

# Adaptivity and Personalization in Mobile Learning

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Mobile educational systems have begun to emerge as potential educational environments supporting life-long learning. However, these environments still suffer from various technological and access related problems in many parts of the world. For example, the access to course materials is slow; courseware does not adapt to individual students; the real time interaction between student and the environment is hard to achieve because of connection unreliability and bandwidth limitations. There is also a lack of pedagogical infrastructure for mobile learning. This paper focuses on adaptive approaches for individual learners through the use of mobile technology. Various aspects of the research are discussed that aim to exploit the benefits of location, device and learner modeling, and to combine them with mobile technology to achieve personalized delivery of multimedia-rich learning objects: anywhere and anytime.

*Keywords: Mobile learning, adaptivity, personalization, learning style, student model, context-awareness, museum.*

## INTRODUCTION

In a mobile learning environment, learners can receive the learning materials provided by a system according to where they are when learning in the mobile learning environment (Chang & Chang, 2006; Chen, Kao, Yu, & Sheu, 2004). A mobile learning strategy can actually achieve the goal of learning at anytime

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and anywhere. Ubiquitous learning has recently become an interesting and important issue in informal learning (Syvanen, Beale, Sharples, Ahonen, & Lonsdale, 2005). The focus of this work is on enabling learners to learn topics of interest to them transparently and immediately, using various devices, and whenever and wherever they want.

Generally speaking, personalization can be achieved via two adaptive approaches: (1) the learning service can adapt to learners' characteristics, such as learning styles, requirements, status, performances, preferences, and profiles; and/or (2) the learning service can adapt to the context surrounding the learners. The first approach is easy to understand. For example, the learning service can deliver multimedia materials to learners with a visual learning style or can provide step-by-step instructions to the learner who has difficulty solving specific problems. The second approach applies the capability of context-awareness to the learning service. For instance, it would probably be useless for a learning service to deliver botanical materials to a learner who is inside an art gallery.

In this paper we discuss two solutions based on the abovementioned adaptive approaches for realizing personalization in mobile learning. One solution uses learners' characteristics such as their learning styles to provide learners with personalized learning experiences. The other solution uses a context-awareness knowledge structure to generate personalized learning activities for learners according to the learning objects and relevant domain knowledge that exist in the surroundings of the learners.

Section 2 introduces past research related to the two solutions and identifies the gap in the research that our solutions attempt to fill. Section 3 describes a personalized mobile learning solution which adapts to the learner, *viz.* learning style. In Section 4, we discuss how to use a context-awareness knowledge structure to generate different learning activities for learners in different environments, for example, in a museum. Section 5 describes findings of an exploratory study using a context-aware and personalized educational game in a museum. Section 6 provides a conclusion and discusses possible visions of the future.

## **RESEARCH BACKGROUND**

In traditional learning environments, the educational process typically takes place in a classroom, where teachers and learners meet face to face at the same time and in the same place. The learners typically receive only the learning materials prepared in advance by the teacher. As a result, the learning activities are limited to what the teacher has arranged, and consequently it is rather difficult to

adapt the learning materials to the learning requirements and demands of the individual learners.

E-learning, on the other hand utilizes the capabilities of computer technologies and the Internet to assist teachers' to teach and learners to learn (Brodersen, Christensen, Dindler, Grønbæk, & Sundararajah, 2005). A mix of e-mail, learning management systems, web cameras and other online tools is used in e-learning in order to facilitate learning without requiring the teacher and learners to be present in one location (Martin, 1994). However, both traditional classroom-based learning and e-learning are not specifically designed for those courses in which authentic learning demands making observations in real environments, for examples, butterfly watching and plant observation in a biology course (Chang & Chang, 2006; Chen, Kao, Yu, & Sheu, 2004; Thornton, & Houser, 2004).

Mobile learning extends the learning environment from indoors to outdoors by giving learners opportunities to understand the learning materials through touch, observation and feel of the learning objects in real environments (Kuo, Wu, Chang, Chang, & Heh, 2007; Yatani, Sugimoto, & Kusunoki, 2004). Furthermore, mobile learning can also enable learners to apply what they have learned in real environments (Darmarin, 1993). Mobile learning therefore adds a new learning strategy to e-learning; however, the issue of flexible learning still remains. Without the consideration of adaptivity towards individual learners and their surrounding environments, and implementation of such adaptivity in real-time, the learning activities remain limited to the specific learning environment in which the specific domain knowledge and appropriate learning materials have been addressed and arranged (generally by the teacher) in advance.

