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A dynamic ubiquitous learning resource model with context and its effects on ubiquitous learning

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ABSTRACT

Most ubiquitous learning researchers use resource recommendation and retrieving based on context to provide contextualized learning resources, but it is the kind of one-way context matching. Learners always obtain fixed digital learning resources, which present all learning contents in any context. This study proposed a dynamic ubiquitous learning resource model with context. The model has context information and a flexible content structure that allows contents to be adjusted dynamically in different contexts, thus providing learners the contextualized resources that best match their contexts. In order to verify the effects of the contextualized resources, a contrast experiment was carried out in a vocational school in China. The experimental results showed that the contextualized resources could better improve learners' learning achievement and efficiency, improve their self-learning efficiency while reducing their cognitive load. Learners thought the ubiquitous learning system which provided contextualized resources was more useful.

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Context-adaptive; resource aggregation; resource context; resource model; ubiquitous learning

Introduction

The development of technology has promoted advancements in learning styles, and ubiquitous learning has become a new trend in the field of e-Learning (Hwang, Wu, Tseng & Huang, 2011; Ley, 2007). Ubiquitous learning refers to the process in which learners can obtain the needed resources anytime and anywhere to carry out learning. In the Web 2.0 era, vast learning resources have been created for supporting ubiquitous learning (Yang, Guo, & Yu, 2015; Yang & Yu, 2015). Finding ways to help learners gain easy access to the needed resources has become an important research topic in the field of ubiquitous learning (El-Bishouty, Ogata & Yano, 2007). Ubiquitous learning relates to the actual learning context and focuses on the solution of context problem; thus, ubiquitous learners need the learning resources that match their contexts.

To paraphrase an ancient Chinese poem, we can obtain different visages of a mountain from different perspectives – from near or far or from low or high viewpoints. Similarly, a resource can present and deliver different kinds of messages coming from varied perspectives. A learning resource may contain several knowledge objects and more than one aspect of each knowledge object. In the real environment, learners in varied contexts need different knowledge objects or different aspects of a knowledge object. For example, a learning resource about “rose” contains information about its leaf and flower characteristics as well as its ecological habits. However, one learner may only want to learn

about its leaves, while another may only want to read about its ecological habits. Learning resources mainly consist of several segments of content, and the combination of different content fragments may present different aspects of knowledge. So we need to focus on the relationship of contents and context. Ubiquitous learning requires contextualized learning resources, which must present available contents that meet the demand of context. Too much knowledge may increase the cognitive load of learners. Therefore, we should not only consider the knowledge needed by the learner, but also the aspect of knowledge required. The best learning resources should be those that present content that matches exactly what the learner needs. Several researchers have indicated that this kind of adaptive learning content is important to individual students (Klausmeier, Rossmiller, & Saily, 1977; Tseng, Chu, Hwang, & Tsai, 2008; Witkin et al., 1977). Also, some researches have proved that the adaptive learning content has positive effects on learning (Hwang, Sung, Huang, & Tsai, 2012; Mampadi, Chen, Ghinea, & Chen, 2011; Tseng et al., 2008). But most learners do not have the ability to choose the best-fit contents (Hwang, Sung, Hung, & Huang, 2013), who need an e-learning system to provide dynamical and adaptive content for them intelligently.

In most ubiquitous learning studies, researchers used resource recommendation and retrieving to provide the appropriate resources for learners (Liu, 2009; Liu, Chu, Tan & Chang, 2007; Shih, Chu, Hwang, & Kinshuk, 2011), which is a method of one-way context matching to match learning context and resource characteristics to obtain suitable resources. Resource recommendation and retrieving only focuses on the degree of match between the whole resource and the context, and it is still difficult to understand the degree of match the internal elements and context due to the lack of context description in digital learning resources model. Moreover, the traditional digital learning resource is difficult to present the contents dynamically that are suitable for the context as a result of static resource structure. Thus, traditional digital learning resource model cannot meet the requirements of contextualized learning resources in ubiquitous learning.

Based on the problems stated above, the study proposed a dynamic ubiquitous learning resource model with context. The model has a flexible structure and context information, which can support the bi-directional matching of resource context and learning contexts to obtain suitable contents which meet the demands of the ubiquitous learning context. In order to explore the effects of this learning resource, we developed a learning system and conducted an empirical experiment in a vocational school located in Shandong Province, China.

Relevant works

Ogata, Akamatsu, and Yano (2005) developed a ubiquitous learning environment to support language learning, called TANGO (Tag Added learNinG Objects). The research focuses on learners' location information and provides static digital learning resources related to their surrounding objects. All learners in the same place will obtain the same entities and digital learning resources, the contents of which also are same. The research focused on language learning, and the learning resources have been accurately designed in advance.

El-Bishouty et al. (2007) developed a ubiquitous learning environment using personalized knowledge map to provide learners with the learning resources that match their contexts, called PERKAM (PERsonalized Knowledge Awareness Map). The environment constructs a personalized cognitive map through the perception of the geographical location, environment, and needs of the learners. The environment is not for a specific learning situation, but it only filters learning resources by matching keywords and titles. Moreover, it also presents all the contents in the resource, while ignoring the relationships between contents and context.

de Jong, Specht, and Koper (2010) developed a mobile language learning system to provide learners with language learning resources according to their locations or learning objects. In terms of location, the system can present all learning resources within the scope of the learner's location (room). As for the learning object, the system can also provide the contents that match the learning

objects of the learners. However, their system also focuses on language learning and presents all the learning contents, rather than selecting the specific contents that conform to the context.

