# Knowledge-based mobile learning framework for museums

Tien-Yu Hsu

*Department of Information, National Museum of Natural Science, Taipei, Taiwan*

Hao-Ren Ke

*Library and Institute of Information Management, National Chiao Tung University, Hsinchu, Taiwan, and*

Wei-Pang Yang

*Department of Computer and Information Science, National Chiao Tung University, Hsinchu, Taiwan*

## Abstract

**Purpose** – The purpose of this study is to propose a knowledge-based mobile learning framework that integrates various types of museum-wide content, and supports ubiquitous, context-aware, personalized learning for museums.

**Design/methodology/approach** – A unified knowledge base with multi-layer reusable content structures serves as the kernel component to integrate content from exhibitions for education and collection in a museum. The How-Net approach is adopted to build a unified natural and cultural ontology. The ontology functions as a common and sharable knowledge concept that denotes each knowledge element in the unified knowledge base, and associates each learner's learning context and usage with a content and usage profile respectively. Data mining algorithms, e.g. association mining and clustering, are applied to discover useful patterns for ubiquitous personalization from these content and usage profiles.

**Findings** – A pilot project based on the proposed framework has been successfully implemented in the Life Science Hall of the National Museum of Natural Science (NMNS), Taiwan, demonstrating the feasibility of this framework.

**Originality/value** – This study proposes a mobile learning framework that can be replicated in many museums. This framework improves learners' learning experiences with rich related content, and with ubiquitous, proactive and adaptive services. Museums can also benefit from implementing this framework through outreach services for educational, promoting and usability needs from combining mobile and Internet communication technologies and learning services.

**Keywords** Mobile communication systems, Museums, Information media, Resource description framework, Taiwan

**Paper type** Research paper

## 1. Introduction

Museums attempt to create a learning environment by using digital technologies to produce and deliver knowledge. The resulting learning environment exists both onsite as digital interactive content, and online on web sites (Pieter and Justin, 2003; Hamma,

2004; Hawkey, 2004). The rapid evolution of information and communication technologies encourages museums worldwide to develop mobile learning solutions by creating extra channels for users with mobile handheld devices to supplement conventional docent and audio guides, and current digital technologies (Luchini *et al.*, 2002; Mifsud, 2002, Goh and Kinshuk, 2004). Many studies have indicated that mobile learning presents a chance to revolutionize the way that museums interact with visitors. Some applications designed for mobile devices can enhance visitor experience in museums (Hsi, 2002; Gay and Spinazze, 2002; Zern, 2002; Proctor and Telli, 2003; Manning and Sim, 2004; Wilson, 2004). However, most mobile learning projects for museums, particularly in Taiwan, have not successfully developed of onsite tour guide applications for exhibitions. A friendly interface, attractive application (Yatani *et al.*, 2004; Milene, 2005), multimedia presentation (Wilson, 2004), and interactive accessibility (Kirk, 2001; Manning and Sim, 2004) are major concerns in such projects. Very few projects combine museum-wide content and services with related domains, applications and projects to create a ubiquitous, proactive and adaptive learning service. Therefore, most relevant knowledge cannot be integrated and reused; the learning content is uniform and constrained to particular domains; the learning environment is restricted in locations of museums, and services cannot be adapted to individual learners.

This study addresses some major factors in addition to these general design factors. Major factors include the type and subject of a museum (art, history or science), audience types and their requirements (student, teacher, general public or expert), integration of related content resources (collection, exhibition, education and entertainment) and the integration of service and business models with the physical museum (inside and outside the museum). This study proposes a framework of ontological knowledge-based mobile learning with ubiquitous, context-aware and personalization services to fulfill these key factors. A ubiquitous learning service (Gay and Spinazze, 2002) enables learners to undertake learning activities covering the pre-visit, onsite-visit and post-visit stages. A context-aware system serves people intelligently and interactively using users' contextual information, such as temporal and spatial information, in the museum around them (Wu *et al.*, 2004; Lonsdale, 2003; Cinotti *et al.*, 2004). A personalization service provides a new communication strategy based on a continuous process of collaboration, learning and adaptation between a museum and its visitors during all learning stages (Jonathan, 2004).

Ontology defines the characteristics of a formal, explicit specification for a shared and common understanding of various domains (Zhang *et al.*, 2002). A unified knowledge base developed in a digital archiving project for the National Museum of Natural Science (NMNS), Taiwan acts as the kernel component to integrate content from exhibition, education and collection resources in a museum. Ontology acts as a common, sharable knowledge concept for communication between learners and the unified knowledge base. The learners' learning records can be represented by an ontological usage profile aggregated from the content profiles at a conceptual rather than titular level. These usage profiles identify useful usage patterns of individuals, groups and global learners. These patterns are used to recommend content for active learners. A practical mobile learning project based on the proposed framework was implemented and opened in July 2005 at the life science hall of the NMNS. This model is likely to be extended to the entire museum before the end of 2006.

