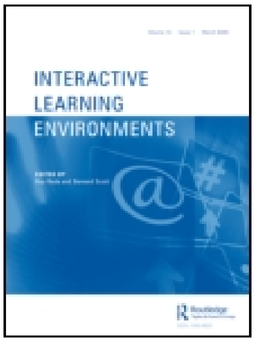

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A context-aware ubiquitous learning approach for providing instant learning support in personal computer assembly activities

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Personal computer assembly courses have been recognized as being essential in helping students understand computer structure as well as the functionality of each computer component. In this study, a context-aware ubiquitous learning approach is proposed for providing instant assistance to individual students in the learning activity of a computer-assembly course. In addition to comparing the learning achievements and learning satisfaction of the students who learned with context-aware ubiquitous learning and conventional technology-enhanced instruction, the computer-assembling performance, cognitive load, learning perceptions, as well as the learning attitudes of the students are also discussed. It was found that those students utilizing context-aware ubiquitous learning achieved better effects than those with conventional technology-enhanced learning. Moreover, with context-aware ubiquitous learning, the field-independent students presented higher acceptance of cognitive load, and more positive learning experience, learning perceptions, learning satisfaction, and learning attitudes than the field-dependent students.

Keywords: context-aware ubiquitous learning; computer courses; situated learning; cognitive style; cognitive load

Background and motivation

From basic secondary school courses to professional computer concept courses in college, computer hardware instruction plays an important role in computer education. In addition to the theoretical disciplines, the Council of Labor Affairs in Taiwan also conducts subject and operation tests concerning computer assembly, which are essential for fostering students' knowledge of computer structure as well as of the functionality of each computer component. Although the hardware knowledge presented in introductory computer courses in secondary school is not very complex, many students still have difficulty completing the assembly of a computer. Some schools have attempted to provide demonstration videos to show the details of the computer-assembly process to the students in class; however, no significant improvement has been presented. Scholars have indicated that the

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learning difficulty is not only due to insufficient practice, but also due to the lack of instant assistance (Hwang, Wu, Tseng, & Huang, 2011). To improve the practice efficiency and learning efficacy of such courses, it has been suggested that teachers provide students with one-on-one operation guidance in a real-world environment (Hwang, Chu, Lin, & Tsai, 2011). Unfortunately, in a secondary school computer course, a teacher usually needs to instruct a class of up to 40 students, indicating the difficulty faced by the teacher in catering to the needs of individual students.

The advance of wireless, mobile, and sensing technologies provides an opportunity to cope with this problem (Chen & Li, 2010; Chu, Hwang, & Tsai, 2010; Hwang, Yang, Tsai, & Yang, 2009). In this study, the term "context-aware ubiquitous learning (u-learning)" defined by Hwang, Tsai, and Yang (2008) is adopted to represent the learning approach that employs wireless, mobile, and sensing technologies to provide learning supports in real-world environments. In a context-aware ubiquitous learning environment, individual students are guided to learn in real-world situations with supports or guidance from the learning system via a mobile device with wireless communications (Hwang, Tsai, et al., 2008). Moreover, the learning system is able to detect the learning behaviors of the students in the real world with the help of the sensing technology (Chiou, Tseng, Hwang, & Heller, 2010; Hwang, Chu, et al., 2011; Minami, Morikawa, & Aoyama, 2004; Tan, Liu, & Chang, 2007). In the past decade, ubiquitous learning technologies have been successfully applied to learning activities in various fields such as natural science, social science, and languages, in that the learning motives and interest of the students have been raised, as well as good learning performance being presented (Chu et al., 2010; Hwang & Chang, 2011). On the other hand, researchers have also reported some critical elements of applying such an approach. For example, the students might spend much time reading the learning content on the mobile devices, while ignoring the learning targets surrounding them; moreover, they might not be able to link what they are learning to their previous knowledge learned in the class without proper guidance or instant supports (Wong & Looi, 2011; Wu, Hwang, Tsai, Chen, & Huang, 2011). Consequently, it is important to guide the students to focus on the correct learning targets and provide them with instant supports when they encounter problems during the ubiquitous learning process, in particular, for those learning tasks that require frequent interactions with the learning targets, such as computer assembly (Chiang et al., 2011; Hwang, Wu, et al., 2011).

