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A Context-Aware Ubiquitous Learning Environment for Enhancing Science Inquiry Ability of Students via On-Site Device Operating

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Abstract: Enhancing science inquiry ability of students has been recognized to be one of the most important education issues nowadays. Although various simulation programs have been developed for training science knowledge and ability, several problems have been revealed in practical learning activities. One major problem is owing to the lack of experiences in practical applications for what have learned from the textbooks. To deal with this problem, this study presents a context-aware ubiquitous learning system that employs Radio Frequency Identification (RFID) technology to detect and examine real-world learning behaviors of students and provide personalized learning guidance accordingly. Experimental results from a science course of an elementary school show that this innovative approach is able to improve the learning achievements of students as well as enhance their learning motivation.

Keywords: ubiquitous learning, sensing technology, context awareness, RFID

1. Introduction

In the past decade, various computer-assisted or web-based learning systems have been developed to provide a more adaptive learning environment with plenty of learning resources. Much attention has been focused on new learning strategies with appropriate software tools and environments [1], such as Computer scaffolding [2][3], the activity-theoretical approach [4], and Computer-Supported Intentional Learning Environments (CSILE database, e.g., [5]). These learning strategies have been applied, together with Internet access, in classroom teaching.

Several studies have demonstrated the benefits of computer- and network-based learning (e.g., [6][7][8][9]), but experienced educators have emphasized more the importance and necessity of "authentic activities" in which students are able to work with problems from the real world [10][11][12]. In order to situate students in authentic learning environments, it is necessary to place them in a series of designed lessons that combine both real-world and virtual learning environments [13].

Recently, the advance of wireless communication, sensing and ubiquitous technologies has provided unprecedented opportunities to carry out new learning strategies by integrating real-world learning environments and the resources of the digital world.

Thanks to these new technologies, individual students, by using a mobile device to access the digital content via wireless communications, are able to learn in real-world situations with support or instructions from the computer system. Moreover, the learning system is able to detect and record the students' learning behaviors in both the real world and the digital world with the help of the sensing technology. Such a sensing technology-enhanced mobile learning model has been called context-aware ubiquitous learning [13]. It not only provides learners with an alternative to deal with problems in the real world, but also enables the learning system to interact with the learners more actively [14][15].

Without proper support, the new learning scenario might become too complex for the students. Educators have indicated that "technologies should not support learning by attempting to instruct the learners, but rather should be used as knowledge construction tools that students learn with, not from" [16]. Computers, among the existing technologies, have been recognized as being a potential tool to support learning and instruction, such that the learners act as designers, and the computers function as tools for interpreting and organizing their personal knowledge [16] [17] [18]. Hence, it has become an important and challenging issue to develop personalized learning guidance systems to assist learners to interpret and organize their personal knowledge for mobile and ubiquitous learning.

In this paper, a ubiquitous learning system that employs RFID technology to detect the learning behaviors of students and provide learning guidance in the real world is presented. Moreover, a learning activity on a science course has been conducted to evaluate the effectiveness of the innovative approach in comparison with traditional approach. Those experiences could be helpful to those who intend to develop context-aware ubiquitous learning environments and activities.

2. Relevant research

Although technology-enhanced learning has been widely discussed and employed in past decades, researchers have indicated the necessity and importance of "authentic activities" in which students can learn to cope with problems in real-world environments [10] [13] [19]. Four criteria concerning the instructional design of situated learning have been pointed out as follows [13]:

(1) To select the situation or sets of situations that will afford the particular knowledge that the teacher wishes each student to acquire [20].
(2) To provide the necessary "scaffolding" for novices to operate in the complex realistic context and for experts to work in the same situation [3] [21] [22].
(3) To provide supports that allow teachers to track progress, assess information, interact knowledgeably and collaboratively with individual students or cooperating groups of students, and prepare situated learning activities to assist the students in improving their ability in utilizing skills or knowledge [23] [14] [24] [25].
(4) To define the role and nature of assessment and what it means to "assess" situated learning [26] [27].