The remainder of this study is structured as follows. Section 2 describes a mobile learning scenario in a user-centered ubiquitous, context-aware and personalized learning environment. Section 3 presents a framework that is modularized into three layers, ubiquitous learning service layer, adaptive application layer and ontological knowledge base layer, to realize the design issues. Section 4 describes an ontology-based model, which is designed to denote and combine learning content for collection, exhibition and education, as well as user context and usage. Section 5 describes a personalization service to carry out recommendations adaptively and proactively during the pre-visit, onsite-visit, and post-visit stages for each active learner. Section 6 draws conclusion and suggests future research directions.

## 2. Learning scenario

The following scenario shows how a student learns in a ubiquitous, context-aware, personalized environment with a knowledge-based mobile learning service. The scenario is described with the division of pre-visit, onsite-visit, and post-visit stages (see Figure 1).

### 2.1. The pre-visit learning stage

Assume that a student wishes to visit a natural science museum for two hours, concentrating on exhibitions about fossils. Before visiting the museum, the student creates a learning plan at home using the internet by specifying his subjects of interest, visit date, and stay duration. The system recommends all relevant learning content from a global perspective of the museum based on his demography and preference for fossils. The student then determines his final learning plan according to the recommendation, and registers for his planned visit.
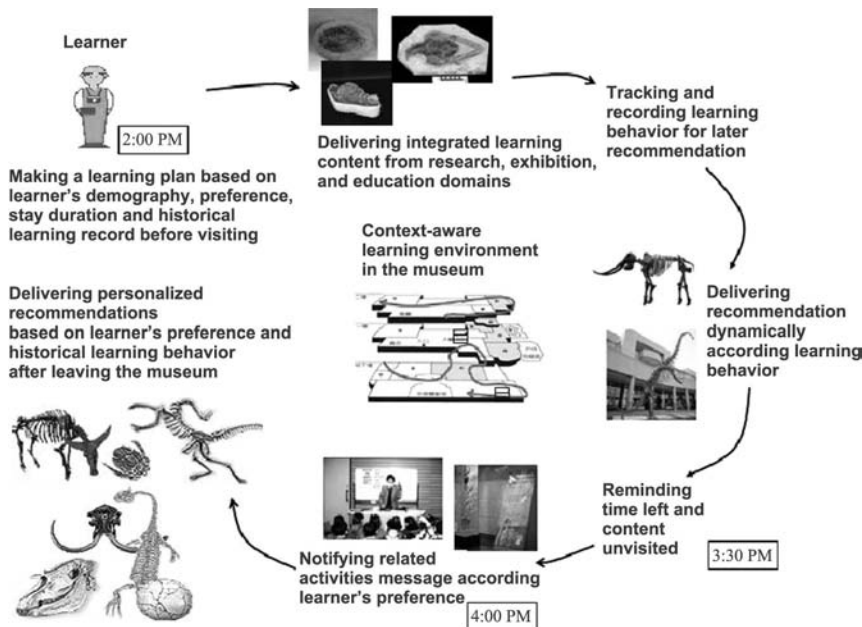


Figure 1.
Learning scenario during pre-visit, onsite-visit, and post-visit stages

## 2.2. The onsite-visit learning stage

When the student visits the museum, he downloads his previously created learning plan and conducts his learning activity by a handheld device. If the student does not wish to learn by planning, then he can learn by following some learning packages prepared by the museum, or learn freely without constraints. All three learning modes are served in a context-aware environment, and the system automatically pushes relevant guiding maps, learning content and messages based on his location and related context. The student may, while learning, follow the original visiting plan about fossils, or he may be interested in another exhibition about dinosaurs, which is not in the original plan. In this case, some exhibition items and messages of science educational activities about dinosaurs are also delivered to the student. All learning behavior is tracked and analyzed to provide further intelligent and proactive recommendation services to the student.
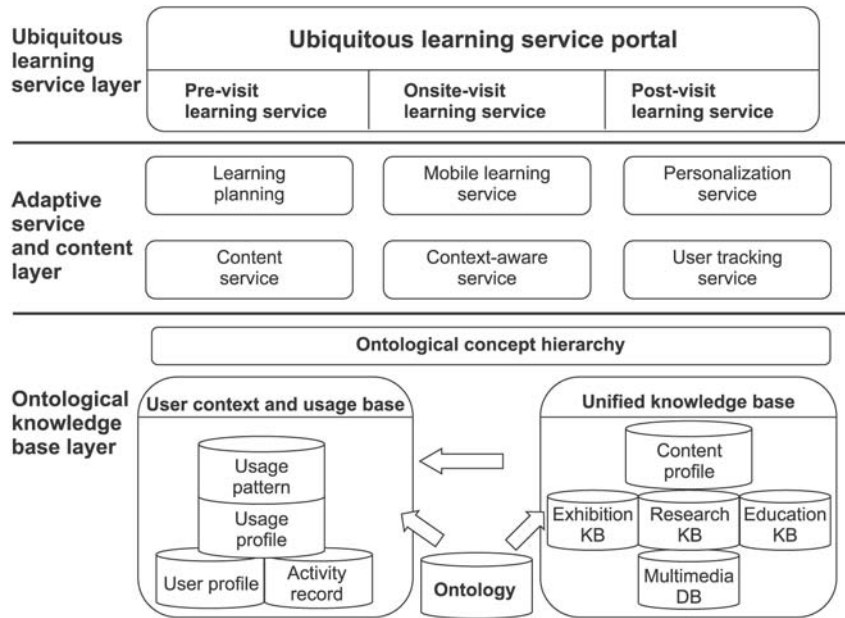
## 2.3. The post-visit learning stage