It is important to recognize that learners are not just passive receivers of learning materials from teachers. They have the ability to learn the concepts, knowledge and skills by interacting with real-life objects in their surrounding environment (Vygotsky, 1978). Brown, Collins, and DuGuid (1989) argue that concepts and knowledge are situation-based, and learning is influenced by a combination of teaching activity, situation and interactions, called situated learning. The research in ubiquitous/pervasive learning aims to exploit this dimension (Thomas, 2005).

## **ADAPTIVE LEARNING CONSIDERING STUDENTS' CHARACTERISTICS**

In this section, we introduce an adaptive mobile learning environment, which offers many services for students to learn anytime and anywhere, using the advantages of mobile learning. Figure 1 illustrates the architecture of the environment.

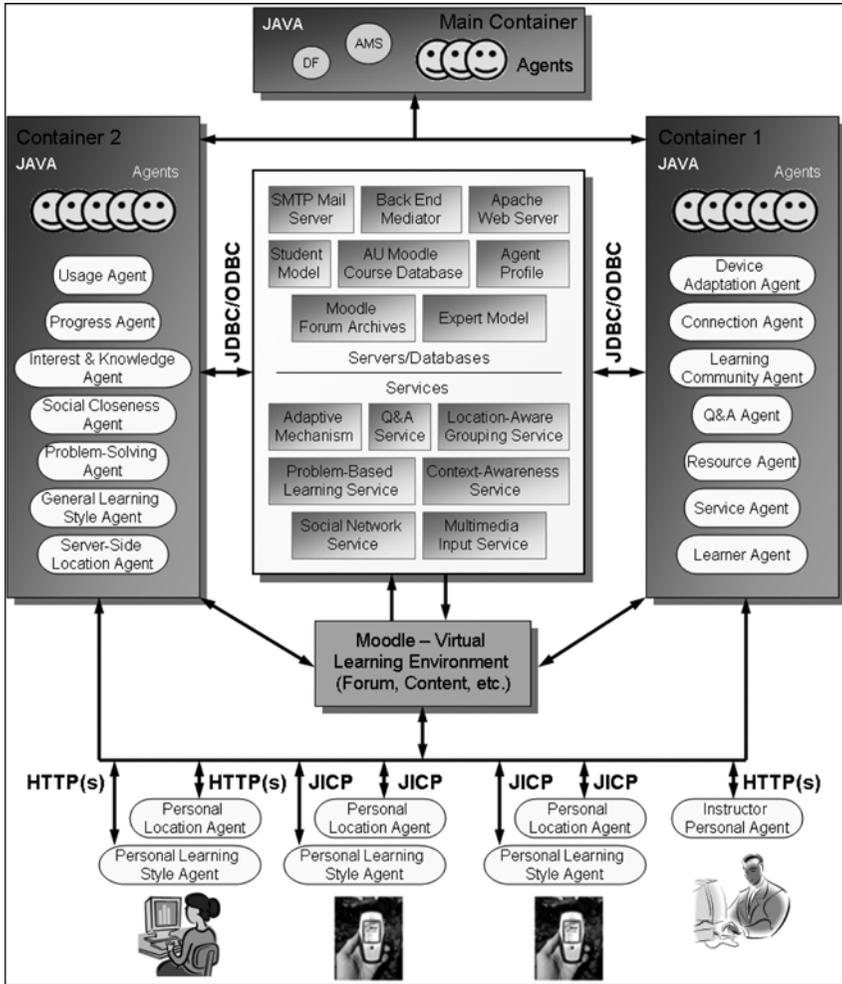


FIGURE 1  
Architecture of the adaptive mobile learning environment.