Chen and Huang (2012) developed a location-aware learning system to provide appropriate guidance and resources for learners. Using RFID (Radio Frequency Identification) and assessment module, the system provides different learning resources and guidance according to learners' study results. Although learners in different contexts may obtain different learning resources, learning resources are still static, that is, the learning content cannot be changed according to context.

Chen, Chiang and Yu (2014) developed a context-aware ubiquitous learning environment to provide learners with appropriate learning resources according to the geographical location and objective of the learners. Their system can dynamically adjust the presented contents according to the learning objective. Although the resources in the learning environment are dynamic, the learning environment only considers the location and learning objective while ignoring other elements, such as learner's characters.

Sotsenko, Jansen, and Milrad (2014) developed a mobile application called LnuGuide app to support campus tour activities. The app can provide the corresponding learning objects according to a learner's location. When a learner choose a learning object, the app would provide a suitable media type of that object based on the environment context (e.g. location and light) and learner's behavioral state (e.g. walking, sitting, etc.). Although the media type of learning object matches the context, its learning contents remain the same. In addition, although the app considers the environment context, device context (e.g. battery), and behavior status of the learners, it ignores some other characteristics related to learning, such as the knowledge and cognitive levels of the learner.

From the previous studies, we can find that different researches focus on varied context factors when filtering resources; however, overall, the selection of learning resources is related to the contexts of location, environment, learning needs (learning objective), learner characteristics, and devices. Moreover, different situations focus on varying context factors. But most resources are still fixed, that means the contents of resource are always the same in any context.

Though the selected learning resources are more related to the current context than others, but contents of individual learning resources may contain several knowledge objects or different aspects of such knowledge objects, whereas learners may just need some knowledge or some aspects of that knowledge. Due to the fact that the current resource is static and lacks context description, external systems are unable to determine which contents are suitable for what context; hence, the systems are unable to dynamically adjust the contents.

Most studies still follow the principle of using learning resource recommendation and retrieving. Current learning resources use static metadata to describe general attributes while ignoring to describe application contexts. Thus, the way of learning resource recommendation and retrieving needs to analyze context information to determine the characteristics of the required learning resources, and then matches the characteristics with resource's metadata to obtain the needed learning resources. For example, Luo, Dong, Cao, Song, and Liu (2008) proposed a multicontext-aware resource recommendation mechanism to find contextualized resources, whereas Wang and Wu (2011) developed an adaptive ubiquitous learning system with context-aware and a personalized recommendation module to find contextualized resources. In this process, the matching accuracy of context and resource is affected by the double errors that may arise from the analysis of the learning resource characteristics and the potential mismatch between the characteristics of the resources and the metadata. Given that learning context is dynamic, the system needs real-time analysis of the characteristics of the needed learning resources to make recommendations or retrieving potential resources. With too many resources to filter, the process slows down, thus affecting the speed with which learners can access the resources. Thus, the approach of recommending and retrieving resources based on context would not be able to meet the need to provide to find contextualized ubiquitous learning resources.

Therefore, to provide more accurate contextualized learning resources for ubiquitous learners, which can present the most suitable learning contents, learning resources needed context information and flexible content structure.

The dynamic ubiquitous learning resource model with context

This study proposes a dynamic ubiquitous learning resource model with context to support to provide accurate contextualized learning resources for ubiquitous learners. The main parts of the model are content, resource context, association information, and context interface, as shown in Figure 1.

Contents: Different from the traditional learning resource, the content in the model is fragmented and can be flexibly adjusted. As such, the resource can transfer different aspects of a knowledge object to a learner.

Resource context: It refers to the context in which learning resources play an effective role. This study proposes a framework of resource context, which contains the main context factors that can be used in a vast majority of resources, including education, learner, space-time, device, and environment contexts (Figure 2). The framework also can be extended for a few special resources that need other context factors.

Association information: It refers to the information of learning contents associated with the resource contexts. The contents can be linked to some contexts, which means that it can effectively support learning in those contexts.

Context interface: It is used to interact with an external system, that is, the external system can obtain resource context information through this interface while the matching results can return to the resource.

Based on the model, the learning system can dynamically adjust the learning contents by matching resource contexts and learning contexts, so as to meet the demands of learner. For example, Figure 3 shows a learning resource about *Murraya paniculata*, which contains basic information, morphological characteristics, ecological habits, propagation method, and general knowledge of flowers and leaves (they are the prior knowledge of morphological characteristics). When the context is Context A (Learning objective: morphological characteristics, Learner: having mastered the basic knowledge of leaves and flowers), after matching the resource contexts with Context A, the

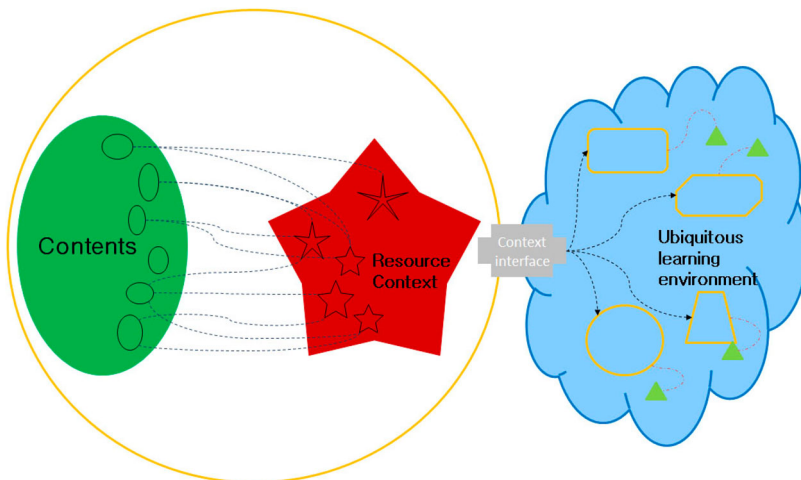


Figure 1. The logic structure of the ubiquitous learning resource with context.