The student can continue learning via the Internet at any place and time after leaving the museum. The learning service recommends additional content to the student based on his preference and learning records tracked by the system during his onsite visit. The recommendation includes extra exhibition content that interests the student, but which he has not yet appreciated during his onsite visit. Other related content in collection and education knowledge bases are also recommended to the student. The system tracks and analyzes the student's learning behavior from his rating and navigation. Hence, the automatic recommendation service for the student's next pre-visit plan or post-visit learning is close to his requirements.

## 3. Learning service framework

A knowledge-based mobile learning framework in a museum (see Figure 2) can be sketched out according to the learning scenario in Section 2, and modularized into three layers, namely the ontological knowledge base layer, adaptive application layer and ubiquitous learning service layer.

## 3.1. The ubiquitous learning service layer

The ubiquitous learning service layer provides pre-visit, onsite-visit and post-visit learning via a single service portal. The pre-visit learning service provides an ontological interface to determine the learning content chosen by a user or recommended by the system. The learner can arrange a visiting plan, and register it before visiting. The learner can download a registered learning plan to choose package learning or free learning when visiting the museum. Our implementation discards infrared, ultrasound, WiFi and RFID solutions, due to their problems with operating efficiency, roaming and usability in exhibitions. Instead, a context-aware system based on ZigBee/IEEE 802.15.4 technology (Kinney, 2003) was developed to serve learners by determining their demography, preferences, interests, locations, stay duration and visiting behavior. The post-learning service allows learners to continue learning from more recommended content related to past onsite visits.

## 3.2. The adaptive service and content layer

The adaptive service and content layer provides several services for learners in the pre-visit, onsite-visit, and post-visit stages. The learning planning service provides an ontology-based interface allowing a learner to create a learning plan during the pre-visit stage. The mobile learning service provides plan-learning, package-leaning and free-learning modes for a learner to proceed with his learning activity during the onsite visit. The service collaborates with the context-aware service to transmit requests to the content service during the onsite visit, and reminds the learner of his time spent and his current learning status. The context-aware service senses the learner's temporal and spatial context, and notifies the content service to deliver the appropriate guide maps, learning content and related activity messages to the learner. The user tracking service tracks the learning behavior of a learner during the onsite visit to capture the preference information for the personalization service. The learner's learning activities are dynamically tracked and recorded to refresh his learning preference of each learner. The personalization service adaptively and proactively recommends learning content to the learner in every stage. The content service delivers relevant content from requests of the learning planning service, the mobile learning service and the personalization service.

## 3.3. Ontological knowledge base layer

The ontological knowledge base layer generates and manages learning content, and maintains user context information and learning records for all learners. This layer consists of three components: ontology, unified knowledge base and user context and usage base. The ontology provides common and sharable concepts to denote the unified knowledge base and the user context and usage base. The unified knowledge

base comprises a multimedia database and an integrated knowledge base in research, exhibition and education, and is created under an ontology-based concept hierachy for content creation, management and publication. The user context and usage base includes user profiles, learning records, usage profiles and usage patterns. Section 4 describes in detail the unified knowledge base and the user context and usage base.

## 4. Ontology-based content and user context modeling

Ontology has been applied in the past to digital archives, digital museums and museum-related e-learning projects to provide shared and reusable knowledge standards from user and system perspectives. The HowNet approach (Dong and Dong, 2001) is adopted herein to build a unified natural and cultural ontology for NMNS (see Figure 3). This study adopts the unified classification hierarchy from our previous work (Hsu *et al.*, 2006), and extends knowledge concepts about exhibition and education topics in natural science to establish the ontology. This ontology plays several significant roles in this study. First, this ontology serves as a sharable thesaurus describing entities, attributes, relationships and events for the unified knowledge base and user context. Second, the ontology maps content onto a simplified and standard specification, and processes it consistently for the learning service. Third, the concept tree of the ontology can be naturally employed to design access interface and calculate the similarity of concept definitions from the user context and the unified knowledge base in the personalization service.