To cope with the learning problem of computer assembly, this study proposes a situated multimedia ubiquitous learning (SMUL) system which applies personal digital assistants (PDAs), wireless communication networks, and radio frequency identification (RFID) technologies in the learning activities of computer assembly. Moreover, an experiment has been conducted on the computer-assembly course of a secondary school in southern Taiwan to evaluate the effectiveness of the proposed approach in terms of students' learning achievement and computer-assembling performance. To investigate the factors that might affect the learning performance of the students, their learning satisfaction, cognitive load, learning attitudes, and learning perceptions were measured as well. Furthermore, the learning performances of the students with different cognitive styles are compared to investigate how the SMUL system can be improved in the future to more effectively support the students with different cognitive styles in computer-assembly activities.

Literature review

Ubiquitous learning and instant learning supports

With the help of mobile, sensing, and wireless communication technologies, the learning environment can provide learners with timely and appropriate guidance (Kynaslahti, 2003; Pownell & Bailey, 2001). Context-aware ubiquitous learning usually involves a learning activity situated in a real-world environment, the setup of a wireless communication infrastructure, and the use of mobile devices so that the learners can be guided to explore real-time information and interact with the learning environment (Chen, Kao, & Sheu, 2003; Chu, Hwang, Tsai, & Tseng, 2010; Hwang, Tsai, et al., 2008). In the past decade, many context-aware ubiquitous learning studies have been carried out in different learning domains and have shown positive results (Chen, Kao, Yu, & Sheu, 2004; Wilde, Harris, Rogers, & Randell, 2003). For example, Rogers et al. (2005) introduced mobile and wireless communication to assist students in observing and collecting data in woodlands; Joiner, Nethercott, Hull, and Reid (2006) used sensing devices to offer timely vocal statements related to activities for students in real conditions; Chu, Hwang, Huang, and Wu (2008) found that fifth graders revealed high interest in using PDAs with a butterfly ecology e-library to learn in a natural science activity; while Hwang et al. (2009) further developed a context-aware ubiquitous training system with mobile, wireless communication, and sensing technologies for guiding inexperienced researchers to practice single-crystal X-ray diffraction operations. In comparison with traditional single-crystal X-ray diffraction training, it was found that the students who learned with the context-aware u-learning approach showed significantly better learning performance. Moreover, several studies have demonstrated the benefits of mobile and ubiquitous learning in helping students to improve their learning outcomes (Chu et al., 2010; Hwang, Yin, Hwang, & Tsai, 2008), implying the potential of this approach.

On the other hand, researchers have indicated the importance of providing learning supports, such as supplementary materials, feedback, or advice, based on individuals' needs in real-world learning scenarios (Hwang, Wu, & Ke, 2011). Denton, Madden, Roberts, and Rowe (2008) have indicated that providing helpful instant supports to individual students is a great challenge to instructors; therefore, the development of computer-assisted mechanisms for providing instant learning supports has become an important issue (Hwang, Chu, Shih, Huang, & Tsai, 2010). In the past decade, many studies have reported the benefits of providing instant supports to students in Web-based learning environments (Chu, Hwang, Tsai, & Chen, 2009; Draper, 2009; Jordan & Mitchell, 2009; Narciss & Huth, 2006). For example, Wu, Hwang, Milrad, Ke, and Huang (2011) proposed a Web-based learning environment with an instant support mechanism for helping students develop concept maps in a natural science course and found it to be beneficial in improving students' learning achievement and motivation. Nevertheless, it remains a challenging issue to provide instant learning supports for situated and authentic learning activities such as computer-assembly activities.

In this study, a context-aware u-learning system, SMUL, is developed to cope with this problem. The SMUL is able to provide instant supports to individual students when they are engaging in computer-assembly learning activities. The students can work at their own pace during the learning process as instant learning supports are provided via the mobile devices for when they encounter problems.

Cognitive styles

A previous study has noted that learning styles are likely to have an impact on students' learning performance (Saracho, 1998); therefore, in addition to the comparisons of learning performance between the context-aware ubiquitous learning approach and the conventional technology-enhanced learning approach, this study aims to analyze the effects of the context-aware ubiquitous learning approach on the performance of students with different cognitive styles. Cognitive styles are defined as the preferences of individuals for personal experience or information organization (Chen & Macredie, 2002; Lee, Cheng, Rai, & Depickere, 2005; Messick, 1984). Distinct cognitive styles show the mental differences of individuals influencing their reception, processing, and organization of information input (Riding & Rayner, 1998). Being aware of the cognitive styles of learners and learners' perceptions of engagement in learning activities has been recognized as being important in improving students' learning, retention, and retrieval (Federico, 2000). Several previous studies concerning technology-enhanced learning have further reported that the students' learning performance could be improved if cognitive styles are taken into consideration when developing the learning systems (Aragon, Johnson, & Shaik, 2002; Mampadi, Chen, Ghinea, & Chen, 2011; Smith & Ragan, 1999).