In recent years, researchers have noticed the efficiency and popularity of mobile and sensor technologies. Several studies have been conducted to demonstrate the practice of those new technologies in supporting authentic learning. Chen, Kao, and Sheu [22] reported a mobile learning system that uses handheld devices for scaffolding students' learning about bird watching. Chen, Chang, and Wang [28] presented a learning environment to scaffold learners with mobile devices and sensor techniques. Chu, Hwang, Huang and Wu [29] demonstrated a technology-enhanced authentic environment where the learning system guided the students to learn in the real world with sensing technology, and detected the learning behaviors of individual students. It is obvious that guiding the students to learn in the real world with supports from the digital world has become an important and challenging issue. To effectively and efficiently assist students in interpreting and organizing their personal knowledge, the provision of knowledge construction tools is needed. The necessity of developing computer-assisted tools or environments to engage learners in constructive, higher-order, critical thinking about the subjects they are studying has been acknowledged [17]. Several recent studies have also demonstrated the effectiveness of applying computer facilities to provide personalized learning guidance [30]. Therefore, it has become an important and challenging issue to develop personalized learning guidance systems for ubiquitous learning with sensing technology.

In the following sections, we shall present a ubiquitous learning system that is able to provide personalized learning guidance in the authentic learning environment. In addition, the experimental results of conducting a learning activity on a science course are presented to demonstrate the effectiveness of this novel approach.

3. Ubiquitous learning Environment with RFID Technology

In this study, the authentic learning environment is a science park located at southern Taiwan. It contains various science devices, and nine devices concerning planetology, optics and electromagnetic induction have been selected as the target learning objects of this study. Each target object is labeled with an RFID tag, while each student holds a mobile device equipped with an RFID reader. In addition, wireless communication is provided to enable communication between the mobile device and the computer server that executes the learning system.

Figure 1. The context-aware ubiquitous learning environment

The students who participate in the learning activity are guided to learn to operate those devices in the science park. As they move around in the authentic learning environment, the learning system can detect the location of individual students by reading and analyzing the data from the nearest RFID tag. Accordingly, the learning system is able to actively provide personalized guidance or hints to individual students by interacting with them via the mobile device, as shown in Figure 2.

Figure 2. Authentic environment and learning scenario

Personalized Ubiquitous learning Guidance Mechanism

A personalized learning guidance mechanism was employed in developing the ubiquitous learning system for assisting the students to learn to operate those target devices by employing a cognitive apprenticeship approach [22] [23] [31]. We aim to provide systematic teaching and guidance for the learners, and opportunities of practicing learning tasks as well as reviewing learning processes. The flowchart of the learning guidance mechanism is given in Figure 3.