### 4.1. Modeling of knowledge-based learning content

A global knowledge system with an ontology-based concept hierarchy and relationships in a domain or between domains was previously built for a digital archiving project (Hsu *et al.*, 2006). Content from exhibition and education is integrated into the global knowledge system to support a mobile learning service. Figure 4 illustrates the conceptualization of knowledge elements in the unified knowledge base and the user context based on the shared ontology.

The multi-layer reusable content structures defined previously (Hsu *et al.*, 2006) can express and organize many classes of content. An entity called knowledge element represents the superclass of all content, and consists of core knowledge elements, advanced knowledge elements and innovative knowledge elements. A core knowledge element is the basis of knowledge content, and consists of a multimedia object and its semantic metadata. An advanced knowledge element is further structured from a set of core knowledge elements, and can be a multimedia document, a knowledge unit, a knowledge group or a knowledge network. A multimedia document integrates several core knowledge elements to describe an item related to an object of nature or culture (one species of bird or plant, or an artifact), or an exhibition and education topic. A knowledge unit possesses a hierarchical structure, and is adopted to structure all related multimedia documents to interpret a particular object or topic. All knowledge units can be categorized into three subclasses, namely the collection knowledge unit, exhibition knowledge unit and education knowledge unit.

A new entity, knowledge package, is defined to support the package-learning mode. This entity comprises a set of knowledge units with the same properties to present a research, education or exhibition topic. The knowledge package consists of two subclasses, the original knowledge group entity and a newly-defined entity, knowledge

ontology
  實體 entity
    蒐藏 collection
      植物 botany
        非維管束植物 nonbundle
        維管束植物 bundle
      地質 geology
        化石 fossil
      人類 anthropology
        民族 ethnology
        考古 archeology
      動物 zoology
        無脊椎動物 invertebrate
        脊椎動物 vertebrate
          兩棲類 amphibious
          鳥類 bird
          爬蟲 reptilia
    展示 exhibition
      生命科學廳 The life science hall
        恐龍時代 The era of dinosaur
          飛行爬蟲類 The flying reptile
          挖掘恐龍化石 Excavating the dinosaurs' fossil
      中國科學廳 The Chinese science hall
      地球環境廳 The Earth environment hall
    教育 education
  屬性 attribute
    外觀 appearance
    量度 measurement
    特性 property
    關係 relationship
    狀況 situation
  事件 event
    動作 action

Figure 3.
A unified natural and
cultural ontology

chain. A knowledge group is a set of learning content items, and a knowledge chain denotes a sequence of knowledge units in a learning path. The knowledge chain entity can be applied to design learning packages for the package-learning mode. Specialists in content domains can define the cross-relationships between any pair of the above various elements, whether from within the same domain or different domains, to form a knowledge network.