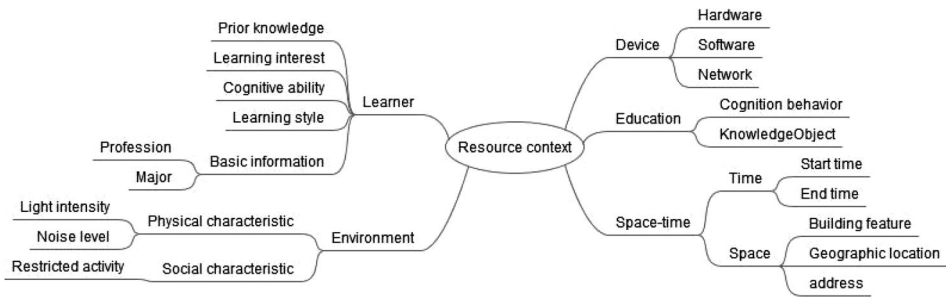


Figure 2. Framework of the resource context.

aggregate module presents the matched paragraphs of basic information and morphological characteristics to the learner. When the context is Context B (Learning objective: morphological characteristics, Learner: having not mastered the basic knowledge of flowers), the aggregate module presents the paragraphs of basic information, morphological characteristics, and the basic knowledge of flowers to the learner. Finally, when the context is Context C (Learning objective: ecological habits), the aggregate module presents the paragraphs containing basic information and the plant’s ecological habits to the learner.

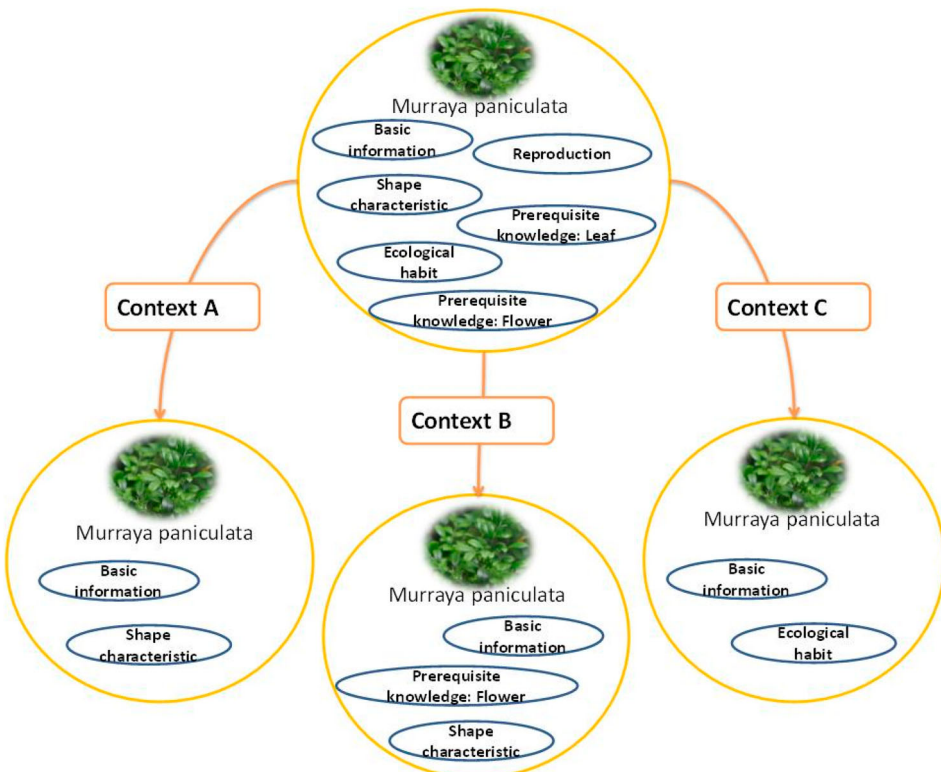


Figure 3. An example of the dynamic ubiquitous learning resource with context.

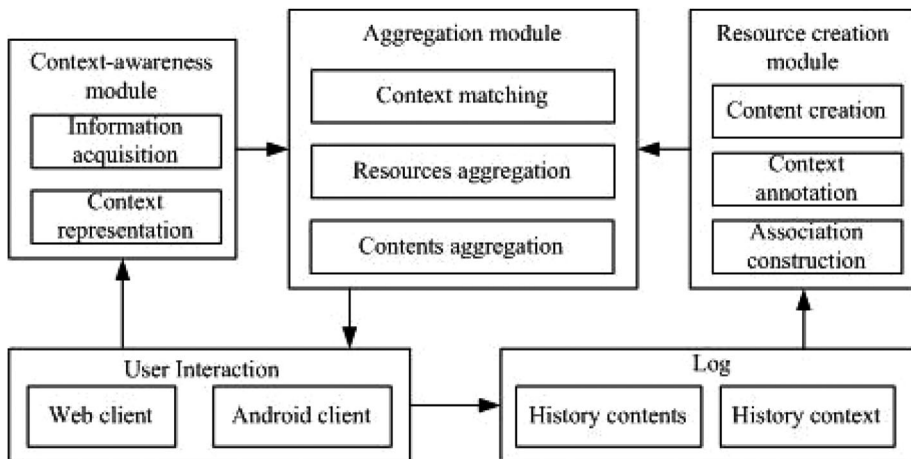


Figure 4. The architecture of the ubiquitous learning system.