Among different cognitive style categories, the Group Embedded Figures Test (GEFT) proposed by Witkin, Moore, Goodenough, and Cox (1977) has been widely used to identify those students who are field independent (FI) or field dependent (FD; Lee et al., 2005). Field dependence means the degree to which the contextual field affects the learners' perception or comprehension of information (Jonassen & Grabowski, 1993). Higher FD learners would like to have information presented in order or in clear and concise ways and tend to accept the provided information without reorganizing it; on the contrary, higher FI learners are more likely to exhibit superior performance in learning tasks of discovery activities which engage them actively in discovering the information that is important for them (Akdemir & Koszalka, 2008).

In response to the GEFT, FI learners can quickly identify the positions of embedded figures and obtain higher scores; conversely, FD learners have lower scores in the test. It has been found that FI students prefer individual learning and are active in finding and constructing individual learning experiences (Chen & Macredie, 2002), while FD students like group activities. Several researchers have indicated that considering cognitive style could be helpful to system developers in improving interface design, such that the learning system can provide more effective learning supports (Chen & Macredie, 2002; Triantafillou, Pomportsis, Demetriadis, & Georgiadou, 2004); consequently, in this study, we attempt to investigate the effect of the students' cognitive styles on their context-aware u-learning performance. The investigation results can be a good reference for improving u-learning systems in the future.

Method

Participants

A unit of a vocational high school computer course was selected as the learning content for conducting the context-aware ubiquitous learning activity. The participants were two classes of grade two students with an average age of 17. One class was assigned as the experimental group ($N = 39$) and the other was the control group ($N = 39$). Both groups were provided with the same learning materials for computer assembly, but used different instructional media and strategies.

Measuring tools

Various measuring tools were utilized before and after the experiment, including a pretest, a post-test, and the questionnaires concerning learning satisfaction, cognitive load, learning attitude, and learning perception. The pretest and post-test were used to compare the learning achievements of the two groups of students to examine the effectiveness of the context-aware u-learning approach, while the questionnaires were used to further investigate the possible factors that affected the students' learning performance. For example, several previous studies have indicated that students' learning attitudes, learning perceptions, and cognitive load could be attributed to the adopted learning approach and, subsequently, become the factors affecting their learning achievements (Chu et al., 2010; Hwang & Chang, 2011).

The pretest was the Certificate Test of Computer Hardware Assembling Class C developed by the Council of Labor Affairs in Taiwan (Primary Degree of PCDIY, 2009). The test consists of 50 multiple-choice items with a perfect score of 100.

In addition, a learning satisfaction questionnaire consisting of 5 five-point Likert-scale items was used to compare the feedback of the students in the two groups after participating in the learning activity. Its Cronbach's α value was .90.

For the assessment of cognitive load, the scale adopted in this study consisted of two dimensions, namely, mental load and mental effort (Paas, Renkl, & Sweller, 2003; Sweller, van Merrienboer, & Paas, 1998). Mental load is viewed as the individual inner cognition load when a person is simultaneously confronted with the stress of the amount of information and learning comprehension. Mental effort is treated as the individual external cognitive load which results from the combined pressure of the methods of teaching, the degree of difficulty of the activities, and the suitability degrees of high-level thinking. Cronbach's α values of mental effort and mental load were .86 and .85, respectively.

The perception questionnaire and the learning attitude questionnaire were originally developed by Chu et al. (2010). The perception questionnaire consisted of 19 six-point Likert-scale items that were categorized into three dimensions, that is, "experience of using PDAs to learn," "feelings about the context-aware ubiquitous learning system," and "satisfaction with the learning approach," with a reliability coefficient of .91. Cronbach's α values of the three dimensions were .67, .88, and .91, respectively. The learning attitude questionnaire consisted of 7 six-point Likert-scale items. Its Cronbach's α value was .89.

Furthermore, to compare the learning performance, perceptions, and attitudes of the students with different cognitive styles in the experimental group, this study employed the GEFT proposed by Witkin et al. (1977) to determine the cognitive styles of the students. The reliability of the GEFT has been reported by Lawson (1983) as being .88. Students are asked to trace 18 simple items embedded within a complex figure within 10 min. The scores of the GEFT range from 0 to 18. Most previous studies have adopted a cut-off point of 9; that is, those students with scores from 0 to 9 are classified as FD (Bertini, 1986; Doebler & Eicke, 1979), while those from 10 to 18 are classified as FI.

