	28	3.79	0.499
Part 2. Ease of use of the CULP user interface		3.80	0.761
P2-1: QR-code is easy to use	28	3.86	0.932
P2-2: The content browsing function is easy to use	28	3.89	0.629
P2-3: The SOS function is easy to use	28	3.71	0.763
P2-4: The answering SOS function is easy to use	28	3.64	0.826
P2-5:Overall, the CULP System user interface is easy to use	28	3.89	0.629
Part 3. Usefulness of the supplementary materials provided by CULP		3.95	0.579
P3-1: The safety precautions teaching content for PC-DIY practice is helpful	28	4.07	0.539
P3-2: The boot problem detection teaching content for PC-DIY practice is helpful	28	4.07	0.539
P3-3: The CPU teaching content for PC-DIY practice is helpful	28	3.93	0.539
P3-4: The RAM teaching content for PC-DIY practice is helpful	28	3.93	0.663
P3-5: The HDD teaching content for PC-DIY practice is helpful	28	3.93	0.604
P3-6: The CDROM teaching content for PC-DIY practice is helpful	28	3.96	0.508
P3-7: The floppy teaching content for PC-DIY practice is helpful	28	3.96	0.508
P3-8:The discovery card teaching content for PC-DIY practice is helpful	28	4.00	0.544
P3-9: The power supply teaching content for PC-DIY practice is helpful	28	3.89	0.685
P3-10: The monitor teaching content for PC-DIY practice is helpful	28	3.93	0.591
P3-11: The keyboard teaching content for PC-DIY practice is helpful	28	3.86	0.591
P3-12: The mouse teaching content for PC-DIY practice is helpful	28	3.86	0.591
Part 4. Perceptions of the CULP system performance		3.68	0.811
P4-1: I am satisfied with the connection speed of CULP	28	3.68	0.772
P4-2: I am satisfied with the stability of the CULP connection	28	3.68	0.863
Part 5. Attitude towards the use of CULP		3.67	0.649
P5-1: I will use CULP to obtain the necessary PC-DIY practice content	28	3.71	0.600
P5-2: I will use the SOS function of CULP to get help from my classmates	28	3.75	0.585
P5-3: I will use the answering SOS function of CULP to help other classmates	28	3.61	0.629
P5-4: If given the chance, I am willing to re-use CULP assisted learning	28	3.61	0.786
Part 6. Overall perceptions		3.89	0.677
P6-1: Generally speaking, I am satisfied with the CULP system	28	3.93	0.716
P6-2: I am willing to use mobile devices to support learning	28	3.82	0.723
P6-3: I am willing to use the QR-code–related mobile services	28	3.93	0.604

PC-DIY, Personal Computer- Do It by Yourself; SOS, System Online Support; CULP, context-aware ubiquitous learning platform; QR, quick response; CPU, central processing unit; RAM, random-access memory; HDD, hard disk drive; CDROM, compact disc, read-only-memory.

is a little bit longer. Such a finding could be a good reference for those who intend to develop mobile learning systems with sensing technologies.

For the 'Usefulness of the supplementary materials provided by CULP' dimension, the questionnaire items have relatively high ratings (from 3.86 to 4.07), conforming to the finding in the 'Usefulness of CULP functions' dimension that the students prefer to get instructions from the supplementary materials provided by the learning system.

The 'Perceptions of the CULP system performance' dimension gets a relatively low rating (3.68), implying that the performance of the low-cost mobile devices (ie, the cellular phones owned by the students) is currently not satisfactory; however, this problem could be overcome soon owing to the rapid development of mobile and wireless communication technologies.

In addition, the 'Attitude toward the use of CULP' gets the lowest rating (3.67) among the six dimensions, which also conforms to the findings in the 'Usefulness of CULP functions' and the 'Usefulness of the supplementary materials provided by CULP' dimensions.

Finally, in the 'Overall Perceptions' dimension, the ratings of the questionnaire items 'P6-1: Generally speaking, I am satisfied with the CULP system', 'P6-2: I am willing to use mobile devices to support learning' and 'P6-3: I am willing to use the QR-code–related mobile services' are 3.93, 3.82 and 3.93, respectively. This implies that most of the students are satisfied with CULP and have shown quite positive feedback regarding its usefulness.

Conclusions and future work

In this study, we propose a CULP, which uses low-cost mobile phones equipped with cameras and wireless communication facilities to support ubiquitous learning. Moreover, QR-code technology is adopted to identify the learning objects. The use of these low-cost and popular technologies makes CULP more available than most of the previously developed u-learning systems. In addition to the consideration of availability, CULP provides a real-time help-seeking function to support collaborative learning in an authentic environment.

To evaluate the efficacy of CULP, an experiment was conducted to compare the performance of the students' learning via this platform with those learning with the traditional approach. It was found that the experimental group finished the assembly job in nearly 30% less time than the students in the control group. The *t*-test result on the time for completing the learning task showed significant difference between the two groups of students, implying that learning with CULP was helpful to the students in improving their learning efficiency.

Moreover, from the ANCOVA results on the pretest and the posttest scores, it was found that the learning achievement of the experimental group students was significantly better than those in the control group. In addition, the questionnaire survey showed that the students were satisfied with the assistance and instructions provided by CULP.

The proposed approach can be applied to other courses concerning procedural operations, skills training, or object identification and classification, such as Chemistry experiments, in which students might require assistance from peers during the learning process. Before applying this approach, several items need to be prepared or conducted:

1. A server for executing the learning system.
2. An available learning environment with a wireless communication network.
3. Clear instructions about the objectives and criteria of the learning activity.
4. A database containing the learning status of each student.
5. Instructions about how to download and install and QR-code software.
6. Instructions about how to use each function of CULP.

It is also interesting to find from the questionnaire survey that the 'Usefulness of the supplementary materials provided by CULP' dimension had the highest rating, implying that most of the students preferred to get help from the learning system instead of from peers. This finding conforms to those reported by several studies (Chu, Hwang, Tsai & Chen, 2009; Hwang, Yin, Wang, Tseng & Hwang, 2008; Tseng & Hwang, 2007).Therefore, it is worth enhancing the learning support function by providing a FAQ database. Moreover, as CULP provides an online discussion function that allows students to share knowledge and skills during the learning process in addition to the help-seeking mechanism, it would be interesting to apply CULP to some collaborative mobile/ubiquitous learning activities, which have been reported to be effective in improving the knowledge and skills of students (Fischer, Bruhn, Grasel & Mandl, 2002; Nussbaum *et al.*, 2009).

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