Development of a context-aware ubiquitous learning system

In this study, we developed a ubiquitous learning system that can provide dynamic contextualized learning resources. The system can create dynamic learning resources based on the proposed resource model, perceive contexts, and realize dynamic aggregation of learning contents. The system consists of resource creation, context awareness, and aggregation modules as well as the Android client (Figure 4). In this study, we used Learning Cell Knowledge Community (LCKC) (<http://lcell.bnu.edu.cn>), originally developed based on the core concept of Learning Cell (LC) (Yu, Yang & Cheng, 2009; Yu, Yang, Cheng, & Wang, 2015), as the digital resource platform. LC is the smallest unit of learning resource. LC has a flexible content structure, which enables the proposed system to perform dynamic resource adjustment.

Resource creation module: It contains content creation, context annotation, and association construction. The system uses the LC creation function in LCKC to create learning contents. After creating the LC, the creator can use the annotation model to edit context information of some paragraphs to establish the association between contents and resource contexts. Afterwards, the system will automatically fill the rest of the context information (e.g. device context and environment context) according to certain inference rules and the context information provided by the creator. Once learning resource was used in a certain context, the system will record the contents and contexts, and then automatically adds the new contexts into the resource context to update the resource contexts as well as annotating the context of the corresponding paragraph.

Context awareness module: This is mainly used to determine a learner's learning context. It contains information acquisition and context representation. Time and space information, learners' personal information can be automatically obtained by the system. Environmental information is manually entered by the learner. Hardware and operating system information of device can be directly obtained by the system, whereas the application software information must be provided by the learner. This system also uses the semi-automatic approach to obtain learning objective. As soon as the system determines the context information, the system will use a semantic approach to represent the learning context.

Aggregation module: According to location information, the module selects the digital learning resources corresponding to the entities around learner, after which it calculates the semantic similarity of the resource context and learning context. If there are some resource contexts similar to the learning context, the system will decide on those resources are able to support current learning. Then, the system presents to the learner the pictures of the entity resources corresponding to the digital learning resources. The learner uses the pictures of the entities to find the entities he/she

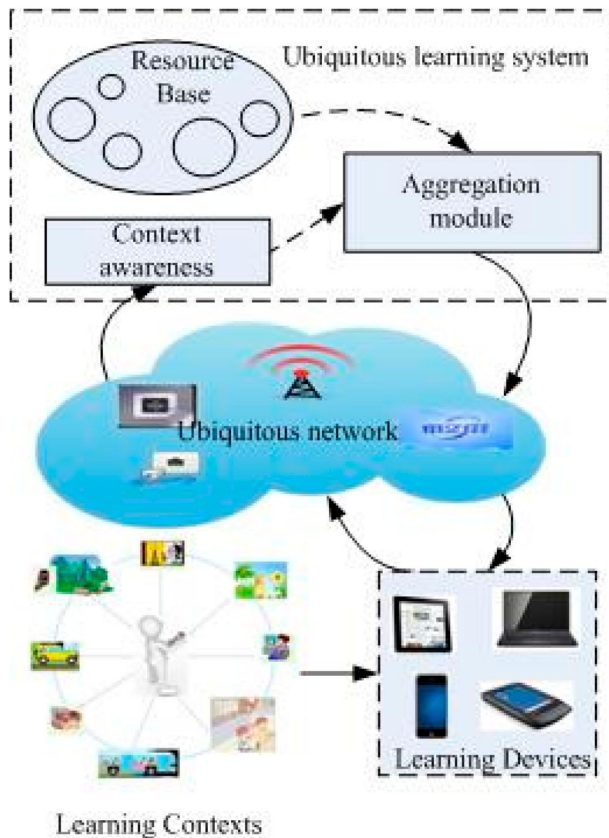


Figure 5. A diagram of how the proposed system supports ubiquitous learning.

wants to study. When the learner enters a digital learning resource, the system will present the contents associated with the contexts. [Figure 5](#) shows the process by which the system supports ubiquitous learning.

Experiment design

This experiment was conducted in the course called “North Greenhouse Plants” in a vocational school in Shandong Province, China.

Participants

The participants included 62 students (40 girls and 22 boys) from the same school. Of these, 42 students studied Garden Technology, whereas the other 20 students were Biotech Applications majors. They all chose the course taught by the same teacher. We randomly divided the students into the same structure of experimental group ($n = 31$) and control group ($n = 31$). Each group has 11 boys and 20 girls: 10 were Biotech Applications majors, whereas 21 were students of Garden Technology.

Materials

Learning resources were designed and provided by the teacher who had 18 years of teaching experience. After choosing 20 species of plants from the school’s botanical garden as the

representative learning objects, the teacher created the corresponding learning resource and quick response (QR) code in the ubiquitous learning system. Each learning resource contains basic information, morphological characteristics, living environment, ecological habits, gardening application, producing and cultivation techniques, disease control, and some prior knowledge. In terms of resource context annotation, in order to find available learning resources within the scope of the learning place, location context is necessary. And the teacher also told us that he chose the learner context (e.g. basic knowledge of learner) and education context (e.g. learning objective), and then annotated the context information for some paragraphs in some learning resource by considering students' large gap of basic knowledge (because the students came from different grade), and different students having different learning objectives (because every student could freely chooses one of the three learning objectives in a learning activity). Moreover, the learning resource he created consisted of text with some graphics, which are not special requirements to learning device and environment, so he did not choose the device context and environment context.