Experimental process

Figure 1 shows the experiment design of this study. Before the learning activity, a pretest was conducted to evaluate the students' computer-assembly knowledge, and then the learning activity was conducted in a computer laboratory. During the learning activity, both groups of students used the same computer components to complete the assembly tasks; moreover, the same multimedia learning materials were provided to them. The two groups differed in that the students in the control group received the learning materials via conventional technology-enhanced instruction, while the experimental group students received the learning materials from and interacted with the context-aware u-learning system.

Figure 2 shows the structure of the context-aware ubiquitous learning system, which consisted of a registration and authorization module, a learning sequence guiding module, an RFID tag identification module, a management system, a student account database, a learning material database, a learning portfolio database, and mobile devices (i.e., PDAs) for individual students to access the learning materials via wireless communications. During the learning process, RFID technology was used to facilitate the learners in accessing the required learning materials. Each computer hardware component was labeled with an RFID tag and each student in the experimental group held a PDA with an RFID reader. When the students encountered problems in assembling some components, they acquired the relative learning materials and the hardware assembly operation video via sensing the tag on the computer components. The use of RFID technology was a critical factor of the proposed approach. With the help of the RFID technology, the learners can conveniently and efficiently access the learning materials related to any computer

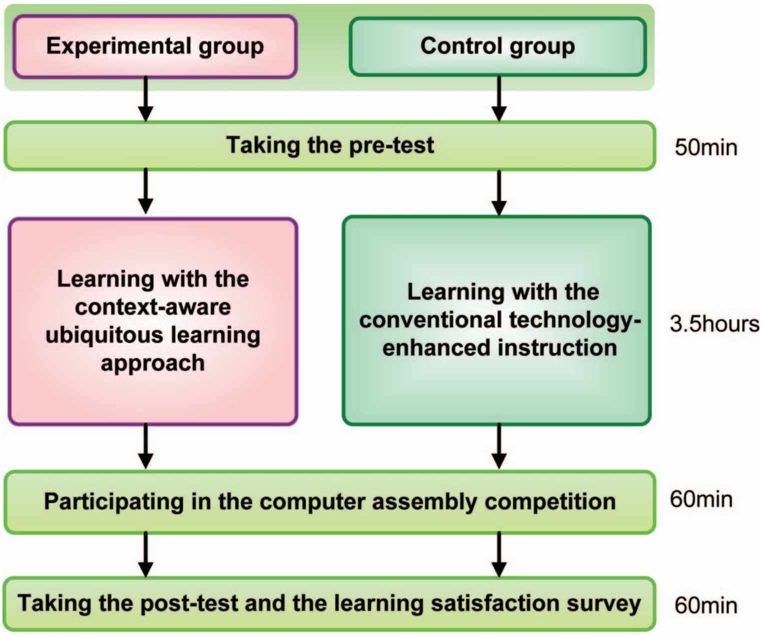

Figure 1. The experiment design of this study.

component without inputting the ID or name of the target components via the mobile device.

On the other hand, the students in the control group practiced the computer-assembly process with the traditional technology-enhanced learning approach, which has been carried out in the sample school for years. The teacher first taught the computer-assembly process to the students using a projector for presenting the relevant learning materials. The students were then asked to assemble the personal computers while referring to a demonstration video, as shown in Figure 3. During the learning activity, digital learning materials, including the instructional files and the demonstration videos, were provided, so that the students could review the content they had learned via personal computers whenever they needed. When encountering some problems, the students could seek help from the teacher or find the relevant demonstration videos on the computer. In such a problem-dealing mode, the learning process is likely to be interrupted since they need to wait for the teacher who usually takes care of dozens of students at the same time; in addition, finding the required video is also time-consuming.

After the experiment, the two groups took part in the computer-assembly competition and took the post-test of computer-assembly knowledge. In addition,