Each knowledge element is converted to a content profile according to the shared ontology. All knowledge elements can thus be converted to content profiles with a consistent specification and process for the personalization service. Section 5 describes the process for creating content profiles.
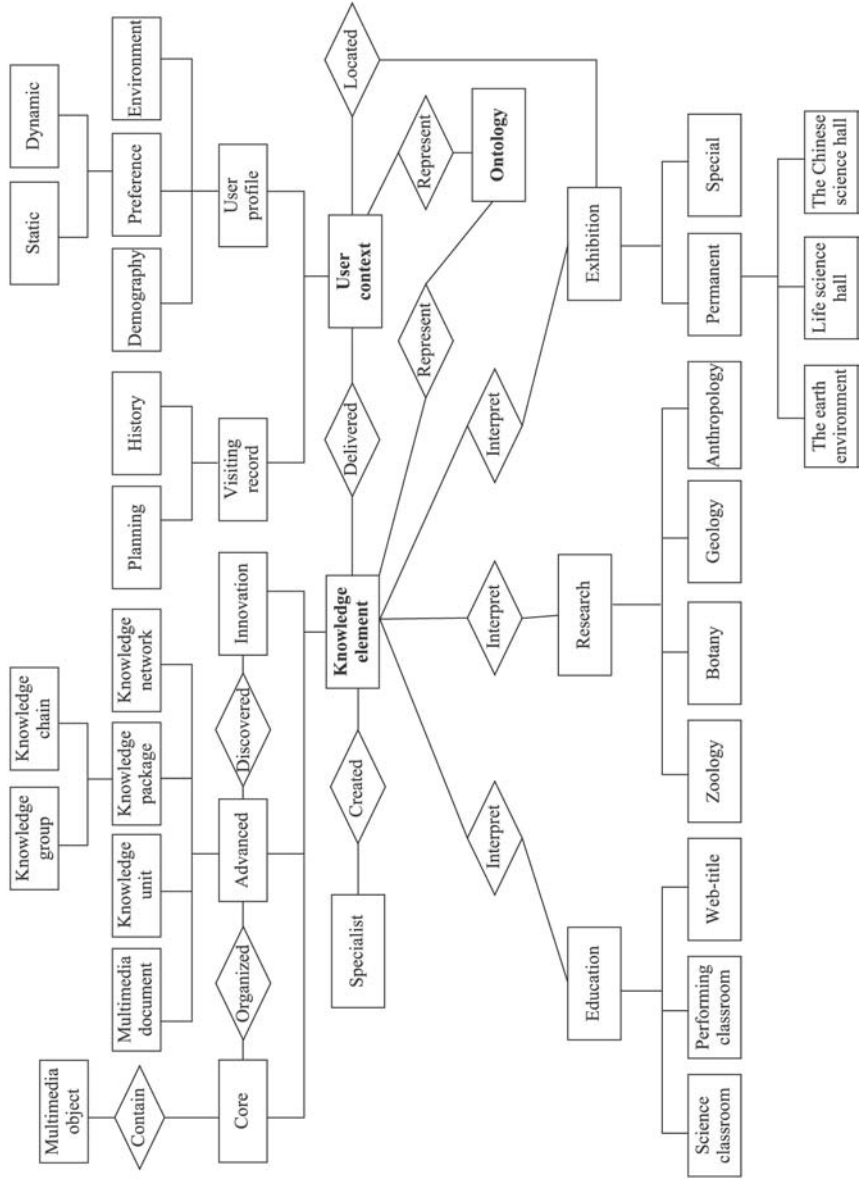
**Figure 4.**
Ontological content and
user context modeling

*4.2. User context and usage information modeling*
Information on the user context of a learner is vital to provide intelligent and proactive services to support context-aware and personalized mobile learning. Each registered user has a user context, which includes the user profile and learning records. As well as demographic information such as ID, age, education, sex, address and e-mail, a user profile also includes static and dynamic preferences and environment context. The static preference includes interesting domains specified by a user, and the dynamic preference is updated from the historical learning records tracked by the system. The environment context contains a learner's location, time used and time left, which are identified and measured by the system. The learning records contain the learning plan and historical learning records, and are denoted by a usage profile with a set of concept definitions aggregated from the content profiles. Usage patterns of individuals, groups and global learners are further discovered from usage profiles and used by the personalization service.

This work models user context and usage information using ontology. This method has two major advantages. First, the recommendation results based on content accessed can be assured to be accurate if the concepts are consistently represented in learners' usage profiles as knowledge bases. Second, learners can easily inquire about concepts when they do not precisely understand topics or know the titles of all learning content items.

## 5. Ubiquitous personalization service
Dai and Mobasher's (2003) approach was adopted to design a personalization service for ubiquitous mobile learning. This approach can be split into three phases, semantic preprocessing, pattern discovery and online recommendation. The first two phases can be processed off-line, while the third must be processed on-line. Figure 5 shows the personalization learning service framework.

*5.1. Preprocessing phase*
The preprocessing phase consists of two stages, content preprocessing and usage preprocessing. In the content preprocessing stage, the system generates a content profile for each knowledge element. A content profile consists of content ID, knowledge class, type and a set of concept definitions. For instance, two exhibition topics "Flying reptiles" and "Digging dinosaur fossils" belong to the exhibition area entitled "The age of dinosaurs". These topics can be conceptually defined as (dinosaur, reptile, extinguish, fly) and (dinosaur, fossil, dig) respectively.