A fundamental consideration in design was to use a multi-agent system (MAS) paradigm to seamlessly integrate and deploy software components, devices, learners, educational services, and situations to form mobile learning communities and facilitate collaborative problem solving. Another important design consideration was to have a global student model and several student modeling agents which capture specific information about the learners, such as learning styles, location, context, behaviors, actions, and performance. The student modeling

agents are responsible for gathering the required data from the respective services and making the information accessible for all services. The services themselves are responsible for providing learners with an adaptive and mobile learning environment. The location-awareness service is used to help mobile students form face-to-face learning groups. Moreover, social networking issues were considered and integrated in the infrastructure. An adaptive mechanism was included, which is responsible for providing learners with learning materials that fit to their individual learning styles. The context-awareness service identifies the personalized context-aware knowledge structure and directs individual students to learn and move in the real world using automatically generated guidance messages. Furthermore, students are supported by an intelligent and multimodal asynchronous Q&A knowledge sharing platform. Another service deals with providing effective integration of problem based learning in the adaptive and mobile learning environment. Moreover, different multimedia inputs are considered for providing a richer source of interaction in mobile learning.

This learning environment aims at providing learners with a rich learning experience through different services, supporting learning at any time and any place. Furthermore, adaptivity and personalization are important issues. Therefore, the environment gathers data about students' usage of the environment, learning progress, interests, knowledge level, social closeness, problem-solving abilities, location, and learning styles and uses this information to provide adaptivity.

As an example, we focus on one of these characteristics, namely learning styles, in the next paragraphs and describe how information about students' learning styles can be gathered and how adaptivity can be provided in the proposed mobile learning environment.

With regard to learning styles, the Felder-Silverman learning style model (FSLSM) (Felder & Silverman, 1988) is used. Many learning style models exist in literature (e.g., Honey & Mumford, 1982; Kolb, 1984; Pask, 1976). However, most of these models involved classifying students into a few groups, whereas Felder and Silverman describe the learning styles of a student in more detail, distinguishing between preferences on four dimensions: active/reflective, sensing/intuitive, visual/verbal, and sequential/global. Therefore, each learner is classified as having a preference on each of these four dimensions. By using dimensions and scales, the degree of preference can be expressed to describe a balanced learning style. Another major difference is that FSLSM is based on tendencies, indicating that students with a high preference for a certain behaviour may also act differently at times. In addition, FSLSM is often used for technology enhanced learning systems (e.g., Carver et al., 1999; Kuljis & Liu, 2005).

The student model in the proposed system uses the students' behavior, actions, and preferences in several services, as well as an advanced student modeling approach for identifying learning styles in an automatic, dynamic, and global way. With respect to automatic student modeling, the students' behavior and actions are used in order to automatically infer their learning styles. The dynamic part of the student modeling approach is responsible for using the information about students' behavior and actions for updating the student model immediately while students are using the system for learning. Therefore, using this student modeling approach the system is able to improve and revise the information in the student model frequently, leading to a higher accuracy of adaptivity. Furthermore, the global aspect of student modeling focuses on considering all services integrated in the mobile learning environment for gathering data about the students' behaviour and actions. In addition, the student modeling approach can optionally incorporate information from a learning style questionnaire for initialising the student model, while data about students' behaviour and actions are then used for revising and improving the information from the questionnaire.

Each service in the system is provided with access to the student model. Therefore, the information about students' learning styles calculated by the student modeling approach can be used by the services to provide students with a learning experience which incorporates and fits their preferred ways of learning. The learning styles are used as the basis for the adaptive mechanism which aims at providing students with learning objects and activities that fit their individual learning styles. Furthermore, the problem-based learning service uses the information about learning styles in order to assign suitable problems to students and the location-aware grouping service considers learning styles for building learning groups. In addition, the question and answer service incorporates learning styles in order to provide answers which fit the students' preferred ways of perceiving and acquiring information, such as considering the preferred media type.

## **CONTEXT-AWARE LEARNING ACTIVITIES IN A MUSEUM**

A museum is a place with supports knowledge-building in different domains. Museum learning is a kind of informal learning, which means that the learning occurs outside of school (Nikolaos, Ioanna, Dimitrios, Nikoletta, Vassilis, & Nikolaos, 2008). Mobile applications have already been used in museums to deliver information to visitors, to provide tools to support the learning process, and to present educational multimedia content (Tsung, Tan, & Yu, 2006).

However, these mobile learning applications in museums do not incorporate context-awareness techniques and therefore do not provide the learners personalized learning experiences based on where the learners are inside the museum. In this section, we introduce a learning activity generator for learners experiencing adventures in a museum. Since the generator is context-aware, only the learning activity which involves the artifacts surrounding the learners at their location is generated. Different learners consequently receive different activities based on their locations in different exhibition halls and/or floors.