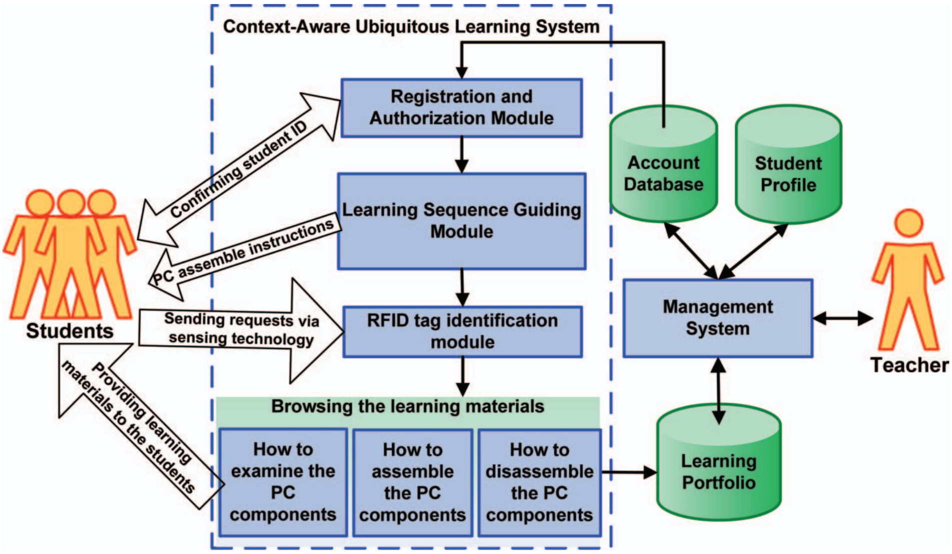

Figure 2. The structure of the context-aware ubiquitous learning system.

Figure 3. Actual learning situation of the control group in the vocational high school.

the experimental group was required to complete the questionnaires about learning attitude, cognitive load, system satisfaction, learning perceptions, and PDA learning experiences. Furthermore, to explore the opinions of the learners regarding the SMUL system, the researchers interviewed two high-achievement and two low-achievement students with different cognitive styles from the experimental group.

Results

Learning achievement

Table 1 shows the test results of computer-assembly knowledge for the experimental group and the control group, where the items for the pretest and the post-test were identical. Prior to taking the pretest, none of the students had experienced any computer-assembly learning activities. The average pretest scores of the experimental group and the control group were 36.69 and 37.18, respectively. The *t*-test on the pretest scores showed no significant difference between the two groups.

After completing the computer-assembly learning activities, the average score for the subject knowledge of computer assembly in the experimental group was six points higher than that of the control group, which was a significant difference ($t = 2.49$, $p < .05$). That is, the proposed multimedia context-aware ubiquitous learning approach was helpful to the students in improving their computer-assembly knowledge. Particularly, it provided individual students with the opportunity to repeatedly learn certain knowledge and skills of the hardware component assembly, aiming at what they were unfamiliar with. Such a finding conforms to the mastery learning theory which emphasizes the need to assist students in repeated practice for the desired achievement of a final goal (Carroll, 1963; Johnson, Perry, & Shamir, 2010).

Computer-assembling performance

In addition to the pretest and the post-test on subject knowledge, the students took part in a computer-assembly competition after completing the course in order to examine the operation results, which presented the objective of this course, that is, being able to assemble the dispersed components for successful power-on. It was found that, on average, the experimental group spent 21.22 min to complete the computer-assembling task, while the control group spent 24.20 min. The assembly speed of the students was further sequenced; the top 19 students were grouped as high-achievers, while the remaining 20 students were grouped as low-achievers. From Table 2, it is seen that the context-aware ubiquitous learning approach could significantly enhance the computer-assembling performance of the low-achievement

Table 1. Independent *t*-test on the scores of the control group and the experimental group.

Examine	Groups	*N*	Mean	SD	*t*
Pretest	Control group	39	37.18	7.99	−0.255
	Experimental group	39	36.69	8.84	
Post-test	Control group	39	62.10	9.83	2.49*
	Experimental group	39	68.05	11.25	

Note: $^*p < .05$.

learners but did not present remarkable differences for the high-achievement students in the two groups. In other words, the context-aware ubiquitous learning approach was able to help the low-achievement students improve their computer-assembling performance.

Learning satisfaction

Table 3 shows the students' feedback in terms of their satisfaction with the computer-assembly course. It was found that all the items except for Q2 achieved significant differences between the two groups. That is, only the satisfaction with the teaching plan did not appear to have a significant difference between the experimental and control groups. Such a finding is reasonable since the teaching plans and the objectives for the two groups were identical. On the other hand, the experimental group presented significantly better satisfaction with the curriculum design (Q1), teaching tools (Q3), and learning assistance (Q4) than the control group, implying that the context-aware ubiquitous learning approach was highly accepted by the students.

As indicated in Figure 4, the students expressed their satisfaction using a five-point scale of ‘‘very unsatisfied,’’ ‘‘unsatisfied,’’ ‘‘average,’’ ‘‘satisfied,’’ and ‘‘very satisfied.’’ In terms of the satisfaction percentages of the two groups given in Table 3

Table 2. Independent *t*-test on the assembly times (seconds) of the control group and the experimental group.

	High-achievement group					Low-achievement group			
Statistics	*N*	Mean	SD	*t*	*p*	*N*	Mean	SD	*t*
Experimental group	19	846.42	177.48	0.16	.87	20	1,678.95	511.00	3.68*
Control group	19	855.32	155.36			20	2,255.05	434.06	

Note: $^{*}p < .05$.