The content profiles of the highest N-frequent concept items in a learning activity are aggregated in the usage preprocessing stage to form a usage profile. A usage profile includes the learner ID, learning activity ID and preferred concept definition. The dynamic preference is then updated according to the usage profile. For instance, if both "Flying reptiles" and "Digging dinosaur fossils" appear in a learner's learning activity, then the preference concept definition comprises (dinosaur, reptile, fossil, extinguish, fly, dig). The usage profiles of all learners can be aggregated to generate a usage profile matrix, which is utilized to discover useful patterns, as discussed in the next section.
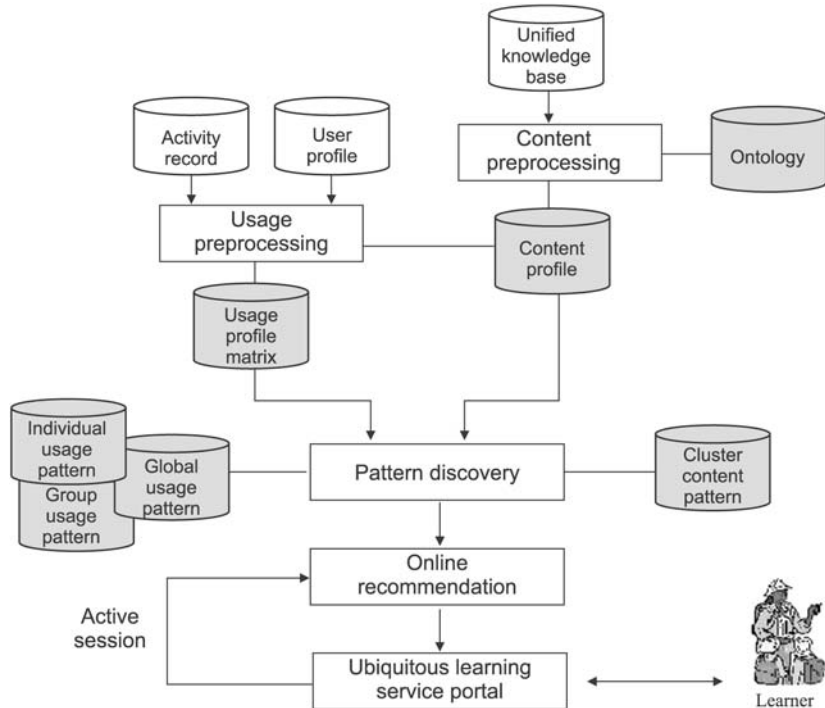
**Figure 5.**
Personalization learning
service framework

*5.2. Pattern discovery phase*

The pattern discovery phase discovers useful usage patterns utilized by the online recommendation phase. One content pattern and three learner usage patterns, namely individual usage pattern, group usage pattern, and global usage pattern, can be discovered in this phase. In this study, these patterns were discovered using association mining algorithms (Han and Kamber, 2001) based on usage profiles.

In the individual usage pattern discovering process, an N-frequent itemset is determined from the concept definitions of each learner's historical learning records to represent his preference. In the group pattern discovering process, all learners are divided into groups according to their demography and static preferences. N-frequent itemsets are obtained from the learning records of all learners in the same group. In the global pattern discovering process, all N-frequent itemsets are found according to all users' usage profiles to represent a set of popular learning content groups among all learners.

In order to recommend and deliver content efficiently, all content items are grouped into clusters based on their similarity in their content profiles. Each cluster can be represented by a cluster content pattern with an aggregated concept definition from all content items in the cluster using clustering algorithms (Han *et al.*, 2001).

*5.3. Online recommendation phase*

The online recommendation phase provides an intelligent and proactive learning service during the pre-visit, onsite-visit, and post-visit stages. The recommendation

service has two modes, user specification and system recommendation. The user specification mode makes recommendations by matching the learner's static preferences and cluster content patterns. The system recommendation mode makes recommendations by matching the individual usage pattern (dynamic preference), group usage patterns and global usage patterns with cluster content patterns. The similarity between the usage patterns and the cluster content patterns is measured by calculating the distribution of concept definitions in the concept tree according to the shared ontology.

During the pre-visit stage, a learner can specify topics from the recommendation list, and arrange a plan to meet his requirements for both modes. The recommended content focuses on exhibition items and education activities that the learner plans to see. During the onsite-visit learning stage, the learner can choose the plan-learning mode by downloading a registered plan, or choose the package-learning or free-learning mode. The extended content is proposed dynamically, while the refreshed individual usage pattern is similar to cluster content patterns. The recommended content focuses on collection knowledge units, exhibition units and messages of education activities according to the up-to-date individual usage pattern. After visiting the museum, the learner can obtain further recommendations from the system based on the last learning activity or matching individual, group or global usage pattern with the cluster content patterns. The recommendations are extended to relevant areas in collection, exhibition and education, and are categorized according to content type in the multi-layer reusable content structures defined in Section 4.1. Figure 6 shows an example of the personalization service during the pre-visit, onsite-visit and post-visit stages.
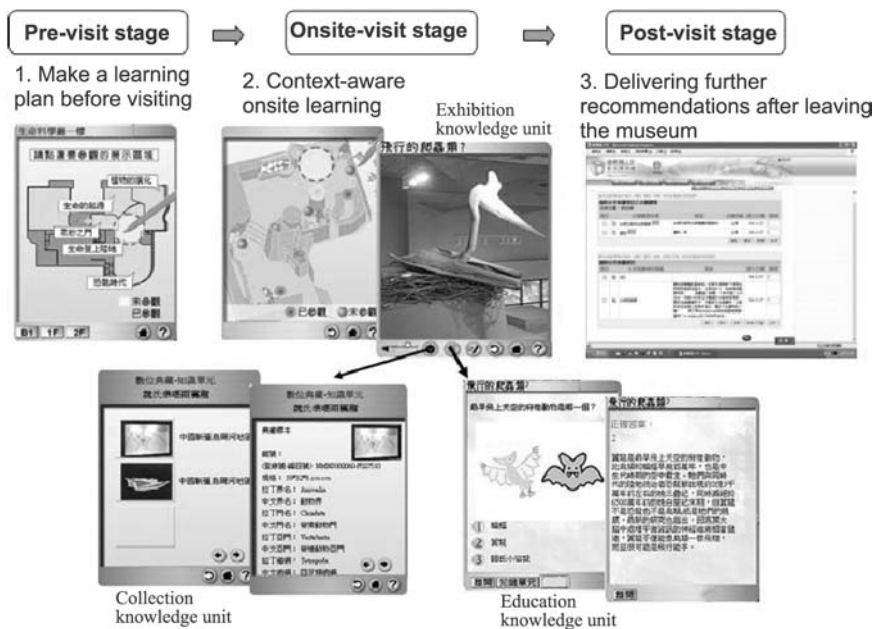