In addition, the teachers designed three learning tasks to promote learning, which are closely associated with learners' learning objectives: (1) to distinguish between healthy and unhealthy plants and determine the cause of the illness by observation and learning the appearance of plants; (2) to find the plants those are not suitable for interior design and explain the reasons by learning gardening application; (3) properly fill in the names of the plants in the form (the teacher gave each student a paper form) depending on different conditions of sunlight, moisture, and temperature by learning ecological habits of plants.

All students used the same tablet devices, in which the Android client of the ubiquitous learning system was installed.

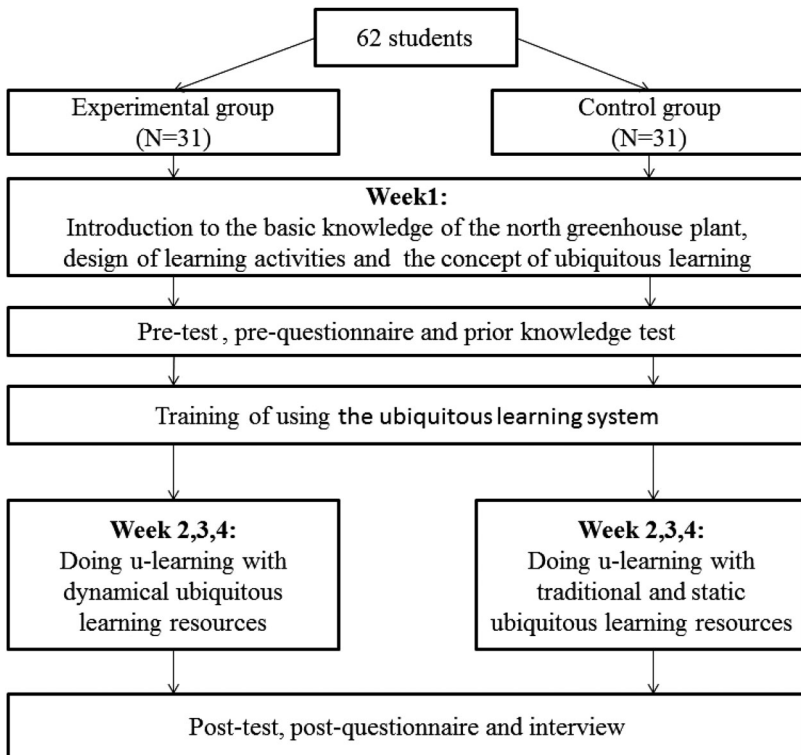


Figure 6. The experiment process.

Procedure

Figure 6 shows the process of the experiment. The experiment lasted for 4 weeks. In Week 1, traditional teaching was conducted. In the beginning, the teacher introduced the two groups of students to the basic knowledge of the north greenhouse plants (e.g. concept of the greenhouse plant), the design of the learning activities, and the related concepts of ubiquitous learning in the classroom. Later, he used the pre-test to gauge the knowledge level of the students with regard to the northern greenhouse plants. He used a pre-test questionnaire to understand the self-learning effectiveness of the students before learning, and then used the prior knowledge test to understand whether the students have gained mastery of some prior knowledge.

For 3 weeks (Week 2, Week 3, and Week 4), students performed ubiquitous learning activities in the botanical garden (1 hour per week for a total of 3 weeks). Participants were required to learn three aspects about the plants, namely, their morphological characteristics, their ornamental values, and their ecological habits. Afterwards, the students are required to complete the three tasks. Each student must choose a task to complete every week and at the end of the third week, everyone should have completed the three tasks. Two groups of students all used the same ubiquitous learning system developed by the researchers. For those in the experimental group, we provided the dynamic contextualized learning resources, the contents of which can be dynamically adjusted and presented according to different contexts. For those in the control group, we provided the traditional static learning resources, the contents of which were the same in any context.

Before the learning activities, the researchers gave the two groups proper training on how to use the ubiquitous learning system. At the end of the learning activities, a post-test and a post-test questionnaire were administrated to all the students. In addition, 12 randomly chosen students from two groups (six students per group) were interviewed. Figure 7 shows that the learners are doing ubiquitous learning.

Instruments

This research adopted pre- and post-tests to measure the learning achievements of the learners, used the questionnaire to measure learners' self-efficacy for learning, cognitive load and user acceptance of information technology, along with their learning behavior records for the analysis of their learning efficiency.

Pre-test and post-test were the same paper. The paper was composed of 10 single-topic selections, 10 of true or false items, and an essay question, for a total score of 100 points. The test was designed by the classroom teacher who had 18 years of teaching experience.

The pre-test questionnaire was used to survey a learner's ubiquitous learning experience (Questions 1–2) as well as their self-efficacy for learning before learning (Questions 3–5). Each question was answered using a five-point Likert scale. The questions of ubiquitous learning experience were designed by the researchers. The questions of self-efficacy for learning were developed based on the scale proposed by Klobas, Renzi, and Nigrelli (2007).

The post-test questionnaire consisted of 17 items pertaining to the dimensions of self-efficacy for learning, cognitive load, and user acceptance of information technology which use a five-point Likert



Figure 7. Learners are carrying out the ubiquitous learning process.

scale. The dimension of self-efficacy for learning had three questions (Questions 1–3) which were the same with the questions in pre-test questionnaire. The part of cognitive load had four questions, including two dimensions of mental load (Questions 4–5) and mental effort (Questions 6–7), which were developed based on the questionnaire proposed by Leppink, Paas, Van der Vleuten, Van Gog, and Van Merriënboer (2013). User acceptance of information technology had 10 questions, including 2 dimensions of usefulness (Questions 8–12) and ease of use (Questions 13–17), which were designed based on the questionnaire proposed by Davis (1989).