Table 3. Satisfaction survey.

	Experimental group			Control group			
Items in the questionnaire	*N*	Mean	SD	*N*	Mean	SD	*t*
Q1. I am satisfied with the content presentation of the course.	39	4.18	0.60	39	3.85	0.78	2.12*
Q2. I am satisfied with the instructional plan and goal.	39	3.97	0.54	39	3.74	0.75	1.56
Q3. I am satisfied with the usage of the instructional facilities in learning hardware composition.	39	3.95	0.65	39	3.23	0.90	4.04**
Q4. I am satisfied with the instructional device and teaching aids.	39	4.00	0.83	39	3.38	0.78	3.38**
Q5. Overall, I am satisfied with this course.	39	4.05	0.56	39	3.72	0.72	2.28*

Note: $^{*}p < .05$, $^{**}p < .01$.

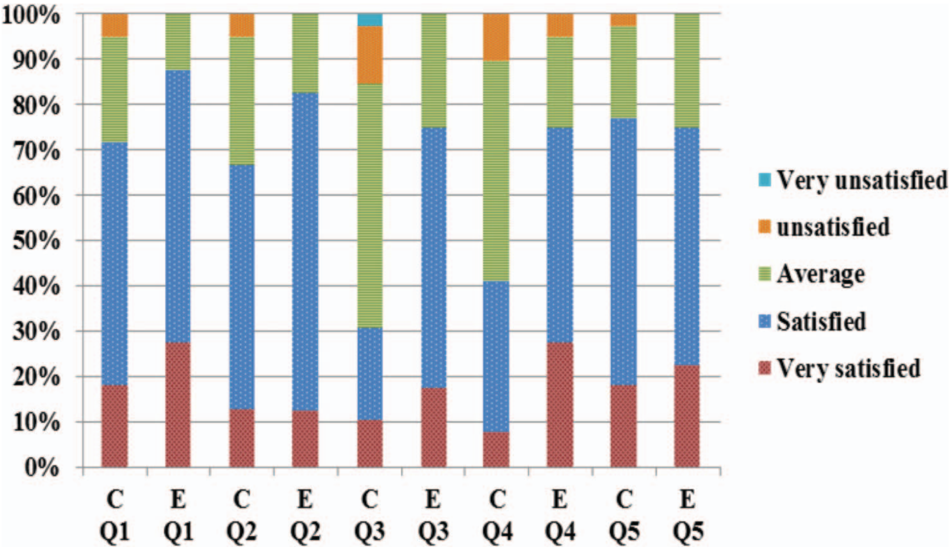

Figure 4. The percentage of satisfaction with each item in the control and the experimental groups.

and illustrated in Figure 4, 100% of the experimental group perceived "average" or above satisfaction with the curriculum design (Q1), with 87.5% perceiving "satisfied" and above. By contrast, 94.87% of the control group perceived "average" or above for their satisfaction with the design, but only 71.79% of them perceived "satisfied" or above. With regard to overall satisfaction, 100% of the experimental group perceived "average" or above satisfaction, with 85% "satisfied" or above, while 97.44% of the control group perceived "average" or above satisfaction, but only 61.54% indicated "satisfied" or above. Regarding teaching tools, the experimental group all showed "average" or above satisfaction, with 75% "satisfied" or above. However, though 84.62% of the control group presented "average" or above, only 30.77% recorded "satisfied" or above. The difference in the satisfaction of the two groups was therefore considerable. In terms of the application of mobile devices, the students in the computer-assembly operation skills' teaching group were better satisfied than the group which used projectors. With regard to learning assistance, 95% of the students in the experimental group presented "average" and above satisfaction, while 75% were "satisfied" or above. By contrast, 89.74% of the students in the control group showed "average" and above satisfaction, whereas only 41.03% appeared "satisfied" or above. This shows that the learners in the experimental group with situated multimedia u-learning of personal computer hardware assembling perceived better learning satisfaction than those who learned with projectors and handouts.

Learning performance of students with different cognitive styles

Via the GEFT, it was found that 19 students in the experimental group were FI and 20 were FD learners. Most previous studies have noted that FI students usually perform better than FD students in hypermedia, especially in nonlinear learning environments (Lee et al., 2005; Parkinson & Redmond, 2002). Table 4 shows the descriptive statistics and the *t*-test results for various dimensions of the learning performance of the FI and FD students. It can be seen that, in terms of learning achievement, no significant difference was found between the FD and FI students in the experimental group. This finding implies that the context-aware ubiquitous learning approach has benefited the students of both cognitive styles in learning the computer-assembly knowledge. Moreover, for the task-oriented tests, the FI students who spent 16.8 min on average on completing the PCDIY task revealed significantly better computer-assembling performance than the FD students who spent 25.42 min on average on computer assembly; that is, the students with different cognitive styles showed different computer-assembling performance when using the SMUL system, and the FI learners outperformed FD learners in terms of PCDIY (Personal Computer, Do It by Yourself) task-solving. Such a finding conforms to the reports of several previous studies (Parkinson & Redmond, 2002).