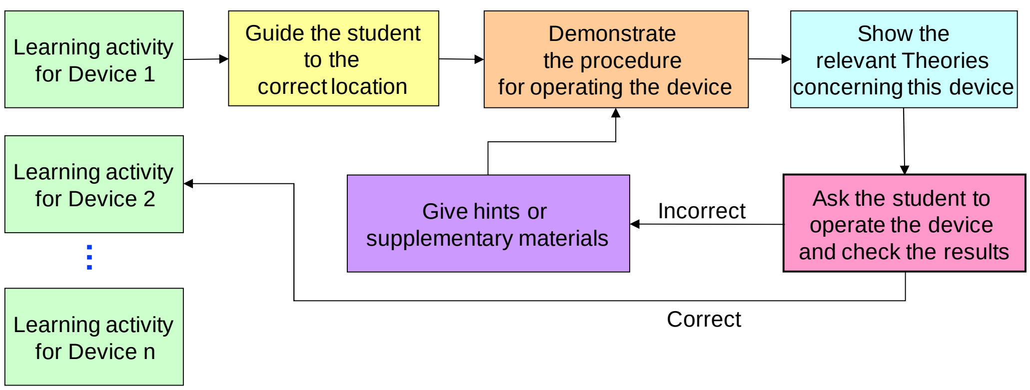


Figure 3. Personalized ubiquitous learning guidance mechanism

With the help of the sensing technology, the ubiquitous learning system can detect the location of individual students, and guide them to find the location of the target devices. Once a student arrives at a target device, a series of questions is presented to guide them to operate that device. Moreover, the learning system guides individual students in further learning based on their responses to the questions; that is, personalized guidance is provided. The details of the personalized ubiquitous learning guidance procedure are given as follows:

Step 1: Guide the student to find the location of the target device.
Step 2: Introduce the device.
Step 2.1: Demonstrate the functions of the device and show how the device can be operated.
Step 2.2: Present the theories and examples that are relevant to the device.
Step 3: Ask the student to operate the device and check if the results are correct.
Step 3.1: If the student fails to correctly operate the device (the results are incorrect), some hints or supplementary materials are given, and the student is asked to go to Step 2.

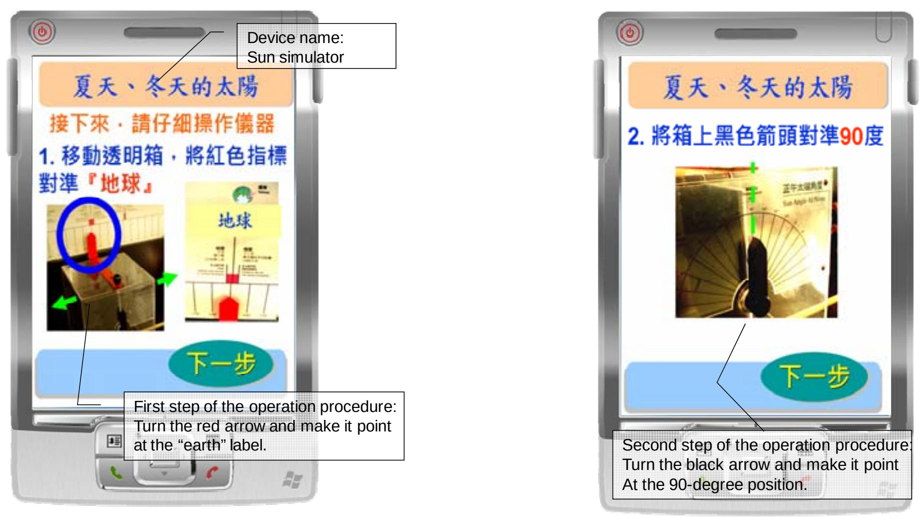
Step 3.2: If the student correctly operate the device (the results are correct), the learning system will show some encouraging information.
Step 4: Guide the student to visit the next target device and repeat Steps 2 to 3 until the student pass the evaluation for all of the target devices.

Ubiquitous learning System for Science Device Operations

Based on this innovative approach, the Mobile Science Device Trainer (MSDT) has been developed to assist the students in operating the science devices. MSDT is able to detect the location of individual students and provide them with adaptive supports via the use of PDA's (Personal Digital Assistants) equipped with RFID and wireless communication equipment.
Figure 4 shows an illustrative example of MSDT in guiding the student to find the target object "Sun simulator" on the science park.

Figure 4. Example of guiding the student to find the target device

While arriving at the location of the target device, the student is asked to operate the device by following the instructions given by the learning system. In the example given in Figure 5, the student is asked to turn the red arrow on the device and make it point to the "earth" label (see Figure 5(a)), and then turn the black arrow to the 90-degree position (see Figure 5(b)).