After testing the consistency of each dimension of the questionnaire, we find that the Cronbach's α values for the consistencies of the dimensions of self-efficacy for learning, mental load, mental effort, usefulness, and ease of use were 0.73, 0.79, 0.79, 0.87, and 0.92, respectively.

Experimental results

Learning achievement

The t -test results of the pre-test ($t = 0.54$, $p = .59 > 0.05$) implied that the experimental group and the control group showed no significant difference prior to the experiment. This indicated that the two groups of students had statistically equivalent knowledge levels of the north greenhouse plants before learning.

After the experiment, the researchers used the same paper to test the students in the two groups. Table 1 shows the ANOVA (Analysis of Variance) results of the post-test. The result ($F = 7.52$, $p = .008 < .01$) showed that the experimental group had significantly better achievement than the control group. This implies that students using the dynamic contextualized ubiquitous learning resource significantly benefited compared with those who used the traditional static learning resource.

The results of the pre–post-test showed that the learning achievements of students improved after participating in the learning activities, with those in the experiment group acquiring more significant improvement than students in the control group. The difference between the two groups can be attributed to the learning resource used. The experiment group used dynamic ubiquitous learning resource, the contents of which can be adjusted according to different contexts. This meant that the dynamic ubiquitous learning resource did not only provide personalized and contextualized learning contents, it can also effectively improve their learning achievements. This finding is consistent with the results of previous research (Hsu, Hwang & Chang, 2013).

In the interview, the experiment group students also thought that the ubiquitous learning system could provide easy-to-understand learning content to help them during the learning process. By contrast, the control group students said that ubiquitous learning system provided many learning contents that had nothing to do with their learning need, consequently increasing their study burden. Therefore, the dynamic contextualized ubiquitous learning resource can improve the learning achievements of the ubiquitous learners.

Learning efficiency

In the learning activities, two groups of students had the same learning time, and the ubiquitous learning system recorded their learning behaviors. The record can help us know how many plants the learner scanned in each task. After the learning activities, the teacher can also determine how many plants the students had learned about by checking their task reports. Table 2 shows that

Table 1. Descriptive data and ANOVA results of the post-test.

Groups	N	Mean	SD	Adjusted mean	Std. error.	F
Experimental group	31	67.74	10.36	67.83	1.85	7.52**
Control group	31	60.74	10.18	60.65	1.85	

** $p < .01$.

Table 2. Average number of scanned and learned plants.

Groups	Average number of plants					
	Task 1		Task 2		Task 3	
	Scanned	Learned	Scanned	Learned	Scanned	Learned
Experimental group	11.47	3.23	11.71	3.68	14.81	13.62
Control group	6.64	3.14	8.21	3.24	10.50	9.08

the average number of plants scanned and learned by the experimental group was higher than that scanned and learned by the control group in all three learning tasks. This result indicated that the learning efficiency of the experimental group was higher than that of the control group.

In order to support the three learning tasks, the teacher provided as much comprehensive knowledge as possible for every plant. At the same time, in order to help the students with different prior knowledge levels, the teachers also added some basic knowledge in the learning resources. Given that the experiment group students were provided the dynamic contextualized ubiquitous learning resources, the contents they acquired were associated with their current learning tasks and conformed to their cognitive level. Hence, they did not need much time to find the key contents. Meanwhile, the control group who used the traditional learning resources acquired the whole contents of the resource, including the prior knowledge contents they had mastered. Thus, they needed to spend a certain amount of time finding the contents related to their current learning task, increasing their cognitive burden. Therefore, the dynamic contextualized ubiquitous learning resource was more beneficial for improving learning efficiency.

Moreover, we found two phenomena. One is the average number of plants scanned and learned by each group in Task 3 was greater than the numbers in Tasks 1 and 2; another is in Tasks 1 and 2, the average number of plants scanned by the experimental group was greater than that by the control group, but the former only learned a little more about the plants than the latter. This is because Tasks 1 and 2 need more comprehensive application ability and logical thinking than Task 3. And the experimental group students who used specific contents could determine whether a plant was unhealthy or suitable for interior design in a shorter time so that they scanned more plants than the control group students. However, because the numbers of unhealthy and unsuitable plants were limited, there was only a slight difference in the number of plants learned by two groups of students.

Self-efficacy for learning

We designed a pre–post-questionnaire to understand the difference between the two groups in learning self-efficacy before and after the learning activities. The *t*-test results of the two groups in learning self-efficacy before the learning activities ($t = -0.27, p = .79 > .05$) implied that the experimental group and the control group showed no significant difference before the experiment. It indicated that the two groups had statistically equivalent self-efficacy before learning. Table 3 shows the ANOVA results of the two groups in self-efficacy after the learning activities. The results ($F = 23.08, p = .000 < .001$) indicated that the experiment group had significantly better self-efficacy than the control group. And Table 4 shows the *t*-test results of the improvement of the two groups in self-efficacy before and after learning ($t = 4.32, p = .000 < .001$), which showed the self-efficacy of the control

Table 3. Descriptive data and ANOVA results of self-efficacy for learning.