In terms of cognitive load, it was found that the FD students had higher cognitive loads (as shown in Table 4), which conforms to the findings of previous studies that FD students generally have lower working memory capacity than FI students (Bahar & Hansell, 2000; Graf, Lin, & Kinshuk, 2008; Pascal-Leone, 1970). Such a finding is consistent with the statistical results that showed significant differences between the time spent on completing the PCDIY task; that is, the higher cognitive load led to longer task completion time for those FD students. In terms of learning attitudes and perceptions of participating in the u-learning activity, it was also found that the FI students revealed more positive feedback than the FD students did. It was inferred

Table 4. *t*-Test results of the performance of the FI and FD students.

Dimension	Scales	Cognitive style	*N*	Mean	SD	*t*	*p*
Academic achievement	Pretest	FD	20	38.30	9.89	1.17	.25
		FI	19	35.00	7.48		
	Post-test	FD	20	70.20	12.45	1.23	.23
		FI	19	65.79	9.66		
Task-oriented learning	PCDIY performance (min)	FD	20	25.42	9.97	3.19*	.00
		FI	19	16.80	6.66		
Cognitive loads	Mental load	FD	20	2.73	0.88	2.74*	.01
		FI	19	2.05	0.62		
	Mental effort	FD	20	2.90	1.12	2.18*	.04
		FI	19	2.24	0.73		
Learning attitudes		FD	20	4.52	0.62	−2.96*	.01
		FI	19	5.09	0.57		
Perceptions of participating in the u-learning activity	Experience of using PDAs to learn	FD	20	4.00	0.62	−3.436*	.00
		FI	19	4.86	0.92		
	Feelings about the SMUL system	FD	20	4.54	0.63	−2.43*	.02
		FI	19	5.08	0.75		
	Satisfaction with the learning approach	FD	20	4.53	0.58	−2.26*	.03
		FI	19	5.00	0.70		

Note: $*p < .05$.

that the instructional materials accessed via using the sensing technology were more beneficial to FI learners for completing the task. This finding further confirmed the effect of using the approach on decreasing the cognitive load of the FI students, which therefore shortened their time of completing the learning task. Consequently, it was concluded that the FD students might need more time to accept the context-aware ubiquitous learning approach, in particular, the use of the sensing technology, in comparison with the FI students. Fortunately, this factor did not affect their learning achievements in this course.

Interview results

To collect the participants' opinions regarding the SMUL system, this study interviewed two high-achievement and two low-achievement students from the experimental group with different cognitive styles. Based on these interviews, it was found that the students with the FI cognitive style revealed higher motivations in exploring how to assemble the hardware components via interacting with the SMUL system. Sometimes they preferred to try their own operation sequence instead of following the sequence suggested by the system, which is consistent with the FI style. Moreover, they would repeatedly access the learning materials or videos related to the main points they needed to reinforce by sensing the corresponding RFID tags on the components. In contrast to the FI students, the FD students preferred a more step-by-step approach and thus seemed to follow the guidance sequence of the SMUL system most of the time. As such, the flexibility of the SMUL system catered well to the learning styles of both groups of students. Relevant quotes from the interviews are presented in Table 5.

Discussion and conclusions

In this study, a context-aware ubiquitous learning system is developed for enhancing students' knowledge and skills of computer assembly by integrating mobile, wireless communication, and sensing technologies. Several previous studies have reported that, in such courses as computer assembly that require frequent interactions with real-world learning targets (e.g., computer components), without proper learning guidance, the students might spend much time reading the instructions or learning materials, while ignoring the learning targets; moreover, they might fail to link their prior knowledge to the present learning tasks when encountering problems (Chiang et al., 2011; Wong & Looi, 2011; Wu, Hwang, Tsai, et al., 2011). It is expected that the provision of instant learning supports based on individual student needs is able to improve students' learning efficiency and effectiveness in practicing the computer-assembly tasks.