The context-awareness activity generation process is composed of two phases, as shown in Figures 2 and 3. The first phase of information preprocessing has two steps: the knowledge structure construction step (step 1) and the preferred feature selection step (step 2). Step 1 adapts the learning service to the context of the learner's surroundings. Step 2 adapts the learning service to the learner's preferences. The second phase of the personalized learning

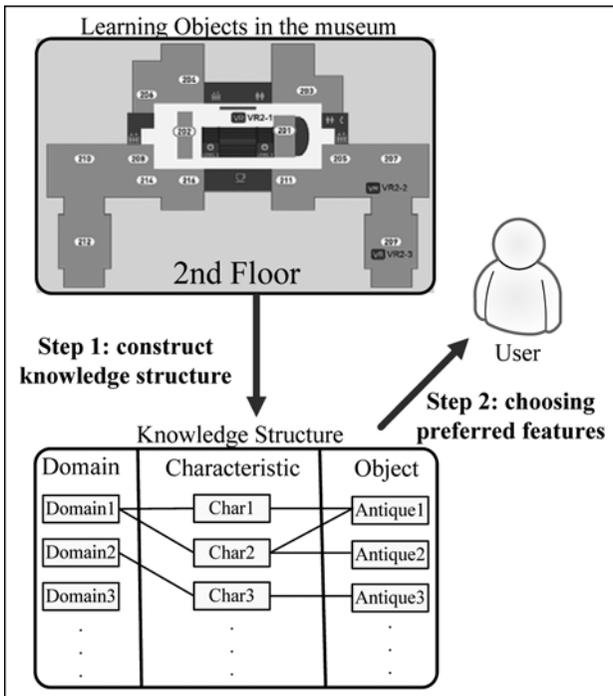


FIGURE 2  
First Phase - Information Preprocess.

experience has three steps: the personalized learning activity generation step (step 3), the activity realization step (step 4), and the personalized experience update step (step 5).

First of all, museums commonly hold many artifacts, and the artifacts in different areas/floors may relate to various topic and knowledge domains. When a learner visits a museum, the learning service must have some idea about what artifacts are in the learner's surroundings, and what characteristics the artifacts have that are suitable to be used in constructing learning activities. This is part of phase 1 - information preprocessing. Figure 2 illustrates two steps in phase 1. The system first discovers the characteristics of the artifacts by using a context-awareness knowledge structure and rough set. The context-awareness knowledge structure is typically analyzed and designed by the pedagogical experts for storing and retrieving multidisciplinary knowledge and relevant learning objects (Wu, Chang, Chang, Liu, & Heh, 2008). After the system has constructed the knowledge structure about the artifacts that are available in the vicinity of the learner, the system then offers the learner some relevant features that the artifacts may have and lets the learner select his or her preferred ones.

As Figure 3 illustrates, the second phase enables the personalized learning experience. In this phase, there are three steps. Step 3 follows step 2 in which the learner has selected his or her preferred artifact features. Different learning topics involve different artifacts in the museum and these artifacts may have the feature(s) in which the learner is interested, hence, the learning service can take the learner's preferred feature as the learner's preferred topic to generate a personalized learning activity. The system selects suitable artifacts from the context-awareness knowledge structure and puts these artifacts into the activity generation engine in order to deliver a different activity series, as shown in the "Topic" box in Figure 3.

In step 4, the learner can choose to undertake one of the learning activities that are generated by the activity generation engine in step 3. Each activity has one or more missions which the learner needs to complete, and every mission has descriptions to indicate the mission goal. The learner has to find the artifacts required by the mission by observing or touching them on the device interface. When the learner accomplishes a mission, he or she gets permission to undertake the next mission in a specific activity. The difficulty levels of missions become increasingly harder; the next mission will be more difficult than the former one. Finally, in step 5 the learning service records and updates the learner's progress into a personal experience database.