Groups	<i>N</i>	Mean	SD	Adjusted mean	Std. error.	<i>F</i>
Experimental group	31	4.06	0.46	4.07	0.12	23.08***
Control group	31	3.24	0.85	3.23	0.12	

*** $p < .001$.

Table 4. Descriptive data and *t*-test result of the improvement of the two groups in self-efficacy before and after learning.

Groups	<i>N</i>	Mean	SD	<i>t</i>
Experimental group	31	0.66	0.66	4.32***
Control group	31	-0.20	0.89	

*** $p < .001$.

group was lower after ubiquitous learning. Thus, the dynamic contextualized ubiquitous learning resource can help improve self-efficacy for learning.

From the interview results, the experiment group students thought they had mastered most knowledge and were able to illustrate what they learned clearly; meanwhile, the control group students thought that they could just recognize different plants but did not understand other aspects of knowledge pertaining to these plants because the learning time was too short. Because of the comprehensive learning contents, the control group students wasted some time to find relevant contents and their learning time was shorter. In order to learn as much as possible in the same time period, they cannot acquire an in-depth understanding, which reduced their self-efficacy.

Cognitive load

After the learning activities, the researchers used a pre-post-questionnaire to investigate the cognitive load of students. Table 5 shows the *t*-test result of the cognitive load. Specifically, the mental load of students in the experiment group was lower than that in the control group ($t = -5.94$, $p = .000 < .001$), and the mental effort exerted by students in the experiment group was lower than that in the control group ($t = -3.61$, $p = .001 < .01$). Therefore, the students using the dynamic contextualized learning resource exerted less cognitive load.

Compared with the traditional static learning resources, the dynamic contextualized ubiquitous learning resource helped the experiment group easily obtain the learning contents suitable for their learning context (e.g. the content matching the learning objectives or the basic knowledge level of a learner), which were also easier to understand. Thus, the kind of learning resource can reduce learners' cognitive load.

From the interview results, we found that the control group students thought that the learning resources made them difficult to find the key contents; by contrast, the experimental group students thought that the learning resources made them easy to understand and quickly carry out an in-depth study. Therefore, the dynamic contextualized ubiquitous learning resource is helpful in reducing the cognitive load of students.

User acceptance of information technology

Table 6 shows the *t*-test results of the user acceptance of information technology. In the aspect of usefulness, both groups thought the ubiquitous system was useful, but the acceptability of the experimental group was significantly higher than that of the control group ($t = 2.21$, $p = .03 < .05$). Thus, the ubiquitous learning system providing dynamic contextualized learning resources was more useful

Table 5. Descriptive data and *t*-test results of cognitive load.

Scale	Groups	<i>N</i>	Mean	SD	<i>t</i>
Mental load	Experimental group	31	1.46	0.31	-5.94***
	Control group	31	2.20	0.62	
Mental effort	Experimental group	31	1.77	0.52	-3.61**
	Control group	31	2.32	0.67	

*** $p < .001$.

** $p < .01$.

Table 6. Descriptive data and *t*-test results of user acceptance of information technology.

Scale	Groups	<i>N</i>	Mean	SD	<i>t</i>
Usefulness	Experimental group	31	4.30	0.39	2.21*
	Control group	31	4.00	0.66	
Ease of use	Experimental group	31	4.17	0.42	1.34
	Control group	31	3.92	0.96	

* $p < .05$.

than the system providing static learning resource. As for ease of use, both groups showed no significant difference, and all the students thought the system was easy to use ($t = 1.34$, $p = .18 > .05$).

All students in both groups used the same ubiquitous learning system client, so there was no significant difference in terms of ease of use. Given that the experiment group students used the dynamic contextualized ubiquitous learning resource, while the control group students used the traditional static learning resource, the experimental group thought the system was more useful. Therefore, we can say that, compared with the traditional static learning resources, the dynamic contextualized ubiquitous learning resource with context is more useful for ubiquitous learning.

Conclusions

This study proposed a dynamic ubiquitous learning resource model with context. The model has context information and flexible content structure. Wrapping context in learning resource package, on the one hand, can provide rich information to describe the suitable contexts in which the resources can be used, and the resource context will be enriched with the use of such resources; on the other hand, it can realize double-context matching of resource context and learning context so that we can provide ubiquitous learners with learning resources more accurate matching with learning context. The experimental results show that the dynamic contextualized ubiquitous learning resource can more effectively improve learners' learning achievements and efficiencies, as well as increase their self-learning efficiency, reduce their cognitive load, and provide better support during learning process.

Of course, learners also provided suggestions to improve the ubiquitous learning system. They thought that scanning a QR code to access the related digital learning resource each time was not convenient; in addition, the QR code identification was often slow or insensitive. These results are consistent with those presented in previous research (de Jong et al., 2010).

This research conducted a preliminary exploration of ubiquitous learning resources that can provide learners more precise learning contents. It tries to provide some reference for the further research of ubiquitous learning resources. Of course, we need to do more, such as to further perfect the system in the future based on learners' suggestions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