**Figure 6.**
Example of ubiquitous personalization service

## 6. Conclusion and future work

This study has presented a framework of knowledge-based mobile learning with unified content from museum-wide related domains to support a user-centered ubiquitous, context-aware and personalized learning service. A pilot project based on this framework has been implemented in the life science hall of the National Museum of Natural Science (NMNS), Taiwan. This model is likely to be extended to the whole museum before the end of 2006. Learners will eventually improve their learning experiences with fun, rich content, and ubiquitous, proactive and adaptive service. The museum will also benefit by outreaching services for educational, promotion and usability needs, by integrating of mobile and internet communication technologies and learning services.

The limitations and disadvantages of today's technology with respect to the hardware characteristics of mobile devices still significantly affect mobile learning applications, the underlying communication infrastructure features and software capability (Colazzo, 2005). However, these problems will be solved using innovative technology in the near future (Myers and Beigl, 2003; Paolini *et al.*, 2005). Unique and attractive content and service are clearly critical to successful mobile learning. We expect that 24/7 learning services for museums can be performed via the internet and mobile communication devices by integrating technology, content, services and applications of digital archives and digital museum projects into a mobile learning project.

### References

Cinotti, T.S., Raffa, G. and Roffia, L. (2004), "Evaluating context-aware mobile applications in museums: experience from the MUSE Project", *Proceedings of the Museum and the Web 2004 Conference*, available at: www.archimuse.com/mw2004/papers/salmon/salmon.html.

Colazzo, L., Molinari, A. and Ronchetti, M. (2005), "Integrating mobile devices in a multi-platform learning management system using web services", *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2005*, pp. 1367-72.

Dai, H.H. and Mobasher, B. (2003), "A road map to more effective web personalization: integrating domain knowledge with web usage mining", *Proceedings of the International Conference on Internet Computing 2003*, pp. 58-64.

Dong, Z. and Dong, Q. (2001), "HowNet", available at www.keenage.com

Gay, G. and Spinazze, A. (2002), "Handscape: exploring potential use scenarios for mobile computing in museums", *Cultivate Interactive*, No. 8, available at: www.cultivate-int.org/issue8/handscape/.

Goh, T. and Kinshuk, D. (2004), "Getting ready for mobile learning", *World Conference on Educational Multimedia, Hypermedia, and Telecommunications (EDMEDIA)*, Issue 1. CD-Rom, AACE, Chesapeake, VA, pp. 56-63.

Hamma, K. (2004), "The role of museum in online teaching, learning, and research", *First Monday*, Vol. 9 No. 5, available at http://firstmonday.org/issues/issue9_5/hamma/index.html

Han, J. and Kamber, M. (2001), *Data Mining Concepts and Techniques*, Morgan Kaufmann Publishers, San Francisco, CA.

Hawkey, R. (2004), *Learning with Digital Technologies in Museums, Science Centres and Galleries*, Futurelab Series, Report 9, National Endowment for Science, Technology and the Arts, London.

Hsi, S. (2002), "The Electronic Guidebook: a study of user experiences using mobile web content in a museum setting", *Proceedings of IEEE International Workshop on Wireless and Mobile Technologies in Education*, IEEE, Los Alamitos, CA, pp. 48-54.

Hsu, T.Y., Ke, H.R. and Yang, W.P. (2006), "Unified knowledge-based content management for digital archives in museums", *The Electronic Library*, Vol. 24 No. 1, pp. 38-50.