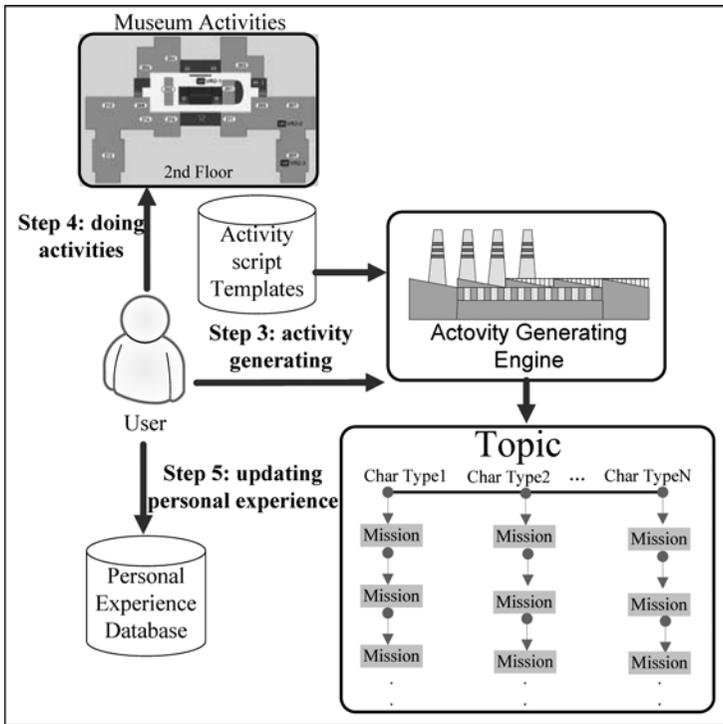


FIGURE 3  
Second Phase - Personalized Learning Experience.

## A PROTOTYPE SYSTEM: DEVELOPMENT AND FINDINGS

We developed the National Palace Museum Adventure (NPMA) educational game and put the learning activity generator into the NPMA as the kernel. The NPMA covered forty-six artifacts in six exhibition rooms and the knowledge of six dynasties (e.g. Ming and Qing), nine materials (e.g. Jade and Copper), eighteen shapes (e.g. Box and Bottle), and twelve applications (e.g. for drinking and for dining). In the game students can play different roles, e.g. artist, cinema property holder, tomb raider, and archaeologist.

We conducted a pilot experiment in the National Palace Museum, Taipei, Taiwan, in May, 2009. Nine students joined our experiment and gave us their feedback and perceptions toward the NPMA and the generated quests. Among the nine students, four were elementary-school students, two were junior-high-school students, and three were senior-high-school students. Their ages ranged from nine to sixteen years old.

Overall, the pilot study yielded three interesting findings:

1. The quest descriptions should be simplified and should provide students with clear information about the quest items.

In this pilot experiment, we designed a complete story and various quests and their descriptions. Students gave their comments on the quest descriptions. They said, for instance:

*“You don’t need to show me the story in the quest descriptions. You can just tell me what quest items you are looking for. I need only keywords to find the quest items out.”*

2. Students were playing a game rather than learning.

We can tell that the students were really playing the game rather than feeling they were learning. In the pilot experiment, there were forty-six artifacts (as quest items) covered by the NPMA. The NPMA asked the students to input the number of artifacts when they turned in the quest. However, the artifacts we designed were sequentially numbered from 1 to 46. We found that many students stood still and kept trying to input different numbers, rather than walking around and finding the number of quest items. They were cheating with the intention of achieving higher scores, similar to what they did in playing other games.

3. Competition occurred and helped students to enjoy learning.

The conversations between students showed us that they were competing with each other and learning. For instance,

- (1) elementary student E1 said, *“I feel the quests provided by the NPMA are fun and I like the process of finding answers”*; and,
- (2) elementary student E3 asked E4, *“How many quests have you done?”*  
After E3 checked E4’s progress, E3 said *“I am better than you!”*

## CONCLUSIONS

This paper described personalization in mobile learning via two adaptive approaches, one by adapting to the learner and the other by adapting to the context of the learner’s surroundings. In this paper, we discussed each adaptive approach and demonstrated how the different methods/systems achieve the personalization. By incorporating students’ characteristics such as learning styles, learners can be provided with learning materials, activities, and experiences that

fit their individual needs and requirements. With the context-aware knowledge structure and the learning activity generator, the system can provide not only the learning activities relevant to the learning objects in the learners' surroundings, but can also enable learners select their preferred topics and activities.

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