- Chen, C.-C., & Huang, T.-C. (2012). Learning in a u-museum: Developing a context-aware ubiquitous learning environment. *Computers & Education*, 59(3), 873–883.
- Chen, M., Chiang, F. K., & Yu, S. Q. (2014). A context-aware dynamical learning environment for multiple objectives. In C.-C. Liu, H. Ogata, S. C. Kong, & A. Kashiara (Eds.), *Proceedings of the 22nd international conference on computers in education* (pp. 471–476). Nara: Asia-Pacific Society for Computers in Education.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–339.
- El-Bishouty, M. M., Ogata, H., & Yano, Y. (2007). PERKAM: Personalized knowledge awareness map for computer supported ubiquitous learning. *Educational Technology and Society*, 10(3), 122–134.
- Hsu, C. K., Hwang, G. J., & Chang, C. K. (2013). A personalized recommendation-based mobile learning approach to improving the reading performance of EFL students. *Computers & Education*, 63(1), 327–336.
- Hwang, G. J., Sung, H. Y., Hung, C. M., & Huang, I. (2013). A learning style perspective to investigate the necessity of developing adaptive learning systems. *Journal of Educational Technology & Society*, 16(2), 188–197.
- Hwang, G. J., Sung, H. Y., Hung, C. M., Huang, I., & Tsai, C.-C. (2012). Development of a personalized educational computer game based on students' learning styles. *Educational Technology Research and Development*, 60(4), 623–638.
- Hwang, G.-J., Wu, C.-H., Tseng, J. C. R., & Huang, I. (2011). Development of a ubiquitous learning platform based on a real-time help-seeking mechanism. *British Journal of Educational Technology*, 42(6), 992–1002.
- de Jong, T., Specht, M., & Koper, R. (2010). A study of contextualised mobile information delivery for language learning. *Educational Technology & Society*, 13(3), 110–125.
- Klausmeier, H. J., Rossmiller, R. A., & Saily, M. (Eds.). (1977). *Individually guided education: Concepts and practices*. New York, NY: Academic Press.
- Klobas, J. E., Renzi, S., & Nigrelli, M. L. (2007). *A scale for the measurement of self-efficacy for learning (SEL) at university* (Working papers No. 2). Retrieved from Murdoch University http://researchrepository.murdoch.edu.au/23551/1/scale_for_the_measurement.pdf
- Leppink, J., Paas, F., Van der Vleuten, C. P., Van Gog, T., & Van Merriënboer, J. J. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods*, 45(4), 1058–1072.
- Ley, D. (2007). Ubiquitous computing. *Emerging Technologies for Learning*, 2, 64–79.
- Liu, T.-Y. (2009). A context-aware ubiquitous learning environment for language listening and speaking. *Journal of Computer Assisted Learning*, 25(6), 515–527.
- Liu, T.-Y., Chu, Y.-L., Tan, T.-H., & Chang, C.-C. (2007). RFID-based ubiquitous learning environment for outdoor learning. In J. M. Spector, D. G. Sampson, T. Okamoto, Kinshuk, S. A. Cerri, M. Ueno, & A. Kashiara (Eds.), *The seventh IEEE international conference on advanced learning technologies* (pp. 675–677). Niigata: IEEE.
- Luo, J. Z., Dong, F., Cao, J. X., Song, A. B., & Liu, B. (2008). A multicontext-aware resource recommendation mechanism for service-oriented ubiquitous learning environment. In M. Al-Akaidi, L. Z. Cui, B. Hu, B. Hu, Z. K. Lin, Y. Zhang (Eds.), *Third international conference on pervasive computing and applications* (Vol. 2, pp. 792–797). Alexandria: IEEE.
- Mampadi, F., Chen, S., Ghinea, G., & Chen, M. (2011). Design of adaptive hypermedia learning systems: A cognitive style approach. *Computers & Education*, 56(4), 1003–1011.
- Ogata, H., Akamatsu, R., & Yano, Y. (2005). TANGO: Computer supported vocabulary learning with RFID tags. *Journal of Japanese Society for Information and Systems in Education*, 22(1), 30–35.
- Shih, J.-L., Chu, H.-C., Hwang, G.-J., & Kinshuk (2011). An investigation of attitudes of students and teachers about participating in a context-aware ubiquitous learning activity. *British Journal of Educational Technology*, 42(3), 373–394.
- Sotsenko, A., Jansen, M., & Milrad, M. (2014). Implementing and validating a mobile learning scenario using contextualized learning objects. In C.-C. Liu, H. Ogata, S. C. Kong, & A. Kashiara (Eds.), *Proceedings of the 22nd international conference on computers in education* (pp. 522–527). Nara: Asia-Pacific Society for Computers in Education.
- Tseng, J. C. R., Chu, H. C., Hwang, G. J., & Tsai, C. C. (2008). Development of an adaptive learning system with two sources of personalization information. *Computers & Education*, 51(2), 776–786.
- Wang, S. L., & Wu, C. Y. (2011). Application of context-aware and personalized recommendation to implement an adaptive ubiquitous learning system. *Expert Systems with Applications*, 38, 10831–10838.
- Witkin, H. A., Moore, C. A., Oltman, P. K., Goodenough, D. R., Friedman, F., Owen, D. R., Raskin, E. (1977). Role of the field-dependent and field-independent cognitive styles in academic evolution: A longitudinal study. *Journal of Educational Psychology*, 69(3), 197–211.

- Yang, X., Guo, X., & Yu, S. (2015). Student-generated content in college teaching: Content quality, behavioural pattern and learning performance. *Journal of Computer Assisted Learning*. doi:10.1111/jcal.12111
- Yang, X. M., & Yu, S. Q. (2015). Designing a resource evolution support system for open knowledge communities. *Journal of Educational Technology & Society*, 18(4), 385–400.
- Yu, S., Yang, X., Cheng, G., & Wang, M. (2015). From learning object to learning cell: A resource organization model for ubiquitous learning. *Journal of Educational Technology & Society*, 18(2), 206–224.
- Yu, S. Q., Yang, X. M., & Cheng, G. (2009). Learning resource designing and sharing in ubiquitous learning environment—the concept and architecture of leaning cell. *Open Education Research*, 15(1), 47–53.