Jonathan, P.B. (2004), Personalization and the web from a museum perspective", *Proceedings of the Museum and the Web 2004 Conference*, available at www.archimuse.com/mw2004/papers/bowen/bowen.html

Kinney, P. (2003), "ZigBee technology: wireless control that simply works", available at www.zigbee.org/en/resources/#WhitePapers

Kirk, J. (2001), "Accessibility and new technology in the museum", *Proceedings of the Museum and the Web 2001 Conference*, available at www.archimuse.com/mw2001/papers/kirk/kirk.html

Lonsdale, P., Baber, C., Sharples, M. and Arvanitis, T. (2003), "A context awareness architecture for facilitating mobile learning", in *Proceedings of MLEARN*, pp. 36-37.

Luchini, K., Curtis, M., Quintana, C. and Soloway, E. (2002), "Supporting learning in context: extending learning-centered design to the development of handheld educational software", *Proceedings of the IEEE international workshop on Wireless and Mobile Technologies in Education*, pp. 107-11.

Manning, A. and Sim, G. (2004), "The Blanton ITour: an interactive handheld museum guide experiment", *Proceedings of the Museum and the Web 2004 Conference*, available at www.archimuse.com/mw2004/papers/manning/manning.html

Mifsud, L. (2002), "Alternative learning arenas pedagogical challenges to mobile learning technology in education", *Proceedings of the IEEE International Workshop on Wireless and Mobile Technologies in Education*, pp. 112-6.

Milene, S. (2005), "Using mobile devices to help teachers and students during a visit to a museum", *Proceedings of the Museum and the Web 2005 Conference*, available at www.archimuse.com/mw2005/papers/silveira/silveira.html

Myers, B.A. and Beigl, M. (2003), "Handheld computing", *Computer*, Vol. 36 No. 9, pp. 27-9.

Paolini, P., Garzotto, F. and Colazzo, S. (2005), "Let's go mobile! Design issues in multichannel 'accessible' applications for culture heritage", *Museum and the Web 2005 Conference Papers*, available at: www.archimuse.com/mw2005/papers/colazzo/colazzo.html

Pieter, A. and Justin, C. (2003), "Impact of ICT-based distance learning: the African story", *The Electronic Library*, Vol. 21 No. 5, pp. 476-86.

Proctor, N. and Telli, C. (2003), "The state of art in museum handhelds in 2003", *Proceedings of the Museums and the Web 2003 Conference*, available at www.archimuse.com/mw2003/papers/proctor/proctor.html

Wu, M., Mitchell, K., McCaffery, D., Finney, J. and Friday, A. (2004), "Real Tournament – mobile context-aware gaming for the next generation", *The Electronic Library*, Vol. 22 No. 1, pp. 55-64.

Yatani, K., Sugimoto, M. and Kusunoki, F. (2004), "Musex: a system for supporting childern's collaborative learning in a museum with PDAs", *Proceedings of the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education*.

Zern, K. (2002), "Evaluation report – handheld computers and learning in the informal museum setting: physical science exhibit interpretation", Harvard Graduate School of Education Cambridge, MA, available at: http://usight.concord.org/documents/probe_report.pdf

Zhang, C., Cao, C. and Gu, F. (2002), "A domain-specific formal ontology for archaeological knowledge sharing and reusing", *Proceedings of the 4th International Conference on Practical Aspects of Knowledge Management*, Vienna, Austria, 2-3 December, Lecture Notes in Computer Science series, Springer, Berlin/Heidelberg, pp. 213-25.

### Further reading

Lin, S.H., Hsu, T.Y., Feng, K.J. and Yang, W.P. (2005), "Feature selection methods for metadata classification on hierarchical union catalogs", *Proceedings of 2005 International Conference on Digital Archive Technologies*, pp. 249-63.

### About the authors

Tien-Yu Hsu is an Associate Research Fellow in the Department of Information Science, National Museum of Natural Science, and is also a PhD candidate in the Department of Computer and Information Science, National Chiao Tung University. His research interests include digital library, digital museum, multimedia database, mobile learning and knowledge management.

Hao-Ren Ke is a Professor of the Library, and Institute of Information Management, National Chiao Tung University, Hsinchu, Taiwan, Republic of China. He is also the Associate Director of the National Chiao Tung University Library. His research interests include digital library, digital museum, web service, and data mining. He is the corresponding author and can be contacted at: claven@lib.nctu.edu.tw

Wei-Pang Yang is a Professor of the Department of Computer and Information Science, National Chiao Tung University, Hsinchu, Taiwan, Republic of China. He is also a Professor of the Department of Information Management, National Dong Hwa University. His research interests include database theory, information retrieval, data miming, and digital library/museum.