From the experimental results, it was found that the context-aware ubiquitous learning approach has effectively coped with these problems. The students who learned with the proposed approach had better learning achievement, higher learning efficiency, and higher satisfaction than those who learned with the traditional technology-enhanced learning approach. From the results, it can be seen that well-designed multimedia instructional materials do not always lead to effective instructional and learning performance. The instructional materials of the control group and the experimental group were the same and were well designed;

Table 5. Qualitative abstracts from the interviews.

Different groups	High achievement	Low achievement
FI	*I have autonomy to operate and learn with the SMUL system. When I want to know the assembly method of any component, I will use the PDA embedded with the reader to read the tag on the component. It is not necessary for me to read and learn the demonstration video and instructions in the suggested sequence. I concentrated on the ones which I selected and wanted to learn. The PDA showed the instructional materials clearly, and the sound played from the headphones was clear; however, the assistant effectiveness would be better if the screen of the portable devices could be bigger.*	*I liked the feature which lets you read any tags on the component you want to learn about. I often felt that I knew how to assemble the components and began trying to assemble the personal hardware components before the video had played to the end. As a result, I did not read the instructional content completely. I skipped part of the demonstration or operation content of the videos.*
FD	*I read the tags in the sequence which the system suggested. I regard the demonstration instructions as important and useful. I perceived this learning method as interesting and new. Although I followed the rules and used the SMUL system for individual learning, I would rather have two people in a group so that I can discuss with or ask my classmate when using the SMUL system to support me to learn.*	*Although this system is convenient for individual learning, I expected that the teacher would instruct us one time in advance before using the SMUL system to individually assist students in assembling the components. I think it would be more effective than me reading the tags and observing the operational demonstration of each component by myself slowly. Also, I would like to have someone to discuss with or to help me while learning about the personal hardware composition.*

however, the learning effectiveness, learning efficiency, and satisfaction of the two groups of students were quite different.

Moreover, it should be noted that the effects investigated in this article are the result of different approaches to providing learning supports. It is not simply a question of mobile vs. non-mobile learning. Via using the RFID technology, the students in the experimental group were able to immediately access the supplementary materials according to their requirements and progress through each learning step; in particular, when the students encountered some problems during the learning process, the technology helped them to find the required guidance instantly. On the other hand, the students in the control group might have needed to find the guidance or supplementary materials in the traditional way; that is, they obtained the supports by searching for information from a printed menu or using keywords to search for the computerized materials, which not only needed extra effort, but was also inefficient.

This result implies that the provision of instant learning supports is helpful to students in improving their learning achievement as well as promoting their interest in learning. Therefore, it is worth employing such an approach in other procedural operations or in those learning activities that require both knowledge and skills, such as chemistry experiments, physics experiments, software and equipment operations, and system testing or debugging procedures.

In addition, this study also found that the students with different cognitive styles showed different learning performance in terms of learning efficiency, cognitive load, and learning attitudes; that is, the FI students showed higher learning efficiency, lower cognitive load, and better learning attitudes than the FD students regarding computer assembly. Such findings conform to several previous studies (Miyake, Friedman, Rettinger, Shah, & Hegerty, 2001; Miyake, Witzki, & Emerson, 2001) and imply that more care is required to satisfy those FD students in learning environments with new technologies or user interfaces (Mitchell, 2000); for example, additional time may be needed to help the FD students get used to the new technologies or interfaces. In addition, previous studies have also reported that the design of the instructional materials and the learning strategies could affect cognitive load and the time spent on tasks (Angeli, Valanides, & Kirschner, 2009); consequently, it could be helpful to assign fewer learning tasks or provide less learning content to the FD students in the same amount of time in order to reduce their cognitive load.

It should be noted that the effectiveness of the proposed approach could be due to multidimensional factors and is not merely an issue of technology. For example, the past experiences of the teacher played an important role in analyzing the possible problems encountered by the students when stuck with an assembly step related to some particular computer components. Moreover, although we attributed the learning effectiveness of the students to the use of the sensing technology (i.e., RFID) since it enabled the students to more efficiently (without inputting keywords or Web addresses) find the supportive instructions or learning materials, the use of the mobile devices (i.e., PDAs) could also contribute to the students' learning performance. To more precisely evaluate and compare the contributions of these two technologies (i.e., the PDA and the RFID), additional experiments are needed in the future.

One limitation of this study is that PDAs are not as popular as smartphones or e-books. Therefore, it remains a challenging issue to implement such an approach on more popular mobile devices with fast reacting sensing technologies. Moreover, in the present study, we have only applied the technology with a limited number of students from the same school, which may be subject to some bias; for example, it does not take into account the different styles of tutors who may be unfamiliar with the technology used. Therefore, it is worth conducting a large-scale experiment in the future.

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