(a) (b)

Figure 5. Example of guiding the student to operate the target device

4. Experiment and Analysis

To evaluate the effectiveness of the innovative approach, an experiment was conducted on a science course of a science park (planetarium) located in southern Taiwan. The experiment aimed to investigate the learning outcomes when the students in the control group employed PDAs to learn (u-learning approach). That is, it aimed to determine whether the students who learned with MSDT had better achievements than those who learned in the u-learning environment. In the following subsections, the design and analysis of the results of the experiment are given in detail.

4.1 Participants

The participants of this study were 43 fifth-grade students taught by the same teacher in an elementary school. After receiving the fundamental science device knowledge in a science course, the participants were divided into a control group (n = 21) and an experimental group (n = 22).

4.2 Learning Design

In the first stage of the experiment, the students receiving the fundamental knowledge of the target devices in the science park (about 80 minutes), all of the students were then asked to answer a pre-questionnaire and take a pre-test (50 minutes). The question items in the pre-questionnaire were concerned with the students' attitudes to the science course. The pre-test aimed to evaluate the students' basic knowledge about the course.

In the second stage, the students in the experimental group were arranged to learn to operate the nine target devices using MSDT, while those in the control group were guided to learn via traditional approach (by the teacher). This stage took almost 120 minutes. After conducting the learning activity, the students were asked to take a post-test and answer a post-questionnaire (50 minutes).

4.3 Learning achievements of students

Table 1 shows the t-test results of the pre-test. Notably, the mean and standard deviation of the pre-test were 71.14 and 14.56 for V1 (experimental group), and 73.09 and 11.21 for V2 (control group). As the p-value (Significant level) =.56 > .05 and t =-0.60, it can be inferred that V1 and V2 did not significantly differ at a confidence interval of 95% in the pre-test. According to the t-test result (t=-0.97, p > .05), it was evident that the two groups of students had equivalent abilities before learning the subject unit.

Table 1. *t*-test of the pre-test results

	N	Mean	S.D.	*t*
Experimental group	22	88.22	13.86	-0.97
Control group	21	91.90	10.87	

Table 2 shows the t-test results of the post-test; in addition, the original means and standard deviations are also presented. The mean and standard deviation of the post-test were 60.19 and 16.76 for the control group, and 70.55 and 15.42 for the experimental group. From the post-test scores, it was found that the students in the experimental group had significantly better achievements than those in the control group (t = 2.11, p < .05). This result implies that learning with MSDT in an authentic learning environment significantly benefits the students more than learning in the traditional environment. That is, this innovative approach is helpful to the students in improving their learning performance.

Table 2. *t*-test of the post-test results

	N	Mean	S.D.	t
Experimental group	22	70.55	15.42	2.11*
Control group	21	60.19	16.76	

*p< .05

5. Conclusions

Recently, mobile and wireless communication technologies have become popular among research groups. In ubiquitous learning, the students are situated in a real-world environment with supports from the digital world. Thanks to the novelty and pleasure of using mobile devices outside the classroom, such learning activities frequently receive promising feedback from the students [20] [22]. Therefore, most researchers and school teachers regard such equipment as a convenient channel that enables students to access digital resources from the Internet. Nevertheless, the issue of developing new strategies or tools to improve the learning achievements of students in such learning environments has attracted relatively little attention.

In this paper, we present a sensing technology-enhanced ubiquitous learning system, which employs a cognitive apprenticeship approach to guide students to learn to operate a set of target devices in a science park of southern Taiwan. The developed system has been applied to a learning activity of a science course in an elementary school. The results of the experiment demonstrate that this innovative approach promotes learning motivation, and improves the learning achievements of individual students as well. This finding is quite different from those of previous studies [29] [32] [33], which mainly investigated the correlation among the learning motivation, the learning behaviors and the technology acceptance in mobile and ubiquitous learning. In addition, the usage of this innovative approach (i.e., learning via operating the devices) is different from those of most previous studies which mainly focused on guiding the student to operate the learning objects [34] [35]. Therefore, this study has the rather positive implication that ubiquitous learning can be effective if proper strategies can be provided to guide the students to interact with the learning context.

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